

Climate Change and Aman Rice Yield Nexus in the North-Western Part of Bangladesh: Using Quantile Regression

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Abstract

Aman is a rain-fed crop that is the second-largest rice crop in Bangladesh in general and in particular, in the study area with respect to the volume of production. It also carries significant value in the case of food security as well as livelihood options for many farmers. At this backdrop, the study focuses on exploring the relationship between climate change variables (Average Maximum Temperature, Average Minimum Temperature, Total rainfall, Average Relative Humidity) and Yield of Aman in Bogra and Joypurhat districts of Bangladesh. In this case, quantile regression at the median is used to examine climate change and Aman rice interrelations using time series data from 1969 to 2013. The findings of the study reveal that Average Maximum Temperature and Total Rainfall has a positive impact on the Aman yield production in the study area. Considering the future severe adverse effects of climate change on food security and nutrition, and employment aspects in the study area, the study, therefore, recommends the concerned authorities to strengthen their efforts to develop, and distribute of drought-tolerant HYV of Aman rice among the farmers at an affordable rate. Meanwhile, the farmers should be encouraged to cultivate drought-tolerant and less water-fed crops.

Keywords: Climate Change; Agricultural Production Of Bangladesh; Quantile Regression

1. Introduction

Bangladesh is one of the most vulnerable countries to global climate change. According to the Global climate risk index (2019), Bangladesh ranks 9th among the ten most affected countries in the world for experiencing extreme weather events with a climate risk index 16. The agricultural sector in Bangladesh is still the backbone of the economy; in FY 2016-17, it was accounted for 14.17 percent of GDP (of which crop sub-sector alone was 7.69 percent) and is employing 40.6 percent of the total national labour force (BBS, National Income Accounts, 2018b; BBS, Labour Force Survey, 2018a). But, our agricultural sector is already on the verge of facing severe consequences of global climate change, because agricultural production and productivity is being regulated by the prevailing climate of any area through temperature, rainfall, light intensity, radiation, sunshine, etc. and the unusual weather during the reproductive period of a crop (Goswami, Mahi, & Saikia, 2006).

A report by Asian Development Bank(ADB), 2014 states that low-lying Bangladesh is at the front line of at-risk countries from climate change and could suffer annual losses of up to 9 (nine) percent of its economy by the end of this century accompanied with vast crop losses, disappearing arable land, displaced communities, poisoned groundwater etc. The negative

impacts of climate change might become noticeable in terms of the production of rice and wheat that might drop by 8 percent and 32 percent respectively in Bangladesh in 2050; however, rice would be less affected by climate change compared to wheat, which is more sensitive to a change in temperature (Faisal & Parvin, 2004). On that way, study conducted by World Bank (2000) projects that by the year 2050, the average temperature will increase by 1.8°C, precipitation will fluctuate 37 % compared to 1990 in the dry season, and sea levels will rise by 50 cm. in Bangladesh.

On the other hand, several studies claim changes in the climate of Bangladesh over last few years. For example, Agrawala et al. (2003) claimed that, Bangladesh has been facing higher temperatures over the last three decades and it is forecasted to experience a rise in annual mean temperatures of 1.4 °C by 2050 and 2.4 °C by 2100. Again, Sikder and Xiaoying (2014) concluded that the impacts of climate change in agriculture are global concern but for Bangladesh where lives and livelihoods depend on agriculture, it's becoming a great threat for national food security.

In the perspective of food security, Govt. of Bangladesh (2009) also claimed that climate change will result in increasingly frequent and severe floods in the central part of the country; flash flood in the north-eastern and eastern part of the Bangladesh and droughts and erratic rainfall in north-western and western Bangladesh. Govt. of Bangladesh and UNDP (2009) again claimed that the erratic manner of climate produces extreme events such as floods and droughts in Bangladesh, which have remarkable harmful effects on major food crops' yield, especially on Aman rice.

In the backdrop of inevitable climate change and its effect on agriculture as evident in different studies found, it is clear that there is nexus among climatic variables and rice production in Bangladesh e.g., Sarker et al. (2012) conducted a study to examine the relationship of yields of three major rice crops (e.g., Aus, Aman, and Boro) and three main climatic variables (e.g., maximum temperature, minimum temperature and rainfall) and came up with the findings that maximum temperature and rainfall have a positive effect on yields of Aman rice, whilst minimum temperature has a negative effect on the same. In contrast with Sarker et al. (2012), a study conducted by Amin et al. (2015) found that both maximum and minimum temperature, rainfall, and sunshine negatively contribute to the yields.

To show the climate change impact on rice production from a regional level perspective, Kabir (2015) found that sign and the level of significance differ between the linear and quadratic model in the south western region of Bangladesh for Aman rice production. In a similar fashion, a recent study conducted by Sarker et al. (2017) found that elasticity differs for using Cobb–Douglas production function in both linear and quadratic form.

However, among the available rice crops, Aman is the second-largest rice crop in Bangladesh with respect to the volume of production after Boro rice. In 2014-15 fiscal year total Aman rice production was 2,186,089 metric ton (MT) in the Rajshahi division¹, of which Bogra and Joypurhat accounted for around 31 percent of total share of the division (BBS, 2016).

But, the impact of climatic variables on Aman rice yields provides mixed results (either negative or positive) as are evident in literatures what so ever we consider Bangladesh as a whole or its any specific region as the study area (the reason might be a variation of climate

¹Rajshahi division is also part of north western region and consisting of eight districts including Bogra, Chapainabganj, Joypurhat, Naogaon, Natore, Pabna, Rajshahi and Sirajgonj.

from one place/ region to another despite in the same season²). Hence, Bangladesh Climate Change Strategy and Action Plan -2009 suggested development of climate resilient cropping systems appropriate to different agro-climatic regions and sub-regions (Govt. of Bangladesh, 2009).

But, there is no specific study devoting to explore the impact of climate change on Aman rice yields in districts or sub-region which are drought-prone in nature. So, this study explores the nexus between climatic variables (Average Maximum Temperature, Average Minimum Temperature, Total Rainfall, and Average Relative Humidity) and Yields of Aman in Bogra and Joypurhat districts of Bangladesh by applying quantile regression at median using time-series data for 44 years, 1969-2013.

2. Methodology

Study Area

Both Bogra and Joypurhat districts are located in the north-western Rajshahi division of Bangladesh. Joypurhat was a sub-division under Bogra district and in 1984, it turned into a separate district.



Source: Adapted from Rahaman et al. (2016)

Figure 1: Location of the Region and Study Area

Data and Variables

In order to examine the relationship between climatic variables (Average Maximum Temperature, Average Minimum Temperature, Total Rainfall, and Average Relative Humidity) and Aman rice yields of Bogra and Joypurhat districts, the study considers 44 years' time-series data covering the year 1969 to 2013. The data of Aman yields have been collected from the Bangladesh Bureau of Statistics (BBS) office, whilst the data of climatic variables have been collected from the Bangladesh Meteorological Department (BMD). In this

²There are traditionally six seasons in the Bengali year: Summer, Rain, autumn, Late Autumn, winter and spring. All the seasons of Bangladesh bear the different characteristics from one to another place. Therefore, Bangladesh has been divided into seven climatic sub-regions like the Seven Soil Tracts of Bangladesh. These seven climatic sub-regions are South-Eastern, North-Eastern, Northern part of the north region, North-western region, Western dry region, South-western region and South-central region (Banglapedia, 2018).

study, June to November has been considered for data assimilation (cultivation period of Aman rice) and Yields (ton) per Acre of Aman Rice has been considered as the regressand and while the regressors are Average Maximum Temperature, Average Minimum Temperature, Total Rainfall, Average Relative Humidity.

Empirical Model Specification

In order to explore the relationship between Aman rice yields and climate change variables, the study considers the following model:

$$Y_{Aman_t} = \beta_0 + \beta_1 amaxt_t + \beta_2 amint_t + \beta_3 train_t + \beta_4 arh_t + \epsilon_t \dots \dots \dots (1)$$

where, Y_{Aman} is the yields per acre of Aman Rice, $amaxt$ is the average maximum temperature ($^{\circ}c$) from June to November, $amint$ is the average minimum temperature ($^{\circ}c$) from June to November, $train$ is the total rainfall from June to November and arh is the average relative humidity from June to November, ϵ_t is the error term, and t for time (i.e., year).

3. Results and Discussion

Econometric Modeling

To estimate model (1), it is imperative to screen time series data whether stationary or not. So, it is important to determinate the integration order of time series analysis through unit root tests (Arltova & Fedorova, 2016). By using unit root- Phillips-Perron test, it is evident that Yields per Acre (in ton) and Average Maximum Temperature ($^{\circ}c$) are non-stationary while, Average Minimum Temperature ($^{\circ}c$), Total Rainfall (mm) and Average Relative Humidity are stationary at mean and variance of which results are reported in Table 1.

Table 1: Results from Unit Root- Phillips-Perron (PP) test

Variable	p-value	Status
Yields per Acre of Aman Rice (ton)	0.8472	I (1)
Average maximum temperature ($^{\circ}c$)	0.1079	I (1)
Average minimum temperature ($^{\circ}c$)	0.0000	I (0)
Total rainfall (mm)	0.0000	I (0)
Average relative humidity	0.0336	I (0)

Source: Authors' computations

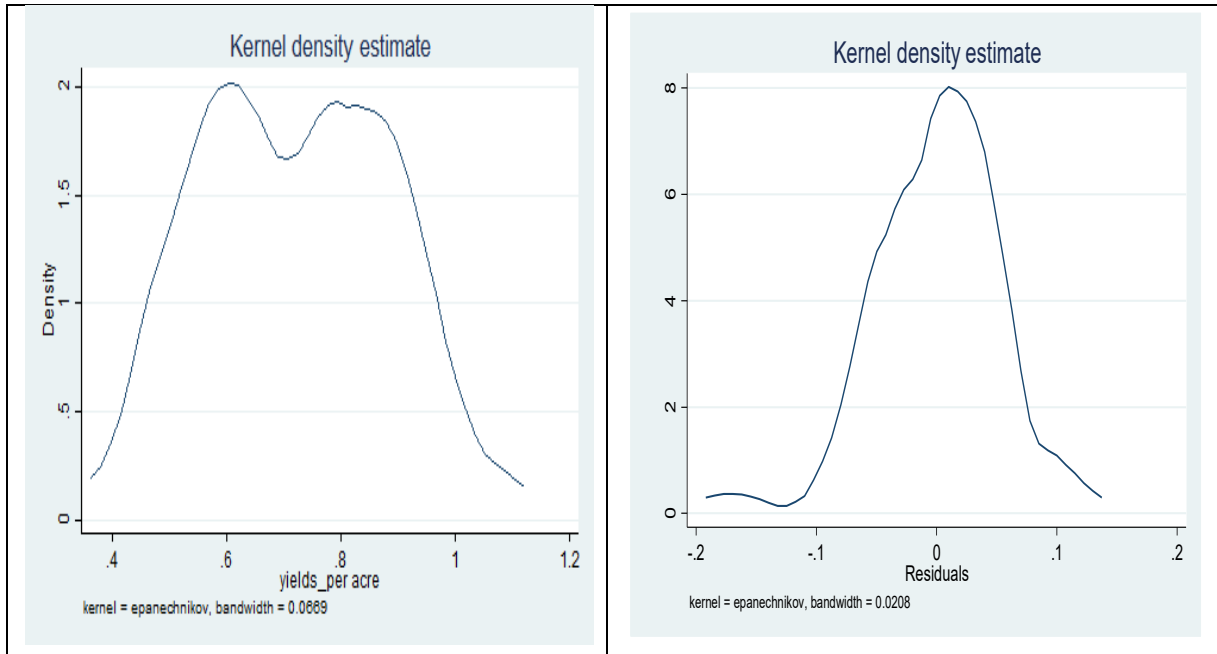
In this case, in order to overcome the problem of non-stationary of variables, log transformation technique or difference technique might be chosen. In this study, the difference technique has been used for solving the unit root problem. After taking the first difference of Yields per Acre and Average Maximum Temperature, it is evident that both the variables are free from unit root problem which are reported in Table 2.

Table 2: Result from unit root test after first difference

Variable	p-value	Status
Yield per acre	0.0000	I (0)
Average Maximum Temperature	0.0000	I (0)

Source: Authors' computations

To estimate the model (1), this study has first relied on ordinary least square (OLS) estimation with basic assumptions. Kernel density estimate (KDE) suggests that both the regressand and errors follow normal distribution as evident in Figure 2.



Source: Authors' computations

Figure 2: Kernel Density Estimate of Yields per Acre and the Residuals

The presence of multi-collinearity has a number of potentially serious effects on the least square estimates of the regression coefficients (Montgomery et al., 2003). From this study, VIF suggests that the assumed model is free from multi-collinearity as evident in Table 3.

Table 3: VIF for detecting multi-collinearity

Variable	VIF	1/VIF
Avg. Max. Temperature	1.36	0.734718
Avg. Min. Temperature	1.03	0.967886
Total rainfall	1.33	0.750044
Avg. Relative Humidity	1.36	0.734718
Mean VIF	1.20	

Source: Authors' computations

Durbin-Watson (DW) test was conducted to detect the auto correlation. From the data, DW d-statistic (5, 44) is found to be 1.933201 which suggests that there is no autocorrelation in the data set according to Gujarati (2007).

Presence of heteroskedasticity, however, destroys the BLUE property (Maddala, 1992). From white test for checking heteroskedasticity, an unrestricted heteroskedasticity problem is evident (H_0 of homoskedasticity is rejected at $\alpha = 5\%$, $P\text{-value} = 0.0043$). In such a case, weighted least square (WLS) or feasible generalized least square (FGLS) method can be applied. Rather applying WLS or FGLS, this study relied on the application of Quantile Regression (QR) at median which is robust in such cases of which results are represented in Table-4

Table 4: Empirical result of Quintile regression at median

Variable	Coeff. $\hat{\beta}_{QR(\text{median})}$	Std. Error	t-value	95 percent CI	
				LL	UL
Average Maximum temperature	0.26***	0.046	5.61	0.166	0.354
Average Minimum temperature	0.05	0.068	0.79	-0.083	0.192
Total Rainfall	0.0001*	0.0007	1.89	-9.78e-6	0.0002
Average relative humidity	0.0049	2.44	-3.87	-0.02	0.03
Number of observations	44				
³ Pseudo R ²	0.40				

Source: Authors' computations

Note: * p<0.10, **p<.05, ***p<.01

Results Interpretations

From table 4, it is found that Average Maximum Temperature is statistically significant which indicates that as Average Maximum Temperature increases by 1^o C, on an average, Aman Yield at the median point increase by 0.26 metric ton per acre holding all other covariates constant; this result also conforms to the results of (Sarker et al., 2012; Amin et al., 2015; Sarkar et al., 2017b). The Total Rainfall is also found to be statistically significant which shows that for 1 mm increase in Total Rainfall, the Yield of Aman rice will increase by 0.0001 metric ton per acre at a median point on an average holding all other covariates constant; this finding also conforms to the findings of (Sarker et al., 2012; Zakaria et al., 2014; Sarkar et al., 2017b).

Rise in temperature and reduction in rainfall should negatively impact the water-fed Aman rice yield. In this case, according to Assaduzzaman and Anik (2017), Aman rice being water-intensive crop, its productivity largely related to water availability but also sensitive to temperature rise during the flowering period –which by far don't conform our results. Perhaps, other factors like introduction of improved irrigation systems, using of HYV of Aman (Brridhan71, Brridhan75, Brridhan80, Brridhan87 and Brridhan90 which are comparatively higher-yielding, drought-tolerant, and shorter-duration than the local Swarna variety), using improved fertilizer and pesticides are responsible for dramatically increase of the production of Aman rice yields.

4. Concluding Remakes

Globally, Bangladesh is one of the most vulnerable countries to the adverse effects of climate change. At this backdrop, considering the threat of food security and income of the farmers due to the severe impact of future climate change reality, there is an urgency of developing more and more the drought-tolerant or less water intensive high yielding Aman rice varieties. At the same time, improved water management practices need to be developed, tested, and disseminated to the farmers as suggested in pillar-1 of Bangladesh Climate Change Strategy and Action Plan (Govt. of Bangladesh, 2008).

Moreover, farmers in the study area should be encouraged cultivating more drought-tolerant or less water-intensive staple crops such as potatoes, maize, lentil, peanut, cowpea, etc. as a part of sustaining their livelihood option, to save the gradual groundwater depletion using for irrigation purposes.

³the value of Pseudo R²as 0.4076, indicates that the fitted model is the best according to the (McFADDEN, 1975) who states that if Pseudo R² value of a model arise around 0.40 then one may claim his or her fitted model is the best.

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Appendix

Descriptive statistics

Variables	Minimum	Maximum	Mean	Std. deviation	Skewness	kurtosis
Yields per acre of Aman (ton)	0.42	1.0542	0.72	0.15	0.07	2.00
Average maximum temperature (0c)	23.27	25.25	24.22	0.38	0.18	3.06
Average minimum temperature(0c)	30.45	32.78	31.75	0.59	-0.32	2.49
Total rainfall (mm)	758	2325	1436.6	353.56	0.47	2.53
Average relative humidity	80	87	83.37	1.62	-0.33	2.81

Source: Authors' computations