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IMPACT OF CLIMATE CHANGE ON RICE PRODUCTIVITY IN BANGLADESH: EVIDENCE FROM PANEL DATA

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Abstract: *The study scrutinizes the possible impacts of climate change on rice productivity in Bangladesh through climatic and non-climatic parameters. Secondary data were used, for this purpose covering 210 observations corresponding to seven districts with panel data for 30 years during 1982-2011. Simple linear regression model was employed to draw the relationship between climatic factors and rice productivity. Empirical results based on Prais-Winsten models with panels corrected standard errors (PCSEs) estimation shows that increase in average minimum temperature and average maximum temperature had positive effect on rice productivity. Non climatic factor (i.e., irrigation area) was found an imperative to increase rice productivity. Among the five climatic parameters (i.e., average minimum humidity, average maximum humidity, average minimum temperature, average maximum temperature, and average rainfall) and two non-climatic factors (viz. irrigated area under rice crop, and share of forest area) average maximum humidity had negative effect on the productivity of rice. Policy guidelines from this study suggest to increase more irrigation facilities and to promote adaptation to climate change by developing new varieties that will be more tolerant to humidity and requires less water.*

Keywords: Bangladesh, Climate change, Panel data, Rice productivity

1. Introduction

Agriculture typically plays a vital role in the economies of developing countries than the developed. Agriculture is one of the most important sectors of Bangladesh

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economy Nargis and Lee (2013). The sector contributes around 16.77 percent to the gross domestic product (GDP) of the country and employs around 47.5 percent of the total labour force. Moreover, the sector feeds up around 160 million people of the country and provides survival and nutrition for the farm households of rural areas (GoB, 2014). Agriculture is a pillar of Bangladesh economy, using more than 70 percent of land area (FAO, 2009) and accounting for nearly 20 percent of GDP and 65 percent of the labour force, employed primarily on small-holder farms (Yu *et al*., 2010). The main agricultural commodities in Bangladesh are rice, wheat, maize, jute, sugarcane, potato, vegetables, oilseeds and pulses. Among these crops, rice is widely cultivated all over the country throughout the year. It is one of the leading food crops to fulfill the demand of carbohydrate in Bangladesh. At present, rice is cultivated in 28228 acres of land. It alone constitutes the lion's share of total food grain production in Bangladesh. It is also the most important crop to millions of farmers, who grow it on millions of hectares throughout the region, and to the many landless workers who derive income from working on these farms. Since independence food autarky of Bangladesh has become dependent on rice production.

Agriculture is situated at the interface between ecosystems and society. As such agriculture is affected by the changes in the global environmental conditions. Both natural and human activities are responsible for this vulnerability. Natural activities include earth motion, sun's intensity volcanic eruption, forest fires and the circulation of the ocean, etc. The earth's climate is dynamic; it is changing since ancient era; and it is most important natural factor that responsible for climate variability. Due to human activities the quantity of green house gases (GHGs) in the atmosphere is rising. Human driven activities are increasing the quantity of carbon dioxide, methane, nitrous oxide, chloro fluorocarbons (CFCs) and other gases has lead to global climate change. Bosello and Zhang (2005) study estimated the relationship between climate change and agriculture. In case of food grain crops, several studies provide the evidence that productivity of food grain crop negatively affected due to climate change. Agronomists have long warned that farms in developing countries are often more sensitive to warming than US farms (Rosenzweig and Perry 1994; Reilly *et al.*, 1996). The impacts of climate change[1] on agriculture food production are global concerns and for that matter Bangladesh,

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[1] Climate change in IPCC usage refers to a change in the state of the climate that can be identified (e.g., using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity. This usage differs from that in the United Nations Framework Convention on Climate Change (UNFCCC), where climate change refers to a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods. The present study uses climatic parameters (e.g., temperature, rainfall and humidity) to represent the climate change. Thirty years climatic data from seven climatic station of Bangladesh has been used for the study.

where lives and livelihoods depend mainly on agriculture, are exposed to great danger. Bangladesh is frequently cited as one of the most vulnerable countries to climate change (Huq, 2001; Rahman *et al*., 2003; UNDP, 2007; Huq *et al*., 2007) because of its disadvantageous geographic location; flat and low-lying topography; high population density; high levels of poverty; reliance of many livelihoods on climate sensitive sectors, particularly agriculture and fisheries; and inefficient institutional aspects (Climate Change Cell, 2006). Many of the anticipated adverse affects of climate change, such as sea level rise, higher temperatures, enhanced monsoon precipitation, and an increase in cyclone intensity, will aggravate the existing stresses that already impede development in Bangladesh, particularly by reducing water and food security and damaging essential infrastructure (MOEF, 2005).

As mentioned earlier, human activities also enhance the vulnerability. Human activities are responsible for climate change and environmental degradation such as growing population, rapid urbanization, higher industrialization, use of modern technology, innovation, higher economic growth and development, transport, building construction, reduction in forest area, burning fossil fuels, grazing cattle, development of cities, and others (Ahmad *et al*., 2011; Patnaik and Narayanan, 2010). For being a sensitive sector now-a-day's agriculture is in hindrance due to high population growth all over the world. The growing population hampers the arable land and it is also a challenging job to feed the increasing population. In Bangladesh, it has been declared as number one national problem. In fact, it's present population has come to a stage of explosion. Bangladesh has high population density, with a current population equivalent to half of the population of the United States living in an area the size of the state of Iowa (Ruane *et al*., 2013).

Many impact studies focus on the agricultural sector for several reasons. The first reason is that agricultural production is directly exposed to change in temperatures and precipitation (Boulidam, 2012; Geethalakshmi *et al*., 2011; Sheehy *et al*., 2006; Sinha, 1991). The second reason is that agricultural production and consumption still comprise a large share of income in poorer developing economies. In this context, it is important to know how climate change affects the productivity of rice crop in Bangladesh. In this study the authors intend to examine the impact of climatic and non-climatic factors on rice productivity to facilitate development of appropriate farm policies.

2. Materials and Methods

2.1 Dataset

The data set for the present study is covering 210 observations corresponding to seven districts (viz. Rangpur, Dinajpur, Sylhet, Rajshahi, Comilla, Jessore and Barisal) with panel data for 30 years during 1982-2011. To estimate the impact on rice productivity, climatic and non-climatic data are used. Agricultural data are taken from 'The Yearbook of Agricultural Statistics' and 'Bangladesh Statistical Yearbook'. Production of rice has been estimated in thousand tonnes. Data of climatic variables are taken from Bangladesh Meteorological Department (BMD). Climatic data includes yearly average rainfall, average maximum temperature, average minimum temperature, average maximum humidity and average minimum humidity.

2.2 Model specification

Simple Linear Regression Model (Mongi *et al*., 2010, Haim *et al*., 2008) is used in the present study, to investigate the impact of climatic and non-climatic factors on rice productivity. This model considers that climatic variables are similar to other agriculture and socioeconomic inputs for agriculture crop growth. The simple linear regression model is specified as:

$$(tp)_{it} = f\{(as)_{it}, (ia)_{it}, (sfa)_{it}, (aminhu)_{it}, (amaxhu)_{it}, (amint)_{it}, (amaxt)_{it}, (arf)_{it},\} \quad (1)$$

Where, tp is total production of rice (thousand tonnes); i is cross sectional groups of districts 1 to 7; t is time period for 1982-2011; as is area sown under rice crop (hectares); ia is irrigated area under rice crop (hectares); sfa is share of forest area (percentage); aminhu is average minimum humidity (percentage); amaxhu is average maximum humidity (percentage); amint is average minimum temperature (degree celsius); amaxt is average maximum temperature (degree celsius); arf is average rainfall (millimeter).

Now divide by tp to as (for production per hectare land or rice productivity) equation (1) is:

$$(tp/as)_{it} = \beta_0 + \beta_1 (ia)_{it} + \beta_2 (sfa)_{it} + \beta_3 (aminhu)_{it} + \beta_4 (amaxhu)_{it} + \beta_5 (amint)_{it} + \beta_6 (amaxt)_{it} + \beta_7 (arf)_{it} + \mu_{it} \quad (2)$$

Where, (tp/as) is rice productivity that is output per hectare of land; β0 is constant coefficient and β_1 - β_2 are regression coefficient for corresponding explanatory variables and μit is an error term.

According to (Baltagi, 2005) cross-sectional dependence is a problem in macro panels with long time series (over 20-30 years). Cross-sectional dependence can lead to bias in tests results (also called contemporaneous correlation). Keeping this view in mind, Prais Winsten models[2] with panels corrected standard errors (PCSEs) estimation are used, to avoid the problem of heteroscedasticity and cross-sectional dependence. Kumar and Sharma (2014) also used this model to investigate climate change and sugarcane productivity in India. However, PCSEs have all the options for panel heteroscedasticity, panel autocorrelation and contemporaneous correlation.

3. Results and Discussion

3.1 Overall scenarios of the study areas

Summary statistics of different variables are given in Table 1. From the table it is evident that Barisal and Comilla districts had more variability compare to other districts in terms of productivity. Conversely, the coefficient of variation for productivity was lower in case of Rangpur district, indicating more consistent productivity. Rice crops under irrigated area were less uniform in Dinajpur district. The variation in irrigated area and share of forest area were less in Sylhet district. The coefficient of variation for average minimum humidity and average maximum temperature were the greatest in Rajshahi district than that of other districts; means that Rajshahi district had more variability in these two climatic parameters. The variability of average minimum temperature in Sylhet district was higher compare to other selected districts for the study. Rice production of Sylhet district had the benefit of rainfall, on the other hand, Rangpur and Dinajpur suffered much for the high inconsistency in rainfall.

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2 Prais–Winsten estimation is a procedure meant to take care of the serial correlation of type AR(1) in a linear model. Conceived by Sigbert Prais and Christopher Winsten in 1954, it is a modification of Cochrane–Orcutt estimation in the sense that it does not lose the first observation and leads to more efficiency as a result. For example, consider the model

$$Y_t = \alpha + X_t \beta + \varepsilon_t$$

Where, Y_t is the time series of interest at time t, β is a vector of coefficients, X_t is a matrix of explanatory variables, and ε_t is the error term. The error term can be serially correlated over time: $\varepsilon_t = \rho\varepsilon_{t-1} + e_t,\ |\rho| < 1$ and ε_t is a white noise. In addition to the Cochrane–Orcutt procedure transformation, which is:

$$y_t - \rho y_{t-1} = \alpha(1-\rho) + \beta(X_t - \rho X_{t-1}) + e_t.$$

for t=2,3,...,T. Prais-Winsten procedure makes a reasonable transformation for t=1 in the following form:

$$\sqrt{1-\rho^2}y_1 = \alpha\sqrt{1-\rho^2} + \left(\sqrt{1-\rho^2}X_1\right)\beta + \sqrt{1-\rho^2}\varepsilon_1.$$

Then the usual least squares estimation is done.

Table 1. Descriptive Statistics

Districts		Rangpur	Rajshahi	Dinajpur	Jessore	Barisal	Sylhet	Comilla
Productivity (tp/as)	Mean	2.18	2.27	2.02	2.31	1.85	1.85	2.52
	SD	0.56	0.64	0.58	0.75	2.01	0.51	2.19
	CV	25.69	28.19	28.71	32.47	108.65	27.57	86.90
Irrigated area under rice crop (Ia)	Mean	288133	311126	254952	238953	77081	238739	223908
	SD	133583	143515	507881	117425	32148	43516	73287
	CV	46.36	46.13	199.21	49.14	41.71	18.23	32.73
Share of forest area (Sfa))	Mean	2.03	2.17	7.97	0.00	57.60	68.16	0.59
	SD	0.75	0.89	2.96	0.00	54.30	3.11	0.15
	CV	36.95	41.01	37.14	-	94.27	4.56	25.42
Average minimum humidity (Aminhu)	Mean	42.32	36.41	38.27	40.98	46.52	40.21	44.68
	SD	2.76	3.10	2.59	2.84	2.67	2.96	2.39
	CV	6.52	8.51	6.77	6.93	5.74	7.36	5.35
Average maximum humidity (Amaxhu)	Mean	99.22	99.34	98.78	98.51	99.96	99.48	99.46
	SD	0.47	0.40	0.51	0.77	0.10	0.63	0.51
	CV	0.47	0.40	0.51	0.78	0.10	0.63	0.51
Average minimum temperature (Amint)	Mean	19.82	19.99	19.64	20.52	20.90	19.61	20.54
	SD	0.41	0.54	0.47	0.42	0.40	3.22	0.39
	CV	2.07	2.70	2.39	2.05	1.91	16.42	1.90
Average maximum temperature (Amaxt)	Mean	29.00	30.12	29.41	31.15	30.12	29.53	29.69
	SD	0.32	2.25	0.36	0.57	0.36	0.62	0.79
	CV	1.10	7.47	1.22	1.83	1.19	2.10	2.66
Average rainfall (Arf)	Mean	6.32	3.87	5.46	4.61	5.62	11.01	5.61
	SD	1.38	0.77	1.25	0.86	0.93	1.76	1.08
	CV	21.84	19.89	22.89	18.66	16.55	15.99	19.25

Source: Authors' own estimation

3.2 Regional climate trends

Agriculture in Bangladesh always depends on nature. The nature itself has peculiar characteristics, for that reason the agricultural production also shows variability. Climatic parameters are less uniform throughout the rice growing seasons. The climate scenarios vary from district to district. The present study also shows the climatic variability among seven districts. Figure 1 shows that average rainfall in Rangpur district had a fluctuating trend and since 2009 it was decreasing. Average minimum humidity had little bit fluctuation, but average minimum and maximum temperature had approximately static nature. With this climatic condition rice productivity in this region indicated increasing trend.

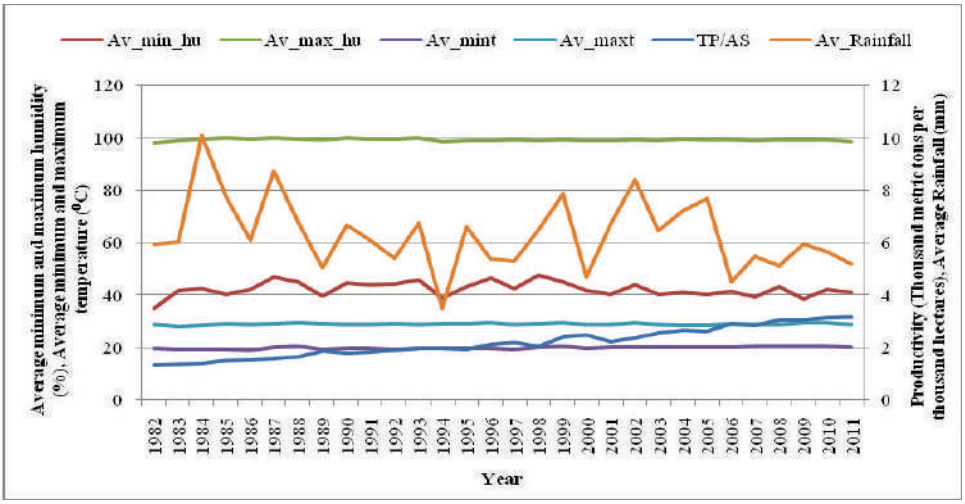

Figure 1. Trend of productivity and climatic variables in Rangpur district

Figure 2 indicates that average rainfall in Rajshahi district fluctuating over the years. From 2007 average rainfall in Rajshahi was decreasing after 2010 average rainfall was increasing. Rice productivity in this region was increasing sharply. In Rajshahi, average minimum humidity was increasing since 2009. Conversely average maximum humidity had more or less static trend. In Figure 3 it is evident that, with the increase in average rainfall, rice productivity in Dinajpur district was increasing. Although average maximum humidity was approximately static but average minimum humidity had increasing trend. Figure 4 reveals that compare to other districts, average rainfall in Jessore had less fluctuation. Productivity in this region was increasing rapidly since 2005 with mild fluctuation. Average minimum humidity was fluctuating over the years.

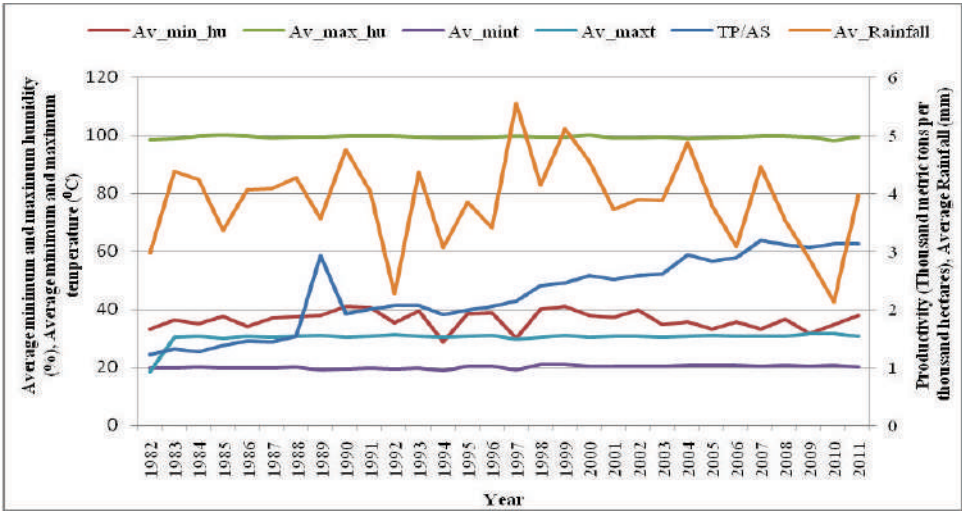

Figure 2. Trend of productivity and climatic variables in Rajshahi district

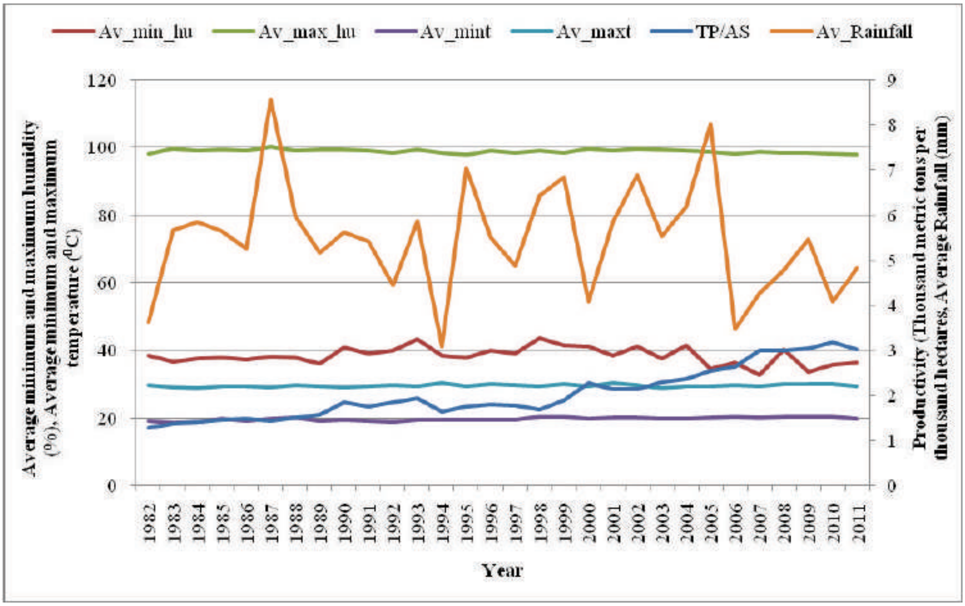

Figure 3. Trend of productivity and climatic variables in Dinajpur district

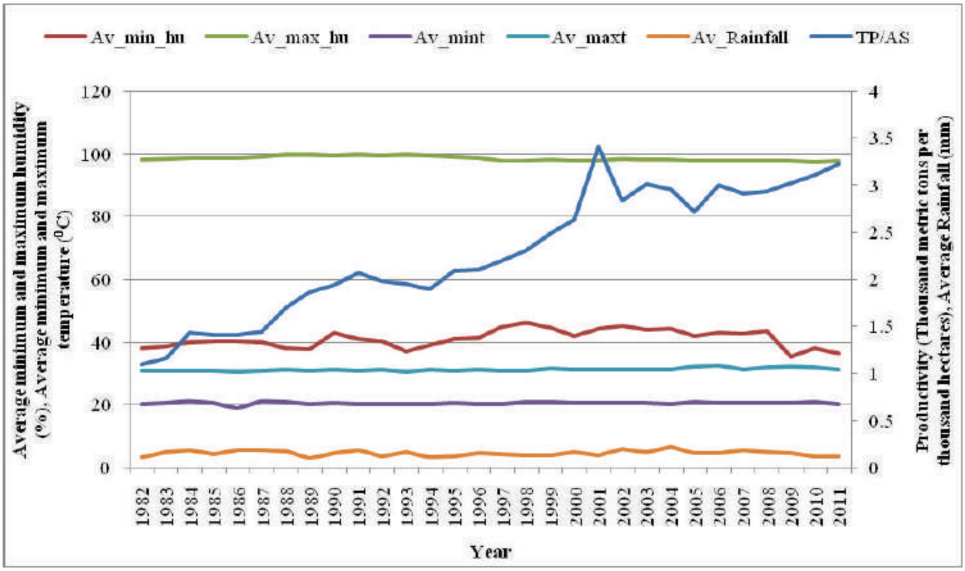

Figure 4. Trend of productivity and climatic variables in Jessore district

Figure 5 shows that average minimum humidity was decreasing in Barisal district. Average rainfall was fluctuating over the years. Figure 6 represents the Sylhet district, where rainfall was decreasing drastically since 2009 and rice productivity was approximately static. Figure 7 indicates that rice productivity in Comilla district was increasing with little bit fluctuation. Rainfall was highly fluctuating there since 1988 to 1994. It is also found that average minimum humidity was fluctuating over the years. Average maximum humidity had little bit fluctuation.

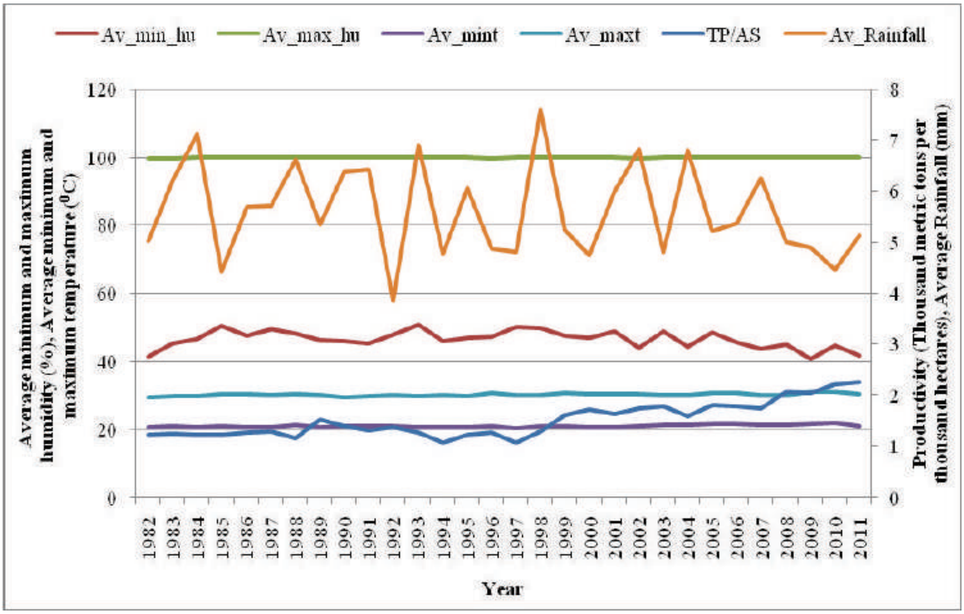

Figure 5. Trend of productivity and climatic variables in Barisal district

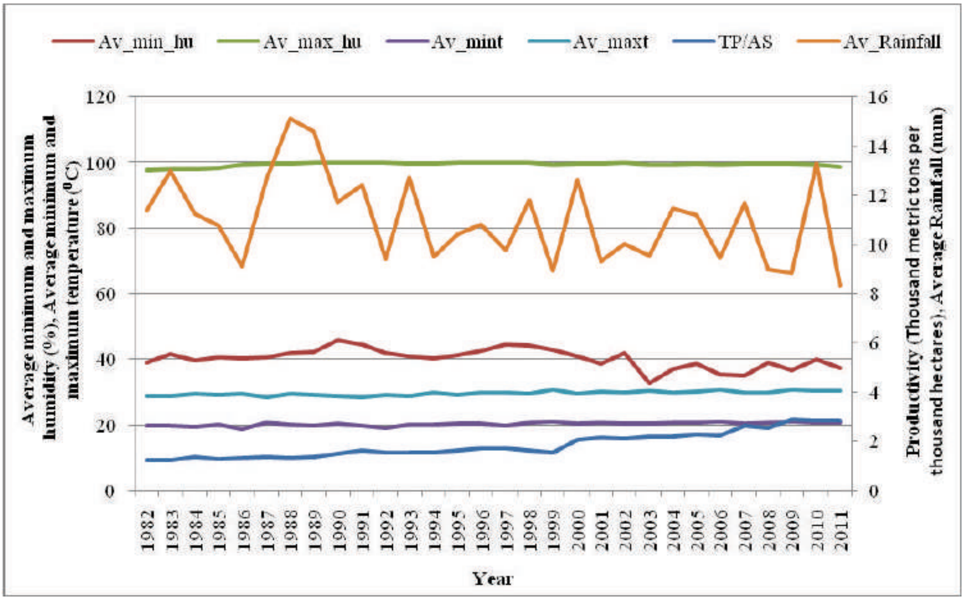

Figure 6. Trend of productivity and climatic variables in Sylhet district

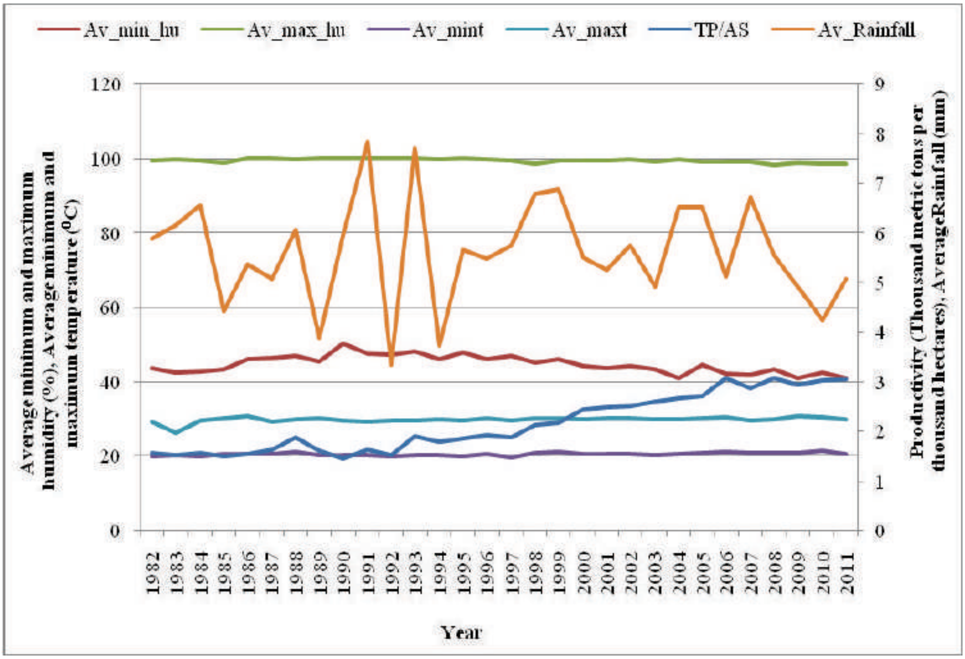

Figure 7. Trend of productivity and climatic variables in Comilla district

3.3 Influential factors on rice productivity

Table 2 gives the empirical results for the regression estimation for rice productivity. Table 2 discloses that irrigation area under rice crop, average minimum temperature and average maximum temperature were found to be significant at 1 percent, 5 percent and 10 percent level of significance, respectively. In case of non-climatic variable irrigation area was found an imperative to increase rice productivity. The results support with the findings of (Olesen and Bindi, 2002; Lee *et al*., 2012; Gupta *et al*., 2012; Kumar and Sharma, 2014). Irrigation area under rice crop was highly significant, which is expected and the sign is intuitive (higher the proportion of land under irrigated rice, higher is the yield). Therefore, providing sufficient water is crucial on rice production, as agriculture is one of the largest consumers of water resources in Bangladesh. (Yeo, 1999) mentioned that agriculture is already the largest consumer of water resources in semiarid regions. (Lee *et al*., 2012) showed that providing sufficient water is crucial on agriculture production in tropical Asian countries, and also mentioned that the characteristic of rice-based Asian agriculture since rice is mostly cultivated in flooded field thus requires water all the time.

Table 2. Regression results based on Prais-Winsten models with panel corrected standard errors (PCSEs) estimation

Variables	Coeff.	Panel corrected Std. Errors	z	P > |z|
Ia	0.0000*	0.0000	5.25	0.0000
Sfa	-0.0031	0.0043	-0.73	0.464
Aminhu	0.0172	0.0199	0.86	0.389
Amaxhu	-0.2714*	0.1081	-2.51	0.012
Amint	0.0856**	0.0375	2.28	0.023
Amaxt	0.0932***	0.0488	1.91	0.056
Arf	0.0149	0.0406	0.37	0.714
Cons. Coeff.	23.5254**	11.1913	2.10	0.036
R-squared	0.1298			
Prob> chi2	0.0000			
Wald chi2 (7)	55.20			
Number of obs	210			

Note: *, ** and *** indicates the 1%, 5% and 10% significance level for respective variables.

Relative humidity (RH)[3] directly influences the water relations of plant and indirectly affects leaf growth, photosynthesis, pollination, occurrence of diseases and finally economic yield. Under high humidity, RH is negatively correlated with grain yield. The yield reduction was 144 kg/ha with an increase in one percent of mean monthly RH for maize, and similarly, wheat grain yield is reduced in high RH (Agrometeorology, 2015). The present study showed that average maximum humidity had negative effect on rice productivity, meaning that an increase in humidity decreases the rice productivity. (Matsui, 1997; Ayinde *et al*., 2013) also have the same results. (Matsui, 1997) showed that in the humidity treatment, the number of pollen grain on each stigma decreased gradually as the relative humidity increased from 45 percent to 75 percent. (Ayinde *et al*., 2013) mentioned that 1 percent increase in humidity caused 17 percent reduction in rice production in Niger state.

Climate change is expected to affect agriculture very differently in different parts of the world (Parry *et al*., 1999). The resulting effects depend on current climatic conditions, the direction of change and the availability of resources and infrastructure to cope with change. In the same fashion, the climatic parameters act in different ways in different parts of the universe. In the current study, average minimum temperature and average maximum temperature had significant positive impact on rice productivity. Meaning that increase in average minimum temperature and

[3] Relative humidity (RH) refers to water vapor, exclusive of condensed water, in the atmosphere. It is the ratio, expressed as a percentage of vapor pressure to saturation vapor pressure at the existing temperature.

average maximum temperature increases rice productivity. This result is in the line of (Lee *et al*., 2012; Olesen and Bindi, 2002; Mahmood *et al*., 2012; Zakaria *et al*., 2014). As we know, rice is C3 plant, and C3 plants are likely to be benefited from extra CO2. However, CO2 fertilization could lead to some increase in agricultural productivity, particularly rice productivity. In field studies in the tropics, the increasing atmospheric concentration of CO2 alone was found to significantly enhance rice crop yield (Lewis *et al*., 1995). Atmospheric CO2 levels are expected to have a positive effect on C3 plants, increasing their growth rate and cutting transpiration rates. Rice plants may also be able to use water more efficiently under higher CO2 levels. Olesen and Bindi (2002) mentioned that global warming will extend the length of the potential growing season, allowing earlier planting of crops in the spring and earlier maturation and harvesting. Lee *et al*. (2012) showed thatincrease in temperature during the summer season marginally increases agricultural production in tropical Asian countries. (Zakaria *et al*., 2014) showed positive effects of maximum temperature on Aus and Aman rice yield in Bangladesh. Sarker *et al*. (2012) mentioned that the influences of maximum temperature and minimum temperature are more pronounced compared with that of rainfall. Although rice yield may rise, an increase in temperature would induce rising demand for irrigation water. Parry (2000) mentioned that more water will be required per unit area under drier conditions, and peak irrigation demands are also predicted to rise due to more severe heat waves.

Increment in forest area may be harmful for rice productivity but it was insignificant, and the meaning is that any rising in forest area may reduce the area under rice crop; and resulting that productivity may go down. Kumar and Sharma (2013) also had the same result with significant impact.

4. Remarks

Based on the findings of this research, it can be concluded that there is existence of climate change in Bangladesh and this is really affecting the productivity of rice. Rice production in Bangladesh is adversely affected by average maximum humidity. Irrigated area under rice crop, average minimum temperature and average maximum temperature had positive effect on rice productivity. Climate change hampers agricultural productivity especially rice productivity but still now, the scenarios are not so worse in Bangladesh. Although average minimum temperature and average maximum temperature increased rice productivity at the same time it increased irrigation demand which ultimately push for high irrigation cost. So, the indirect effect of raising temperature is not ignorable at all. Therefore, attention has to be paid in this regards for future protection. Based on the findings of the study, the following recommendations are suggested: First, it is true that impacts of climatic and non-climatic factors are present on rice productivity in Bangladesh. Therefore, more irrigation facilities for rice production have to be ensured, since the result shows that expansion of irrigated area has positive and significant influence on rice productivity. Policy needs to adopt for reducing irrigation cost. Second, adaptation to climate change will be necessary such as developing new varieties that will be more tolerant to humidity, requires less water and developing proper adaptation programs and policies.

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