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ESTIMATING THE EFFECT OF CLIMATE CHANGE ON RICE PRODUCTION: A STUDY FROM MYMENSINGH DISTRICT OF BANGLADESH USING QUANTILE REGRESSION METHOD

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ABSTRACT

Hossain MJ, Kuri SK, Islam MS, Mondal U (2014) Estimating the effect of climate change on rice production: a study from Mymensingh district of Bangladesh using quantile regression method. *Int. J. Sustain. Crop Prod.* 9(1), 1-7.

This paper examines the influence of ten climatic variables on rice production during 1976 to 2012 of Mymensingh district of Bangladesh. The effect of climate changes on rice production is increasingly evident through movements of climatic variables. Whereas there are empirical studies that examine this issue with parametric approaches focusing on the “mean” level of variables. Quantification of this impact is necessary in order to better understand these changes. Given this paucity, it was characterized the effect on rice production distribution with a more robust non-parametric approach. Employing 37 years of data, it was applied quantile regressions to untangle the climatic impacts across the quantiles of rice production. As well as, the climatic parameters like air pressure (mbs), air temperature (°C), dew point (°C), humidity (%), rainfall (mm), wind speed (kmph), sunshine (hrs.), evaporation (mm), water temperature (°C) and soil temperature at 20 cm depth (°C) were significantly changing over the periods at different selected quantiles of the distributions. Using Quantile regression, it was found the evidence that, rice production responds differently to climatic variables across the different quantiles of rice production distribution. And selected climatic variables were significantly affecting the rice production both positively and negatively which is causing substantial economic loss for the local farmers. So, immediate policy implication like- more adaptive research to develop suitable rice verities, income generating activities and development project is needed to apply in the study area to reduce the economic loss due to the hazards of climate change.

***Key words:** climate change, rice production, quantile regression*

INTRODUCTION

The Earth seems to be containing such kind of environment which could favorable for life generation and regeneration. But the environment of the earth is very much vulnerable if its basic components were altered. Many human activities, including agriculture, tourism and urbanization, lead to an increasingly fragmented and impermeable terrestrial landscape over which it is difficult for species to migrate in response to climate change (Warren *et al.* 2001 and Travis 2002). Now-a-days climate change is a great concern to all over the world. Climate change causes social refugee, home displacement, poor production, salinity problems, drought, floods and irregular patterns of rainfall, high temperature, extreme coldness and hotness along the whole country. Agriculture and people depends on it completely has faced severe threats due to climate change. However, crop sectors of developing country are the main hunt of this phenomenon. Especially, rice growing countries of South Asia is very much vulnerable to climate change. So, food security is totally impaired and in secured in case of South Asian countries especially Bangladesh. Among all over the Bangladesh Mymensingh district is an active rice growing area. But major climatic parameters of this area are changing over time. So, there may be a significant negative effect of climate change on rice production in this area. So, this is a threatening issue of the food security of Bangladesh. Kuri *et al*. 2013 was previously published a scientific article in the Journal of Sylhet Agricultural University where the researchers were only observe the two climatic variables entitled temperature and rainfall and its influence on rice production by using OLS model focusing on the average level of variables. But results obtained by using OLS model cannot examine the influence of climatic variables on low, high or average rice production distribution separately. So, keep this facts on mind, in this article the researchers estimated the influence of ten climatic variables on rice production by using quantile regression model as this model has enable to show more comprehensive picture of the effect of the climatic variables on the rice production distribution across the different quantiles. Therefore, the present study had been undertaken to satisfy the objectives like- to explore the historical status and changing trend of major climatic parameters of the study area and also to explore the influence of changing climatic parameters on rice production using quantile regression model.

METHODOLOGY

The researchers have collected data from Weather Yard, Bangladesh Agricultural University, Mymensingh to find out changing trend of major climatic variables of the study area from 1976 to 2012 (37 years). Moreover, different issues of BBS were also used to gather the data on rice production. The collected data represent the historical status of major climatic variables and rice production. The climatic variables were air pressure (mbs), air temperature (°C), dew point (°C), humidity (%), rainfall (mm), wind speed (kmph), sunshine (hrs.), evaporation (mm), water temperature (°C), soil temperature at 20 cm depth (°C).

Statistical methods were employed to examine the variability of climate and its influence on rice production. Firstly, descriptive statistics such as mean, standard deviation, range, percent of growth changing, coefficient of variation (CV), skewness and kustosis were used to explain the historical status of major climatic variables of the study area. Secondly, simple trend model (Ordinary Least Square, OLS) and quantile regression models were used to examine the historical changing trend of major climatic variables (as mentioned earlier). Moreover, these two statistical models were also used to determine the effect of climatic variables on rice production accordingly.

Linear regression is a statistical tool used to model the relation between a set of predictor variables and a response variable. It estimates the mean value of the response variable for given levels of the predictor variables. The researchers were interested in investigating the relationship between rice production and a set of climatic predictor variables. This model estimates how, on average, these climatic variables affect the production of rice. This model (OLS) can address the question "whether these climatic variables are important for rice production or not?" but it cannot explain the influence of climatic variables on low, high or average rice production distribution separately.

However, results obtained via the OLS and other parametric methods cannot be used to examine, for example, how extreme distribution of the rice production would be affected by climatic variables. To remedy this situation it was focused on the behavior of the entire conditional density of the rice production, and examines climatic variables effect at any arbitrary point on that density, controlling for the effects of other covariates. It was used quantile regression (Buchinsky 1994, 1998; Chamberlain 1994; Koenker and Bassett, 1978, 1982) to estimate effects of climatic variables at different points of the distribution of the rice production.

A more comprehensive picture of the effect of the predictors on the response variable can be obtained by using Quantile regression. Quantile regression models made a relationship between a set of predictor variables and specific percentiles (or quantiles) of the response variable. It specifies changes in the quantiles of the response. For example, a median regression (median is the 50^{th} percentile) of rice production influenced by climatic characteristics that specifies the changes in the median rice production as a function of the predictors. The effect of climatic variables on median rice production can be compared to its effect on other quantiles of rice production (e.g. 5^{th}, 10^{th}, 25^{th}, 75^{th}, 95^{th} and etc.).

In linear regression, the regression coefficient represents the increase in the response variable produced by a one unit increase in the predictor variable associated with that coefficient. The quantile regression parameter estimates the change in a specified quantile of the response variable produced by a one unit change in the predictor variable. This allows comparing how some percentiles of the rice production may be more affected by certain climatic variables than other percentiles. This is reflected in the change in the size of the regression coefficient.

Quantile regression model

To deepen our understanding on how rice production across the different quantiles responds to climatic variables, we employ a quantile regression analysis. Quantile regression was first introduced by Koenker and Bassett (1978, 1982) as a robust alternative to least-squares regression. In quantile regression, quantiles of the conditional distribution of the dependent variable are expressed as a function of observed covariates. Quantile regression offers a number of advantages over least-squares methods. For instance, quantile regression does not require the restrictive assumptions of least-squares regression (assumes that the error terms are independently identically distributed (IID), normally distributed, and homoskedastic). Furthermore, since quantile regression estimates quantiles of the conditional distribution rather than the mean, it is more resistant to outliers than least-squares methods (Leider 2012). The general form of the quantile regression function is specified as:

$Y_t = X_t\,\beta + \varepsilon_t$ With $\mathrm{Quant}\tau(Y_t|X_t) = X_t\,\beta$

Where $\mathrm{Quant}\tau(Y_t|X_t)$ represents the τ^{th} conditional quantile (for this study it was considered 0.10, 0.25, 0.50, 0.75 and 0.95) of rice production and X_t represents the set of independent variables. With this specification, quantile regression provides a flexible way for us to explain how a given quantile of rice production changes as a result of changes in climatic variables. The mean effects of climatic variables on rice production were also estimated with OLS and reported along with the quantile estimates for comparison purposes.

RESULTS AND DISCUSSION

Discussed climatic factors were examined to identify the historical status and rice production in the study area. It was found that among the ten factors and rice production, the coefficient of variation (26.9%) was highest for rainfall (Table 1). So it may be said that climate change has the most devastating effect on annual rainfall. So, irregularity or uneven distribution of rainfall is observing from the data series. Then, the second highest CV was observed for wind speed (21.2%) and considered also to be a very spurious climatic factor in the study area. Some other climatic factors have shown high CV like sunshine (17.4%), evaporation (14.6%), water temperature (8.4%) and air pressure (7.4%). On the other hand, the climatic factors have low CV like air temperature (1.4%), dew point (2.6%), humidity (3.0%) and soil temperature at 20 cm depth (3.5%). In case of the percent of changing column has shown amount of changing have observed among the climatic variables and rice production, and wind speed (70.3%), then rainfall (69.8%), sunshine (60.3%) and evaporation (52.6%) were the highest orientation of changing. However, changing growth of rice production was 49.3% and CV was 22.3%. The skewness and kutosis values have shown that no one variables of the table were following the normal distribution.

Table 1. Status of changing trend of major climatic factors of the study area from 1976 to 2012

Climatic variables	Average	Standard Deviation (SD)	Maximum-Minimum	% of Change	Coefficient of Variation (CV) (%)	Skew ness	Kurtosis
Air pressure (mbs)	767.8	56.7	1005.6-752.9	25.1	7.4	4.173	16.269
Air temperature (°C)	25.3	0.35	26.08-24.34	6.671	1.39	0.049	0.509
Dew point (°C)	21.0	0.54	22.18-19.9	10.27	2.57	-0.135	-0.512
Humidity (%)	80.7	2.41	84.32-73.19	13.19	2.99	-1.295	2.398
Rainfall (mm)	236.45	63.52	503.39-152.11	69.78	26.86	2.041	7.480
Wind speed (kmph)	6.99	1.48	9.44-2.8	70.33	21.17	6.640	-0.934
Sunshine (hrs.)	9.77	1.69	13.02-5.165	60.33	17.35	7.855	-0.836
Evaporation (mm)	137.15	20.02	177.39-84.12	52.57	14.60	93.27	-0.149
Water temperature (°C)	25.40	2.12	35.6-22.2	37.64	8.37	13.40	2.894
Soil temperature at 20 cm depth (°C)	26.58	0.917	27.9-24.2	13.26	3.45	3.700	-0.734
Rice production (kg/ac)	2162.88	481.274	2956.6-1500.04	49.26	22.25	0.456	-1.389

Though, these were climatic variables, so a very lower CV also has carried very much significance. For increasing mean air temperature by 0.04^{0}C, the effect of such increase is very much devastating for crop production (IPCC 2007). However, this study has shown that the percent variations of all the climatic factors are high. So, the climate is changing in the study area and has harmful effect on farm ecosystem. Kuri, 2013 also found the similar type of results in his study.

Historical changing trend of climatic variables

Changing trend of Climate series Evidence from quantile regression analysis

Quantile regression can provide a comprehensive analysis of the pattern of climate change (along the whole range of quantile values from 0 to 1 of the distribution of the dependent variable) than traditional regression techniques such as OLS. Table 2 compares the results of both the OLS and QR models which shows that the QR coefficients vary considerably from the OLS coefficients, even those for median regression. However, QR coefficients are not the same across the selected quantiles; statistically significant differences in trends are observed when quantile values vary from 0.01 to 0.99.

Trends for air pressure were statistically significant with positive trend for the two ends of quantiles of air pressure distribution (e.g. at 0.10 and 0.99). Whereas, middle quantiles of the distribution had possessed decreasing trend over the time but these were not statistically significant. However, the OLS estimate has shown the significant positive trend for air pressure over the period. The trends for air temperature are statistically significant throughout the selected quantiles except 10^{th} quantile. The explanatory power of the trend model for air temperature rises from lower to higher quantiles except 99^{th} quantile (-0.006). But for the OLS estimates it shown significant positive trend over the time at conventional level. For the dew point both OLS and quantile regression estimate throughout the chosen quantiles has indicated highly significant positive trend over the discussed period. Humidity was also following the trend of dew point precisely. In OLS estimate the rainfall was possessed decreasing trend over the period but this was statistically non-significant at the conventional level. However, the quantile regression estimate was showing the rainfall had decreasing trend over all chosen quantile and among of those some were statistically highly significant (10^{th}, 25^{th} and 99^{th} quantile). The trend coefficients of quantile regression for wind speed were clearly opposite trend status from the OLS coefficients and both of them were also statistically significant in both cases.

Trends for sun shine were statistically significant with positive trend for the two ends of quantiles of sun shine distribution (e.g. at 0.10 and 0.99). Whereas, middle quantiles of the distribution had possessed decreasing trend over the time but these were not statistically significant. However, the OLS estimate has shown the significant negative trend for sun shine over the period. In case of evaporation both OLS and quantile regression estimate throughout the chosen quantiles has indicated highly significant negative trend over the explored years. Water temperature has shown the increasing trend in all estimated quantile except 99^{th} one (negative trend). Whereas, the OLS estimate had shown positive trend, but not statistically significant over the estimated years. For soil temperature at 20 cm depth both OLS and quantile regression estimate throughout the chosen quantiles has indicated highly significant positive trend over the period.

Therefore, the QR method provides a more detailed picture of the changing climate at the different points of time. From the above different statistical analyses, it can be established that there has been a change of climate over the time period in Mymensingh district of Bangladesh.

Table 2. Comparative picture of historical trend of major climatic variables between Ordinary Least Square (OLS) Estimate and Quantile Regression (QR) models

		Mean (OLS)	**Quantile parameter estimate**				
			0.10	**0.25**	**0.50**	**0.75**	**0.99**
Air pressure	Co efficient	.076	.022	-.010	-.012	-.008	7.005
	P>|t|	0.017	0.26	0.530	0.282	0.473	0.000
	R^2	0.15	0.0113	0.0012	0.0012	0.0002	0.5154
Air temperature	Co efficient	0.11	0.008	0.007	0.010	0.022	-0.006
	P>|t|	0.035	0.227	0.033	0.096	0.001	0.000
	R^2	0.12	0.06	0.12	0.10	0.16	0.11
Dew point	Co efficient	0.038	0.032	0.044	0.051	0.034	0.033
	P>|t|	0.000	0.000	0.00	0.000	0.000	0.00
	R^2	0.62	0.44	0.45	0.42	0.39	0.37
Humidity	Co efficient	0.172	0.220	0.052	0.151	0.142	0.108
	P>|t|	0.000	0.001	0.000	0.000	0.000	0.000
	R^2	0.63	0.47	0.38	0.39	0.40	0.37
Rainfall	Co efficient	-1.547	-0.966	-2.095	-0.910	-0.310	-10.736
	P>|t|	0.100	0.019	0.058	0.182	0.812	0.000
	R^2	0.07	0.06	0.11	0.05	0.01	0.30
Wind speed	Co efficient	0.065	-0.059	-0.044	-0.065	-0.106	0.001
	P>|t|	0.002	0.287	0.500	0.010	0.000	0.000
	R^2	0.24	0.22	0.05	0.13	0.24	0.42
Sun shine	Co efficient	-0.055	0.113	-0.067	-0.016	-.018	0.065
	P>|t|	0.026	0.013	0.158	0.449	0.630	0.000
	R^2	0.130	0.28	0.14	0.03	0.02	0.09
Evaporation	Co efficient	-1.522	-1.501	-1.260	-1.458	-1.473	-1.728
	P>|t|	0.00	0.002	0.000	0.000	0.000	0.000
	R^2	0.71	0.37	0.41	0.51	0.60	0.62
Water temperature	Co efficient	0.038	0.056	0.065	0.066	0.094	-0.364
	P>|t|	0.235	0.156	0.085	0.13	0.000	0.000
	R^2	0.04	0.22	0.20	0.14	0.04	0.41
Soil temperature at 20 cm depth	Co efficient	0.062	0.078	0.068	0.058	0.037	0.020
	P>|t|	0.000	0.000	0.00	0.000	0.004	.080
	R^2	0.56	0.56	0.49	0.32	0.16	0.14

Effect of climatic variables on rice production

Coefficient estimates for the 10th, 25th, 50th, 75th, 95th quantile regression and the linear regression coefficient estimates for the rice production are presented in the Table 3. It was begun by considering both the magnitude and the pattern of regression coefficients across the production quantiles. The results show that rice production responds differently to climatic variables across the different quantiles of rice production distribution. According to the linear regression model the mean production of rice negatively affected (-0.001) by air pressure but the effect is non-significant. Whereas, the quantile regression results indicated that, air pressure has a larger negative impact on the higher to lower quantiles valued as -1.24 (10^{th} quantile), 0.08 (75^{th} quantile) and -0.61 (95^{th} quantile) of rice production distribution significantly. So, lower air pressure may negatively affect the rice production of the study area. It was found that the effect of air temperature on rice production is positive (0.128) but non-significant as got from OLS estimate and it had increasing trend over the year (Table 3). However, the quantile regression results indicated that, air temperature has decreasing positive impact on the lower to higher quantiles estimated as 2.93 (10^{th} quantile) and 0.44 (95^{th} quantile) of rice production distribution significantly. So, increased air temperature may positively be affected the rice production but sometimes it may negatively affected production of rice (-0.68 at 75^{th} quantile). Amin *et al.* (2004) studied that temperature regulated respiration and translocation rice plant and in turn plant respiration rate increased with temperature. The optimum temperature for the ripening of rice is 21-22°C. At temperature below 21°C translocation was usually decelerated, while at temperature above 22°C the respiration rate was accelerated and the grain-filling period shortened.

In case of dew point, it was observed from the OLS estimate that, it had positive effect on rice production (0.055) but statistically it was non-significant and it has positive trend over the year (Table 2). The quantile regression model had indicated that, dew point has progressively positive effect on rice production from lower to higher quantiles (2.69 at 95th quantile) except -3.37 at 10th quantile. Because, 1°C increasing of dew point may increase the rice production by 2.69 kg/ac at 95th quantile of rice production distribution of the study area.

It was found that the effect of humidity on rice production is positive (0.53) but non-significant as got from OLS estimate and the historical trend was also lower positive over the period (Table 3). However, the quantile regression results indicated that, humidity has decreasing positive impact on the lower to higher quantiles measured as 6.59 (10th quantile) and 0.33 (95th quantile) with highly significant for two ends of the quantile of rice production distribution. So, humidity may positively be affected the rice production. Relative humidity may affect grain formation alter milk stage, ripening and increase disease incidence in rice.

Table 3. Ordinary Least Square (OLS) and Quantile Regression (QR) estimates with significant values of rice production distribution

Climatic factors	**Mean (OLS)**	**Quantile parameter estimate**				
		0.10	**0.25**	**0.50**	**0.75**	**0.95**
	R^2= 0.88	**Pseudo R^2= 0.55**	**Pseudo R^2=0.62**	**Pseudo R^2=0.68**	**Pseudo R^2=0.70**	**Pseudo R^2=0.65**
Constant	-1.978(0.538)	-0.45(0.00)	-1.63 (0.693)	-0.19(0.946)	1.09 (0.949)	4.24 (0.00)
Air pressure (mbs)	0.0001(0.907)	-1.24 (0.00)	-0.42 (0.369)	-0.28 (0.476)	0.08 (0.944)	-0.61 (0.00)
Air temperature (°C)	0.128(0.326)	2.93 (0.00)	1.13 (0.580)	0.73 (0.671)	- 0.68 (0.932)	0.44 (0.00)
Dew point (°C)	0.0553(0.728)	-3.37 (0.00)	0.64 (0.755)	1.06 (0.533)	1.54 (0.886)	2.69 (0.00)
Humidity (%)	0.0528(0.122)	6.59 (0.00)	2.37 (0.089)	1.26 (0.207)	1.41 (0.898)	0.33 (0.00)
Rainfall (mm)	-0.0009(0.187)	-0.35 (0.00)	0.05 (0.680)	-0.02(0.811)	-0.09 (0.863)	-0.08 (0.00)
Wind speed (kmph)	-0.0861(0.028)	-0.23 (0.00)	-0.33 (0.061)	-0.27 (0.027)	-0.23 (0.619)	-0.07 (0.00)
Sunshine (hrs.)	-0.0423(0.142)	-0.37 (0.00)	-0.20 (0.218)	-0.12 (0.249)	0.05 (0.926)	-0.69 (0.00)
Evaporation (mm)	-0.0128(0.000)	-0.69 (0.00)	-0.50 (0.008)	-0.49 (0.020)	-0.71 (0.445)	-1.08 (0.00)
Water temperature (°C)	-0.00001(1.000)	-0.73 (0.00)	0.11 (0.630)	-0.01 (0.945)	0.02 (0.977)	-0.28 (0.00)
Soil temperature at 20 cm depth (°C)	-0.0604(0.322)	-0.75 (0.00)	0.29 (0.764)	-0.01 (0.989)	0.07(0.982)	-0.19 (0.00)

High relative humidity may favor crop growth during the vegetative stage whereas, during grain formation, low humidity may cause grain shrink, but high humidity favors disease, particularly in rained rice (Amin *et al.* 2004). According to the linear regression model the mean production of rice negatively affected (-0.0009) by rainfall but the effect is non-significant and the trend of rain fall over the year is decreasing trend. Whereas, the quantile regression results indicated that, rainfall has decreasingly negative effect on the lower to higher quantiles valued as -0.35 (10th quantile), and -0.08 (95th quantile) of rice production distribution significantly. So, decreasing trend of rainfall may negatively be affected the rice production of the study area. Van and Howden (2003) reported that a 20% increase in precipitation in summer/autumn and a 35% decrease in winter/spring resulted in an 18% (Moora), 16% (Wongan Hills) and 14% (Merredin) decrease in precipitation oil a yearly basis due to differences in precipitation distribution within the year. As a result, production decreased less than in the scenario with a 25% decrease in precipitation across the whole year. Islam et al. (2002) mentioned that rice production mainly depended on rainfall. Deficit rainfall in Bangladesh caused drought in rain fed ecosystem and consequently loss of crop production when was many times higher than the damage from flood.

In case of wind speed, it was observed from the OLS estimate that, it had negative effect on rice production (-0.086) but statistically it was significant. The quantile regression model had indicated that, wind speed has negative effect on rice production from different quantile but it was fluctuating in nature like -0.23 at 10th quantile, -0.33 at 25th quantile, -0.27 at 50th quantile and -0.07 at 95th quantile. It was found that, if the wind speed decreases creases 1 kmph then the rice production was reduced by -0.23 kg/ac at 10th quantile and by -0.07 kg/ac at 95th quantile. According to the linear regression model the mean production of rice negatively affected (-0.0423) by sunshine and the trend (In Table 2 it was increasing in trend) but the effect was non-significant. Whereas, the quantile regression results indicated that, sun shine has a decreasingly negative impact on the lower to higher quantiles valued as -0.37 (10th quantile), -0.20 (25th quantile), -0.12 (50th quantile) and -0.69 at 95th quantile except 0.05 at 75th quantile. So, overall it may conclude that, lowering sunshine had negative effect on rice production though it decreases photosynthesis. But, increased sunshine may also cause drought, pollen desiccation to rice plant so in some cases it may cause production loss of rice of the study area.

In case of evaporation the historical trend is decreasing and it was observed from the OLS measure that, it had negative effect on rice production (0.055) but statistically it was highly significant. The quantile regression model had indicated that, evaporation has gradually significant deleterious effect on rice production from lower to higher quantiles -0.69 at 10th quantile, -0.50 at 25th quantile, -0.49 at 50th quantile decreasingly, except -0.69 at 95th quantile. So, from this study it was found that less evaporation had negative effect of rice production of the study area. Results presented in Table 3 also indicated that water temperature i.e. surface water had no significant effect on rice production (OLS estimates) and in Table 2 it was found that the trend of water temperature is increasing. But from the quantile regression models it was found that at the two ends of the quantile i.e. at lowest quantile (-0.73 at 10th quantile) and highest quantile (-0.28 at 95th quantile) it possessed significant negative impact on rice production. Because in our study area farmers were used surface water for irrigation and due to this warm water cell biology may hamper which may cause production loss of rice plants.

In case of soil temperature at 20 cm depth, the trend of soil temperature is increasing over the period. It was observed from the OLS measure that, it had negative effect on rice production (-0.060) but statistically it was non-significant. The quantile regression model had indicated that, soil temperature has gradually significant deleterious effect on rice production the two ends of the quantiles -0.75 at 10th quantile, -0.19 at 95th quantileof the rice production. Van and Howden (2003) mentioned that temperature effect on production varied between the two soils. An increase in annual temperature of up to 3^{0}C had a positive effect on the clay soil (up to 15%), and slightly negative effect on the sandy soil. Thereafter, production decreased substantially on both soil types (up to 40-55% relative to the control). Therefore, the QR method provides a more detailed picture for the effect of climatic variables on rice production than OLS estimate.

CONCLUSIONS AND RECOMMENDATIONS FOR POLICY IMPLICATIONS

From the findings, it can be established that, the climatic variables of the study area was significantly changing over the period (last 37 years). Among of them major climatic variables like air and soil temperature were increasing whereas, rainfall was decreasing significantly over the period. As well as there was a significant effect of climate variables on rice production of the study area and the effect may vary on different situation (quantiles) based on climatic variables (i.e. both positive and negative effects).

The following recommendations based on conclusions may be adopted to reduce climate variability and its effect on rice production:

I. Develop more adaptive research need to develop suitable rice varieties by Bangladesh Institute of Nuclear Agriculture (BINA), Bangladesh Rice Research Institute (BRRI) or Bangladesh Agricultural University (BAU) only for Mymensingh district to minimize the effect of climate change.
II. More development project implication is needed for this district to generate alternate income generating activities for local farmers which may reduce economical hazards due to climate change.
III. More research is needed for other crops except rice to assess the effect of climate change on overall agricultural crops.

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