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### RESEARCH ARTICLE

#### EXPLORING THE CLIMATE CHANGE EFFECTS ON BORO RICE YIELDS OF RAJSHAHI DISTRICT IN BANGLADESH.

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#### Abstract

Bangladesh is a developing country with high population density and high population growth rate. Rice is the principle food of Bangladesh. Although country considers as fourth rice producer in the world but still it fell food insecurity because of its high population growth rate. The objective of this study was to estimate the relationship between Boro rice yields and climate variables using aggregate-level time series data for the period of 1987 to 2015. The empirical analysis showed that four climate variables minimum humidity at vegetating phase, minimum temperature and consecutive days rainfall average at ripping phase and dummy variables have substantial effects on the Boro rice yield. The result also indicates that average seasonal minimum temperature, minimum humidity and average rainfall are statistically significant and positively affect the yield of Boro rice in case of Rajshahi district. Moreover, excessive rainfall may create water logging condition and flooding that also destroys the crop production. Therefore, the concerned authority should take appropriate policies to fight against the climate change impact on rice production to ensure food security for the ever increasing population of the country through implementing sustainable agricultural development.

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#### Introduction:-

The people of Bangladesh are popularly referred to as “Macche-BhateBangali” or “fish and rice makes a Bangali”. Fish and rice is essential part of the life of Bangladeshi people. Rice is the staple food for over 150 million populations. However, country faces a tremendous challenge for providing food security to the increasing population. Therefore, it is imperative to increase rice production in order to meet the growing demand for food emanating from population growth. Although, there have been ups and downs in the domestic production of food grain. The diverse climatic phenomena like cyclone, drought, changing rainfall patterns and temperature; there has been a significant lost in food grain production in every year. For example, two rounds of floods and devastating cyclone Sidr in 2007 and cyclone Aila in 2009 caused severe damages in agriculture production, especially the rice production. Climate Change Impacts on Rice Production in Bangladesh is important issue. The rice cropping pattern of Bangladesh has changed areas once occupied by the rainfedaus gradually shifted to boro cultivation. As a result, the contribution from each season also changed, aman rice previously contributed a major portion of total rice, but

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boro is now the major contributor to total rice production in the country. Aus, aman, and boro rice were recently reported to account for 7%, 38%, and 55%, respectively, of the total rice production in Bangladesh (Risingbd, 2014). Among these rice only 5% of aman rice and 8% of aus rice are irrigated and boro is fully irrigated rice grown in the dry winter and the hot summer (Mahmood, 1997; Ahmed, 2001). According to BBS (2014), boro is the most important crop in Bangladesh in respect of volume of production. Productivity of boro rice depends on several of climatic parameters such as temperature, rainfall, humidity; hydrological properties of soil such as pH, organic carbon, rice varieties, and major production inputs, such as irrigation and fertilizer management practices. It is very important to have an idea about the contribution of boro rice production of Bangladesh from different statistical viewpoint for different region of Bangladesh. To ensure political stability, achieve sustainable development goal and the self-sufficiency in food of Bangladesh we have to pay attention for increasing rice production despite the serious effect of climatic condition. So, the aim of this paper is to explore the climatic condition of the boro rice yields of the study area based on rainfall, temperature and other climatic condition.

### Previous study

There is a growing body of literature in recent years that has observed the influence of climate change on agricultural productivity. Mahmood (1998) and Mahmood et al., (2003) examined the effects of higher air temperature and atmospheric CO<sub>2</sub> concentration on rice yield they also showed that daily maximum and minimum air temperatures, daily precipitation and daily solar radiation, all of which could affect rice yield significantly. Rashid and Islam (2007) identified droughts, floods, salinity and cyclones as the major extreme climatic events to which Bangladeshi agriculture is most vulnerable.

The effects of climate change are inherently region specific, inciting the need for region-based research on climate change. Ruttan (2002) noted rainfall and sunlight has potential effect on agricultural productivity but the gross effect was largely region-specific. Karimet *al* (1996) conducted a series of simulations using the CERES -Rice and -Wheat models for Aus, Aman and Boro rice, and wheat. Basaket *al* (2010) concluded that climate change was likely to have predominately adverse impacts on the yield of Boro rice. They found that if climate change was to result in increased temperatures, that this would cause grain sterility during the growing season and hence a reduced yield. They also found that while changes to the level of atmospheric carbon dioxide and solar radiation might offset the impact of increased temperatures to some degree, that it would not be sufficient to mitigate it altogether (Iqbal and Siddique 2014). Mahmood *et al* (2004) observed that since rain-fed rice constitutes over 50% of total rice production in Bangladesh, production of this crop is extremely vulnerable to volatility in the supply of water. Chowdhury and Khan (2015) examined the impact of climate change on the rice production in Bangladesh using time series data.

Reilly et al. (1996) found that as temperatures move changed the production of rice. Although the effect of climate change is serious but there are limited researches conducted in case of developing countries (e.g. Boubacar, 2010; Holst et al., 2010), and very few in case of Bangladesh (Sarker et al., 2012; Basak et al., 2013, Hossain and Silva, 2013; Hossain et al., 2012 carried out a study to examine the relationship between three climate variables (maximum temperature, minimum temperature and rainfall) and three different rice crops (Aus, Aman and Boro). Awal and Siddique (2011) estimated the trend of rice production by employing ARIMA model but they did not consider climate influence. Hossain and Silva (2013) have conducted an initiative to find out the climate change impact on rice and wheat yield in Bangladesh. Rimi et al. (2009) concluded that temperature variations had spectacular implications on crop yield. Rahman et al (2018) showed the impact of climatic parameter on Aman rice production in Rangpur district of Bangladesh. From the above study we found that it is recent demand to investigate the effect of climate change for rice production specially boro rice in western part of Bangladesh.

### Research Methodology and Data Processing

The study was conducted in purposely-selected Rajshahi district in Bangladesh. The study was limited to some climatic factors and non-climatic factors. The selected climatic variables were maximum temperature, minimum temperature, average temperature, total rainfall, consecutive rainfall, average consecutive rainfall, maximum sunshine, minimum sunshine, average sunshine, maximum humidity, minimum humidity, average humidity. Time (YAR) and dummy variable (DMY) are the non-climatic variables. Estimation of the model required two sets of data (i) Historical crop yield data from period 1987 to 2015 and (ii) Historical data on a number of agro-climatic variables from period 1987 to 2015. The information furnished in the study based on different database. Data collected from DAE (Department of Agriculture Extension) climatic data will be collected from Bangladesh Meteorological Department (BMD). Rice production data will also be collected from the different Yearbook of Agricultural Statistics of Bangladesh (BBS).

### Time division for boro rice

Boro rice (HYV) cultivation period is from middle December to middle April. Boro rice has three growing stage which called phase. In this study we reduced data for Boro rice growing period from 16 December to 24 April according to these three phases. Growing period of Boro rice are divided into three stages;

**Stage 1** = vegetating phase (16December-18February = 65 days)

**Stage 2** = reproductive phase (19February-25March = 35 days) and

**Stage 3** = ripening phase (26March-24April = 30 days)

After dividing the Boro rice growing period into three stage we found that stage 1 and stage 2 are in the robi season and stage 3 is in the pre-kharif season. For every phase we process climatic data individually.

### Data processing

Data will enter and processing in the computer by using MS-Excel and MS-access programs. All data were converted into standard units (Metric tons, mm, °C). The model is based on the assumption that there exist a quantitative relationship between periodic values of agro-climatic variables and final crop yields. Data is generally available at the district level and second, since many agricultural policies are implemented at district level, the exercise may provide useful inputs for district level planning. Climatic data reduced in different phases are given below:

#### Rainfall:

The daily rainfall data has reduced as total rainfall, average rainfall, consecutive days and consecutive average rainfall according to three phases of crop growth.

#### Maximum temperature:

From the daily maximum temperature data, data has been reduced as maximum temperature and average maximum temperature of different phases of crop growth

#### Minimum temperature:

From the daily minimum temperature data, data has been reduced as minimum temperature and average minimum temperature of the three crop growth phases.

#### Sunshine:

Sunshine data has been reduced as maximum, minimum and average sunshine according to three phases of crop growth.

#### Humidity:

Humidity data has been reduced as maximum, minimum and average humidity of the crop growth phases.

Data analysis performed by statistical package SPSS. In Rajshahi region Boro rice production graphs will be prepared for last decade (1987-2015) and made comparison with different climatic parameters. Then effect of the climatic parameters will be analyzed for Boro rice production.

### Multiple Regression Model

Regression analysis is a statistical technique for investigating and modeling the relationship between variables (Montgomery and Peck, 1982). In fact, regression analysis may be the most widely used statistical technique. The yield forecasting model has been used in this study was specified as:

$$y_i = \beta_0 + \sum_{i=1}^n \sum_{j=1}^k \beta_j w_{ij} + \varepsilon_i \quad ; i = 1, 2, 3, \dots, n \quad ; j = 1, 2, 3, \dots, k$$

where,  $y_i$  is the yield of the boro rice crop,  $w_{ij}$  is the agro-climatic variables,  $\beta_j$  are the coefficients of the relevant variables,  $\beta_0$  is the constant and  $\varepsilon_i$  is the disturbance term. Here we take Y = Dependent variable = Yield and other variable (rainfall, temperature, sunshine and humidity) as independent variables including Dummy variables. This study used dummy variable for better fit the model. The explicit formula of the model is,

$$\text{Model-1: } Y_1 = \beta_0 + \beta_1 DMY + \varepsilon_1$$

$$\text{Model-2: } Y_2 = \beta_0 + \beta_1 DMY + \beta_2 S3\_min\_tem + \varepsilon_2$$

$$\text{Model-3: } Y_3 = \beta_0 + \beta_1 DMY + \beta_2 S3\_min\_tem + \beta_3 S1\_humidity\_min + \varepsilon_3$$

$$\text{Model-4: } Y_4 = \beta_0 + \beta_1 DMY + \beta_2 S3\_min\_tem + \beta_3 S1\_humidity\_min + \beta_4 S3\_con\_rainall\_avg + \varepsilon_4$$

Where,

$B_0$  = Coefficient of the relevant variable

DMY = Dummy variable ( 1= favorable weather condition, 0= Not favorable weather condition)

S3\_min\_tem = Stage 3 minimum temperature

S1\_humidity\_min = Stage 1 minimum humidity

S3\_con\_rainfall\_avg = Stage 3 consecutive rainfall average

$\varepsilon$  = Stochastic term/residual term/error term [  $\varepsilon \sim \text{NID}(0, \sigma^2)$  ]

The models for least square were used to estimate the regression coefficients by SPSS Software. The model was estimated for three reproductive stages (Stage 1 = Vegetating phase, Stage 2 = Reproductive phase, Stage 3 = Riping phase) of Boro rice crop growth, corresponding to 16 December-24 April of the year 1987-2015. For this stage of crop growth models were estimated for HYV (High yielding variety) Boro rice.

### Regression Diagnostic Study

Regression analysis is a statistical technique for investigating and modeling the relationship between variables (Montgomery and Peck, 1982). In fact, regression analysis may be the most widely used statistical technique. Regression analysis based on timeseries data implicitly assumes that underlying time series are stationary. The classical t-test and F-tests are based on this assumption using the unit root test showing that the time series data is stationary (Gujarati, 2004; Yin and Maddala, 1997).

in statistics, **stepwise regression** is a method of fitting **regression models** in which the choice of predictive variables is carried out by an automatic procedure (Efroymson (1960), Hocking, (1976), Draper and Smith (1981), SAS Institute Inc. (1989) . In each step, a variable is considered for addition to or subtraction from the set of **explanatory variables** based on some pre-specified criterion. Usually, this takes the form of a sequence of **F-tests** or **t-tests**, but other techniques are possible, such as **adjusted  $R^2$** , **Akaike information criterion (AIC)**, Bayesian information criterion, Mallows's Cp, PRESS, or false discovery rate. In a **stepwise regression**, predictor variables are entered into the **regression** equation one at a time based upon statistical criteria. At each step in the analysis the predictor variable that contributes the most to the prediction equation in terms of increasing the **multiple** correlation, R, is entered first. Model accuracy is often measured as the actual standard error (SE), MAPE, or mean error between the predicted value and the actual value in the hold-out sample. This method is particularly valuable when data are collected in different settings (e.g., different times, social vs. solitary situations) or when models are assumed to be generalizable.

### Graphical representation of the data

Multiple linear regression analysis requires some assumptions which are given below;

1. the prediction errors are **independent** over cases;
2. the prediction errors follow a **normal distribution**;
3. the prediction errors have a constant variance (**homoscedasticity**);
4. all relations among variables are **linear** and additive.

All of these criteria for multiple linear regressions is shown in Figure 1:

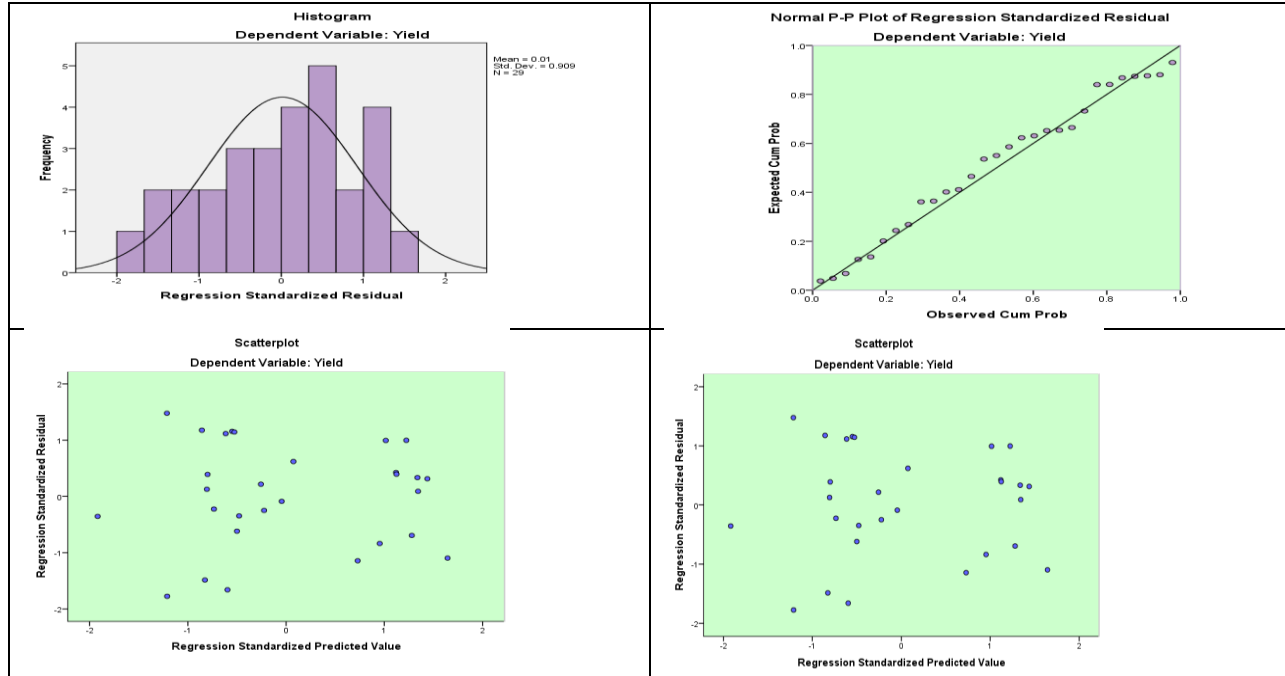


Figure 1:-Histogram, normal probability plot and scatter plot

From the Figure 1 we found that our regression assumptions is that the residuals (prediction errors) are normally distributed with mean 0.01 and standard deviation is 0.909. For normality our finding indicates slight violation of this normality plot suggest that normality assumption is not met. Here we have no major cause for concern. The scatter plot shows that the plotted points creates some homogeneous blocks i.e, the associated random variables have a homogeneity in their variance. So we may conclude that the data set is free of heteroscedasticity. Above individual coefficient plot shows that there is a positive trend between yield and dummy variables i.e, any increment or decrement of other climatic variable will increase or decrease the production respectively.

**Association of the variables with yield**

The association between these variables is reported in figure 2.

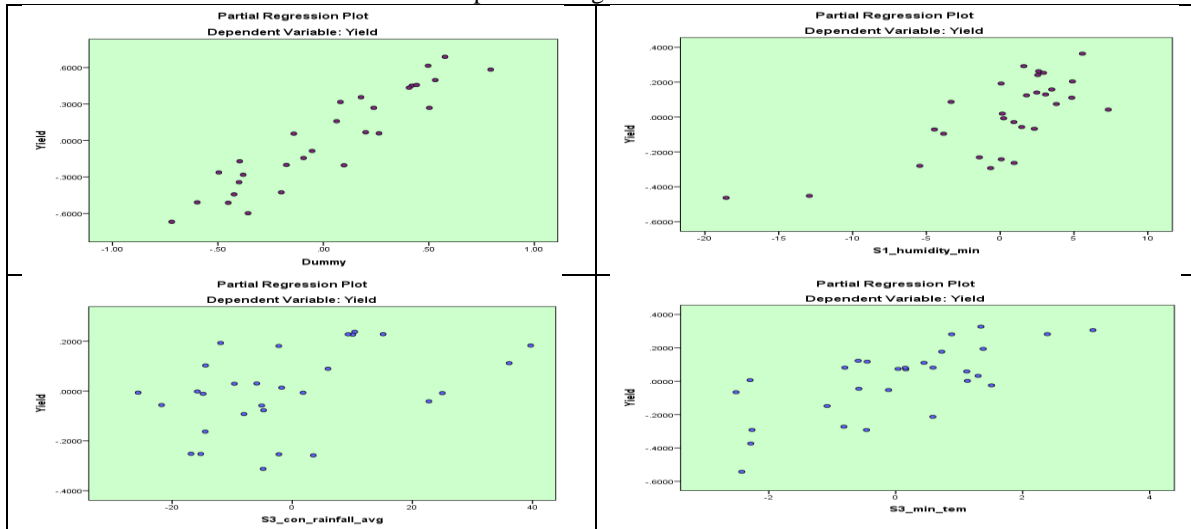


Figure 2:-Partial correlation of dummy, S1\_humidity\_min, S3\_con\_rainfall\_avg and S3\_con\_rainfall\_avg with yield

From figure 2 we found that the coefficient plot shows that there is a positive trend between yield and dummy variables i.e, any increment or decrement of other climatic variable will increase or decrease the production

respectively. This figure also represents the positive trend between yield and S1\_humidity\_min variables and there is a positive trend between yield and S3\_con\_rainfall\_avg variables. And finally, positive trend between yield and S3\_min\_tem variables indicates any increment or decrement of the climatic variable S3\_min\_tem will increase or decrease the production respectively.

**Results and Discussions:-**

This section demonstrated the multiple linear regressions with IBM SPSS using stepwise method. SPSS starts with zero predictors and then adds the strongest predictor Dummy. Then it adds the second strongest predictor (S3\_min\_tem).

**Table 1:-** Stepwise regression method for predicted variables

Model	Variables Enter	Variable Remove	Method
1	Dummy	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
2	S3_min_tem	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
3	S1_humidity_min	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
4	S3_con_rainfall_avg	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

And this procedure continues until none of the excluded predictors contributes significantly to the included predictors. Our empirical result indicates that 4 out of 46 predictors are entered and none of those are removed. The stepwise regression method for predicted variables is shown in Table 1. In order to compare the performance of the model we use the summary statistics such as R, R-square, Adjusted R-square, standard error etc. these are reported in Table 2.

**Table 2:-** Model summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.875 <sup>a</sup>	.765	.756	.2913988	
2	.921 <sup>b</sup>	.849	.837	.2382951	
3	.959 <sup>c</sup>	.920	.910	.1772242	
4	.966 <sup>d</sup>	.934	.922	.1645790	1.695

**Note:** a. Predictors: (Constant), Dummy; b. Predictors: (Constant), Dummy, S3\_min\_tem; c. Predictors: (Constant), Dummy, S3\_min\_tem, S1\_humidity\_min; d. Predictors: (Constant), Dummy, S3\_min\_tem, S1\_humidity\_min, S3\_con\_rainfall\_avg; e. Dependent Variable: Yield

Adding each predictor in our stepwise procedure results in a better predictive accuracy. From Table 2 we found that the Pearson Correlation between actual and predicted Values for model 1, 2, 3 and 4 are 0.875, 0.921, 0.959 and 0.966 respectively which confirm the positive strong correlation between these variables. R-square for the 1<sup>st</sup> model is 76.5%, which means that the predictor dummy variable is account for 76.5% of the variance in overall yield.

**Table 3:-** Parameter estimation result of the regression model\

Model	Unstandardized Coefficients		Standardized Coefficients	Sig.	F-statistics (Sig.)	95.0% Confidence Interval for B		Collinearity Statistics	
	B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF

1	(Constant)	2.99 8	.071		.00 0	84.767 (0.00)	2.85 3	3.14 3		
	Dummy	1.03 8	.113	.875	.00 0		.806	1.27 0	1.000	1.00 0
2	(Constant)	1.14 2	.501		.03 2	70.318 (0.00)	.110	2.17 5		
	Dummy	.821	.109	.692	.00 0		.596	1.04 6	.714	1.40 0
	S3_min_tem	.113	.030	.342	.00 1		.051	.175	.714	1.40 0
3	(Constant)	- .684	.544		.22 1	91.820 (0.00)	- 1.80 7	.440		
	Dummy	.881	.082	.743	.00 0		.712	1.05 1	.696	1.43 6
	S3_min_tem	.113	.023	.342	.00 0		.066	.159	.714	1.40 0
	S1_humidity_min	.029	.006	.271	.00 0		.016	.042	.965	1.03 6
4	(Constant)	- .720	.506		.16 8	81.061 (0.00)	- 1.76 7	.326		
	Dummy	.909	.077	.766	.00 0		.749	1.06 9	.678	1.47 5
	S3_min_tem	.103	.021	.313	.00 0		.059	.147	.685	1.46 1
	S1_humidity_min	.030	.006	.288	.00 0		.018	.043	.946	1.05 7
	S3_con_rainfall_avg	.004	.002	.122	.03 8		.000	.008	.939	1.06 5

#### a. Dependent Variable: Yield

Similarly we can show that R-square for the 2nd model is 84.9%, which means that the predictor variables (Dummy and S3\_min\_tem) are account for 84.9% of the variance in overall yield which also indicates that S3\_min\_tem is account for  $(84.9\% - 76.5\%) = 8.4\%$  change in variance proportion in this model. R-square for the 3rd model is 92% and for 4th model is 93.4%. Adjusted R squared is a corrected goodness-of-fit (model accuracy) measure for linear models. It identifies the percentage of variance in the target field that is explained by the input or inputs. The models 1, 2, 3 and 4 identifies 75.6%, 83.7%, 91% and 92.2% of variance in the target field respectively that is explained by the inputs. Depending on adjusted R2 among all the models the 4th model fit the data more accurately. The Durbin-Watson statistic is 1.695 which is between 1.5 and 2.5 and therefore the data is not autocorrelated. The estimated parameters of the regression equation of these four models are given in Table 3.

A rule of thumb is that Tolerance  $< 0.10$  indicates multicollinearity. As the value of tolerance for each case is  $> 0.10$ , so we can conclude that there exists no multicollinearity. The analysis reveals the value of variance inflation factors (VIF) of the explanatory variables in the final models of equations are less than, so it can be said that the data have no evidence of collinearity problems. Variance inflation factor (VIF) is nothing only a multicollinearity measurement technique of a regression model. From this table most of the parameters of all models are statistically significant except the constant term. It is also evident that all the regression models are highly significant. The table shows that the independent variables are statistically significantly predicted better result as  $F(4,23) = 81.0614$  i.e. the 4<sup>th</sup> regression model are good fit to the data.

Our **unstandardized coefficients** and the constant allow predicting yield precisely:

$$\text{Model 1: } \hat{Y}_1 = 2.99 + 1.03 DMY + \varepsilon_1$$

$$\text{Model 2: } \hat{Y}_2 = 1.142 + 0.821 DMY + 0.113 S3\_min\_tem + \varepsilon_2$$

**Model 3:**  $\hat{Y}_3 = -0.684 + 0.881DMY + 0.113S3\_min\_tem + 0.029S1\_humidity\_min + \epsilon_3$

**Model 4:**

$\hat{Y}_4 = -0.72 + 0.909DMY + 0.103S3\_min\_tem + 0.03S1\_humidity\_min + 0.004S3\_con\_rainfall\_avg + \epsilon_4$

**Interpretation of the models**

Interpretation of the models with standard error, t statistic and significance level of the variables are given below:

**Model 1:**

With the coefficients, standard errors, t-value, p-value and R<sup>2</sup> value of the table we can interpret the model 1. DMY is meaningfulness and so on. This means that respondents who score 1 point higher on meaningfulness will -on average- score 1.03 points higher on yield. Importantly, all predictors contribute **positively** (rather than negatively) to job satisfaction. This makes sense because they are all positive work aspects. All predictors are **highly statistically significant** (p = 0.000), which is not surprising considering our large sample size and the stepwise method we used.

**Model 2:**

The predictors are meaningfulness and so on. This mean that respondents DMY score 1 point higher on meaningfulness will -on average- score 0.821 points higher on yield and respondents S3\_min\_tem score 1 point higher on meaningfulness will -on average- score 0.113. If DMY and S3\_min\_tem becomes 0 then there exists a positive value 1.142 which is the intercept term of the model. Importantly, all predictors contribute **positively** (rather than negatively) to yield. This makes sense because they are all positive work aspects. All predictors are **statistically significant** (p < 0.05), which is not surprising considering our large sample size and the stepwise method we used.

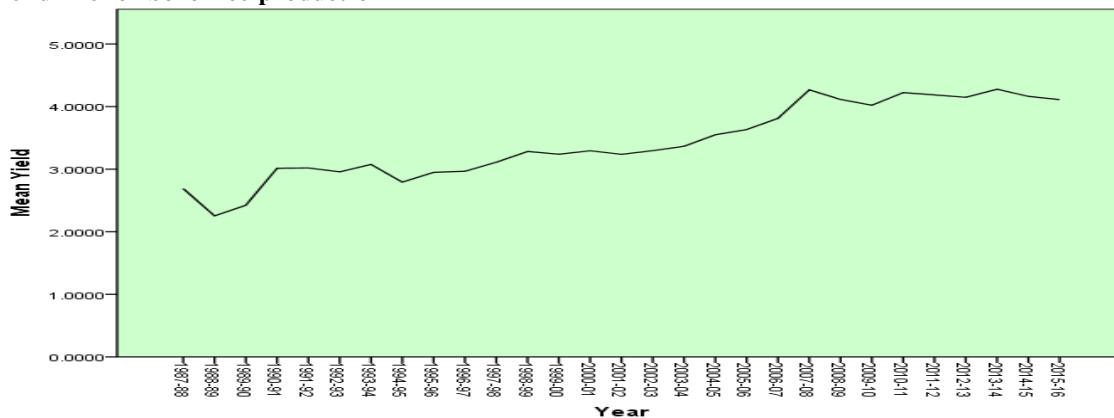
**Model 3:**

The predictors are meaningfulness and so on. This mean that respondents DMY score 1 point higher on meaningfulness will -on average- score 0 .881 points higher on yield, S3\_min\_tem score 1 point higher on meaningfulness will -on average- score 0.113 and S1\_humidity\_min score 1 point higher on meaningfulness will -on average- score 0.029 . If DMY and S1\_humidity\_min become 0 then there exists a positive value 1.142 which is the intercept term of the model. Importantly, all predictors contribute **positively** (rather than negatively) to yield. This makes sense because they are all positive work aspects. All predictors are **highly statistically significant** (p = 0.000), which is not surprising considering our large sample size and the stepwise method we used.

**Model 4:**

The predictors are meaningfulness and so on. This means that if respondent dummy scores 1 unit higher on meaningfulness will -on average- score 0.909 points higher on yield, if predictor S3\_min\_tem increases by 1 unit, the production increased by 0.103 units, if predictor S1\_humidity\_min increases by 1 unit then the yield increased by 0.030 units and if the predictor S3\_con\_rainfall\_avg increases by 1 unit then the yield increases by 0.004 units respectively.

**Trend line for boro rice production**



**Figure 3:-** Trend line for boro rice production



The trend line for boro rice production is given in Figure 3. This line plot shows that the mean yield of boro rice is increasing day by day except some particular year. If DMY, S3\_min\_tem, S1\_humidity\_min and S3\_con\_rainfall\_avg become 0 then there exists a negative value -0.720 which is the intercept term of the model. This happens because of the impact of other variables which were not associated in the model. The predictors are statistically significant ( $p = 0.000, 0.00, 0.00, 0.038$ ), which is not surprising considering our large sample size and the stepwise method was used.

### Conclusions:-

Bangladesh is one of the vulnerable countries to climate change in the world. The climate change and frequent change in the variability of the climate condition of the country have direct impacts on agriculture and environment in various ways. The objective of this study was to estimate the relationship between Boro rice yields and climate variables using aggregate-level time series data for the period of 1987 to 2015. The overall findings reveal that four climate variables minimum humidity at vegetating phase, minimum temperature and consecutive days rainfall average at rippling phase and dummy variables have substantial effects on the Boro rice yield. The result indicates that average seasonal minimum temperature, minimum humidity and average rainfall are statistically significant and positively affect the yield of Boro rice. In terms of the  $R^2$ , p-values and F-values for Boro rice models have been found statistically significant. Every crop has an optimum minimum and maximum temperatures, rainfall and humidity limit for their reproductive and vegetative growth. When temperature exceeded the upper limit or falls below the range or humidity crossed the upper limit, crop production changes drastically. Moreover, excessive rainfall may create water logging condition and flooding that also destroys the crop production. Given the high vulnerability of rice yields to climate variations in Bangladesh, different adaptation strategies should be adopted to offset the adverse effects of climate change. To minimize the effects of the climatic variables farmers of the study area adopt some strategies like changing in planting date, digging of ponds and setting up shallow tube wells, selection of short duration species etc. based on indigenous knowledge and resources. Climate change in Bangladesh is a serious concern since it adversely affects agriculture which is an important sector in the country. Therefore, the concerned authority should take appropriate policies to fight against the climate change impact on rice production to ensure food security for the ever increasing population of the country through implementing sustainable agricultural development.

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