Impact of Some Climatic Variables on the Yields of Boro Rice in Bangladesh

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Abstract

Bangladesh is primarily an Agriculture based country and its economy largely depends on the agriculture. Weather and climate are key determinants of the productivity of crops grown in an agrarian country like Bangladesh. Boro rice constitutes a large share in the domestic food grain of the country. Sometimes its production affected by some climatic factors. Therefore, the objective of this research was to determine the likely climatic factors for Boro rice production in Bangladesh. In this study we employed traditional OLS method and recent Bootstrap technique to identify the influential climatic factors on Boro rice production. Our study revealed that the considered variables rainfalls (RAIN), maximum temperature (MAX), minimum temperature (MIN) and wind speed (WIND) have significant effect on Boro rice production both by OLS and Bootstrap method. Bootstrap method exhibits lower standard errors in comparison to the OLS method indicating that this estimate could be useful in Boro rice production of Bangladesh. The messages from this study could be useful for the policy makers of the country.

Keywords: Multiple Regression, Bootstrap Technique, Climatic Factors, Boro Rice Production, Ordinary Least Squares (OLS)

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Introduction

Bangladesh is primarily an Agriculture based country and its economy largely depends on agriculture. Poverty is still a problem for the country. In South Asia it is still a problem for the rural people. About 70% of South Asia's population lives in rural areas, and it accounts for about 75% of the poor. Most of the rural poor depend on agriculture for their livelihood. Agriculture employs about 60% of the labor force in South Asia and contributes 22% of regional Gross Domestic Product (World Bank). In Bangladesh agriculture sector accounts for about 20% of the country's Gross Domestic Product (GDP). About 90% of the Bangladesh people depend on rice for their calories intake. Rice is a major source of livelihood in terms of providing food, income and employment in Bangladesh. Rice occupies the maximum share of agricultural GDP and it employs about 60% of the total labour force (Alam *et al.* 2008; WDI, 2010).

Because of the increasing demand for food and jobs for many inhabitants, it became necessary for households to embark on agriculture as a means of filling the food demand and supply gap and providing income for other household requirements. In addition, the practice of agriculture has continued to increase in recent years with the structural adjustment of the Bangladeshi economy. The rise in food price, un-employment and inflation brought by the structural adjustment (World Bank, 1990) and the decline in the average real income of both rural and urban households have completed many in to farming areas. Among all other cereal crops, Boro rice has the largest share in the domestic food grain production of the country (WEP, 2011). Since 1999-2000, Boro contributes more than half of the total rice production in Bangladesh. Currently Boro occupies about 41% of total rice area and contributes 56% of total rice production in Bangladesh (Deb *et al.* 2009).

Weather and climate are key determinants of the productivity of crops grown in various regions of the world. Moreover the forecasts of crop production for the coming season require accurate seasonal weather forecasting (Challinor, *et al.* 2003). Climate change is anticipated to have for reaching effects on the sustainable development of developing countries including their ability to attain the United Nations Millennium Development Goals by 2015 (UN 2007). Agriculture is extremely vulnerable to climate change (IPCC, 1990), changes in temperature. Mendelshon (1994) has examined the impacts of the climate change on agriculture for all countries in the world between 1960 and 2000. According to him, temperature and precipitation has the effect from a loss of 0.05% to a gain of 0.9% of global agricultural GDP.

Some studies on various aspects of rice production and its influential factors (Basorun and Fasakin, 2012; Karmokar *et al*., 2012; Karmokar and Shitan, 2011; Nargis and Lee, 2013) have been found in the literature. Most of the cases they used the econometric time series analyses to conclude their research.

Karmokar and shitan (2011) studied some influential factors like, annual rainfall, uses of chemical fertilizer, area of cultivation and lag harvest prices on rice production of Bangladesh on basis of Food and Agriculture Organisation of the United Nations online database (FAOSTAT) for the years 1975 to 2003 to identify which factors play a crucial role on the production of rice in Bangladesh.

As a very simple and widely used technique they considered OLS for their study. But Sometime OLS estimates may be affected by the occurrence of outliers, non-normality, multicollinearity or other causes (Ho and Naugher, 2000). In reliable aspect bias may create problem for the estimators. Bootstrap technique may give the good and minimum biased estimators. As such it would be interested to estimate the Bootstrap estimators of parameters along with the OLS estimators which could be comparatively less affected by any biased or non-normality of errors.

Methods and Materials

A brief discussion of data sources ad selected variables are presented in this section.

Data Source and Selected Variables

This study based on the Bangladesh Meteorological Department (BMD) data. The BMD was implemented through a collaborative effort of the Bangladesh Agricultural Research Council of the Ministry of Agriculture, Government of the People's Republic of Bangladesh. A sample of 40 years (1971 to 2010) has been collected from the meteorological stations in Bangladesh. The yield data used in this study have been collected by Bangladesh Agricultural Research Council.

The predictor variables namely, Rainfall in centimeter (RAIN), Maximum temperature in degree Celsius (MAX), Minimum temperature in degree Celsius (MIN) and Wind Speed in meter per second (WIND) and the response variable per hectare Boro Rice production in kilogram (BRICE) have been used in this study.

Multiple Regression

Regression analysis is one of the most widely used statistical tools which provide simple methods for establishing a functional relationship among a set of variables. It has extensive use in a variety of areas including agricultural science. In this study we are interested to fit a multiple linear regression model to identify the variables influencing the BRICE of Bangladesh. The under usual assumptions the multiple linear regression model is as follows

$$BRICE = \beta_0 + \beta_1 RAIN + \beta_2 MAX + \beta_3 MIN + \beta_4 WIND + \varepsilon \ , \qquad (1)$$

where BRICE is the response variable, RAIN is the Rainfall, MAX is the Maximum temperature, MIN is the Minimum temperature and WIND is the Wind Speed. β_0 is the intercept term, $\beta_1, \beta_2, \ . \ . \ . \ , \beta_k$ are the unknown regression coefficients, and ε is the error term with a $N(0, \sigma^2)$ distribution.

Regression Diagnostics

Sometimes the regression results may mislead the outcomes due to some causes. Among them multicollinearity is phenomenon of data set which occurs due to the dependency or any relationship among the predictors variables. In such case the diagnostic, Variance Inflation Factor (VIF) may indicate either the data set is infected by milticollinearity problem or not? The VIF for independent variables X_j is

$$VIF_j = \frac{1}{1-R_j^2} \ , \ j = 1,2,3, \dots \dots, k \ ,$$

where k is the number of predictor variables and R_j^2 is the square of the multiple correlation coefficient of the jth variable with the remaining (k -1) variables where,

1) if $0 < VIF < 5$, there is no evidence of multicollinearity problem

2) if $0 \leq VIF \leq 5$, there is a moderate multicollinearity problem and

3) if $VIF > 10$, there is a seriously multicollinearity problem of variables (Chatterjee & Hadi, 2006).

When multicollinearity is present in a set of predictor (explanatory) variables, the ordinary least squares estimation of the individual regression coefficients tend to be unstable and can lead to erroneous inferences. There are some alternative estimation methods that provide a more informative analysis of the data than the OLS method when multicollinearity is present. These are

(i) Dropping of bad variable from analysis
(ii) Estimation of linear function of regression coefficient
(iii) Method of estimation by adjusting dependent variable
(iv) Method of reparametarization of the model
(v) Principal component regression
(vi) Ridge regression.

Bootstrapping Method

There are mainly two technique of bootstrap, they are

(i) Fixed X-resampling (Bootstrap-1)
(ii) Random X-resampling (Bootstrap-2)

Fixed X-resampling (Bootstrap-1): when the model matrix X is fixed we can generate bootstrap replication in the following way:

Step-1: Based on an observed sample we have to consider a regression model

$$Y = X\beta + \varepsilon.$$

Step-2: Fit the model by the OLS denote the estimated by $\ddot{\beta}$ and compute residuals$\{\hat{\varepsilon}_1, \hat{\varepsilon}_2, \hat{\varepsilon}_3, \ldots\ldots, \hat{\varepsilon}_n\}$.

Step-3: Resample from $\{\hat{\varepsilon}_1, \hat{\varepsilon}_2, \hat{\varepsilon}_3, \ldots\ldots, \hat{\varepsilon}_n\}$ to obtain $\{\hat{\varepsilon}^*_{r1}, \hat{\varepsilon}^*_{r2}, \hat{\varepsilon}^*_{r3}, \ldots\ldots, \hat{\varepsilon}^*_{rn}\}$; $r = 1,2,3, \ldots\ldots\ldots, B$

Step-4: Enumerate the response values $y^*_{ri}$from the equation

$$y^*_{ri} = x_i^T \ddot{\beta} + \hat{\varepsilon}^*_{ri}\ ; i = 1,2, \ldots\ldots, n;\quad r = 1,2, \ldots\ldots, B$$

Step-4: Estimate the regression parameter by the OLS from the model

$$Y^*_r = X\beta + \varepsilon_r$$

To obtain $\ddot{\beta}^*_r = (X^T X)^{-1} X^T Y^*_r$ then the estimated regression coefficient by using fixed X-resampling bootstrap technique is

$$\ddot{\beta}^b = \frac{1}{B}\sum_{r=1}^{B} \ddot{\beta}^*_r$$

The bootstrap bias and variance

The bootstrap bias equals,

$\widehat{bias}_b = \hat{\beta}^b - \hat{\beta}$ (for further discussion see Efron and Tibshirani, 1993). Following Liu and stine (Liu, 1988; Stine 1990) the bootstrap variance from the distribution $F(\hat{\beta}^b)$ are calculated as

$$Var(\hat{\beta}^b) = \Sigma_{r=}^{B} \left[(\hat{\beta}_r^* - \hat{\beta}^b)(\hat{\beta}_r^* - \hat{\beta}^b)^T \right] / (B-1)$$

The bootstrap confidence interval by normal approach is obtained as

$\hat{\beta}^b - t_{n-p,\frac{\alpha}{2}} * S_e(\hat{\beta}^b) < \beta < \hat{\beta}^b + t_{n-p,\frac{\alpha}{2}} * S_e(\hat{\beta}^b)$, where $t_{n-p,\frac{\alpha}{2}}$ is the critical value of t with the probability of $\frac{\alpha}{2}$ the right for n-p degrees of freedom and $S_e(\hat{\beta}^b)$ is the standard error of $\hat{\beta}^b$.

Results Discussion

We have considered BRICE, RAIN, MAX, MIN and WIND in this research. To have an idea about these variables the Summary statistics have been enlisted in the Table 1.

Table 1. Summary statistics of study variables

Variable	Mean	Maximum	minimum	Variance	Skewness	Kurtosis
BRICE	4443.750	5960.000	3290.000	416285.577	0.810	3.080
MAX	30.408	31.320	29.410	0.151	0.222	3.582
MIN	21.106	21.650	20.580	0.073	0.085	2.269
RAIN	49.993	80.250	23.360	172.922	0.237	2.626
WIND	1.252	1.680	0.870	0.049	−0.166	1.985

It is noticed from the results of Table 1 that the average of BRICE is 4443.750, variance is 416285.577 maximum is 5960.000, minimum is 3290.000, skewness is 0.810 and kurtosis is 3.080. For maximum temperature the average is 30.408, variance is 0.151, maximum is 31.320, minimum is 29.410, skewness is 0.222 and kurtosis is 3.582. The average value of minimum temperature is 21.106, variance is 0.073, maximum is 21.650, minimum is 20.580, skewness is 0.085 and kurtosis is 2.269. The average of RAIN is 49.993, variance is 172.922, maximum is 80.250, minimum is 23.360, skewness is 0.237, kurtosis is 2.626. For WIND, average is 1.252, variance is 0.049, maximum is 1.680, minimum is 0.870, skewness is −0.166 and kurtosis is 1.985. Therefore, all the variables selected in this study are non-normally distributed.

To have an idea about the production trend of Boro rice of Bangladesh five year production percentages of Boro rice among all variety of rice have been computed. A time series plot of these percentages is shown in the figure1.

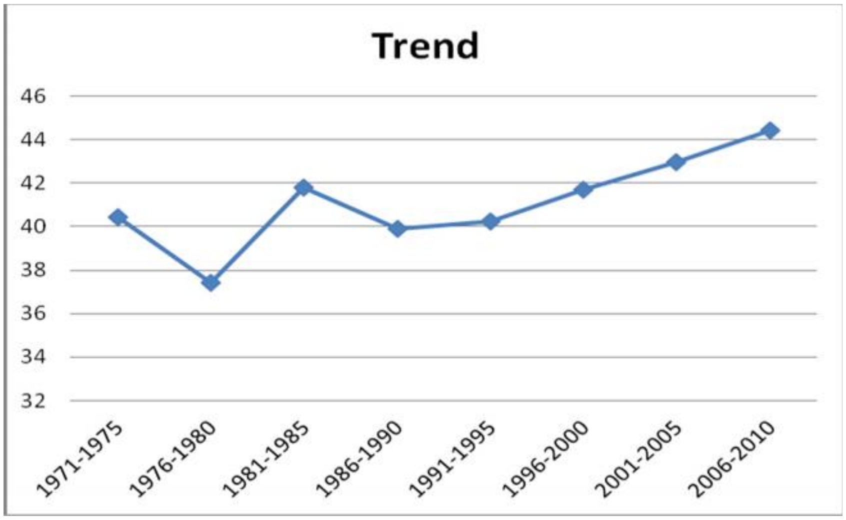

Fig 1. Five year production percentages of Boro rice

It is seen from the above figure that the five year production percentages have somewhat an increasing trend. Therefore year-wise production of Boro rice is increasing in Bangladesh.

To investigate the relationship among a set of variables, regression is one of the most commonly used statistical techniques. In linear regression, the relationship between two variables can be judged by fitting a linear equation. The multiple linear regression attempts to model the relationship between two or more explanatory variables and a response variable by fitting a linear equation to observed data. The ordinary least squares (OLS) method is a way of estimating the parameters of a regression model. We fitted a multiple regression model as given in equation 1 by OLS methods and the estimators, t-statistics, *p*-values and VIF are presented in Table 2.

Table 2. OLS estimators with VIF of multiple regressions

Predictors	Coefficient	t-value	Standard Error	*p*-value	VIF
RAIN	6.124	2.251	2.720	0.031	1.351
MAX	668.679	2.817	237.386	0.008	1.949
MIN	–585.254	–1.798	325.504	0.081	1.779
WIND	–2029.464	–5.975	339.683	0.000	1.301

In Table 2, the estimated value for RAIN is 6.124 and its t-value is 2.252 with p-value 0.031, the estimated value for MAX is 668.679and its t-value is 2.817 with p-value 0.008, the estimated value for MIN is –585.254 and its t-value is –1.798 with p-value 0.081, the estimated value for WIND is –2029.464 and its t-value is –5.975 with p-value 0.000.

Although MIN is significant at 10% level all other variables are significant at 5% level. The VIF values for all the variables are less than 5 indicating that there is no such multicolinearity in the data set. The R^2 value for this model is 0.634 and the Adj R^2 value is 0.592. Therefore, the predictor variables can explain about 63.4% of total variation by R^2 and about 59.2% of total variation by Adj. R^2.

Bootstrap is a re-sampling technique used in statistical analyses has been considered in this research. The Bootstrap results using same variables as used in the multiple regression model are given in the Table 3.

Table 3. Bootstrap results for study variables

Variable	Regression Coefficient	Bias	Standard Error	*p*-value	95% Confidence Interval	
					Lower	Upper
BRICE	6.680	0.570	2.250	0.031	0.880	12.470
MAX	668.270	–0.400	200.130	0.007	152.720	1183.810
MIN	–586.640	–1.390	264.120	0.072	–1267.030	93.750
WIND	–2030.720	–1.260	327.870	0.000	–2875.330	–86.110

From bootstrapping result in the above table it is seen that the regression coefficients are approximately same as it was found in the multiple regression model but the standard errors of all the estimators are less than that of multiple regression standard errors. This may be due to bias correction of Bootstrap method. Hence, we may recommend these estimators as an alternative of OLS estimators.

Conclusion

In this research, the objective was to determine the likely climatic factors for Boro rice production in Bangladesh. Our study shows that the considered variables RAIN, MAX, MIN and WIND have significant effect on Boro rice production of Bangladesh both by OLS and Bootstrap method. The predictor variables can explain about 63.4% of total variation by R^2 and about 59.2% of total variation by Adj. R^2 for OLS estimators. Due to bias correction, Bootstrap method exhibits lower standard errors in comparison to the OLS method indicating that this estimate could be useful in agricultural production like Boro rice production of

Bangladesh. The results and message could be useful and significant for the policy makers in the agriculture sector of the country.

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