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Climate Change and its Impacts on Rice Production in Western Bangladesh: An Econometric Analysis

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Abstract *Many studies have been done about climate change and its impacts in the developing countries. However, scant attention has been given to explore the impacts of climate change on rice production in Bangladesh. This study provides a quantitative investigation concerning the relationships between rice production and climatic variables in the western Bangladesh applying a Crop Yield -Weather Regression model. The production model helps estimate the causal influence of climatic variables on rice production. We use secondary data for the period 1972 to 2010.This study further conceptualizes against the backdrop of the increasing climatic problems associated with rice production. Results from the econometric analysis confirm that most of the climatic variables affect rice production; while some of the variables, like humidity and wind speed affect positively and significantly, others like temperature and average sunshine affect rice production negatively.*

1. Introduction

Rice production is very important to Bangladesh economy. In 1991, 10.3 million hactares – almost 80% of the country's total cropped area – was planted for rice. For many Bangladeshi farmers, this crop is their only source of cash income and livelihood. But rice yields average only 2.7 tonne/hactare and the current growth in production is too low to keep up with the 1.9% annual population growth rate

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and the increased demand for rice (BER, 2011). Recent projections indicate a world rice food need of about 765 million tonnes in 2025. In Bangladesh, rice provides 75% of the calories consumed (BER, 2013).

Bangladesh, once known as “The Golden Bengal” having an area of about 144000 km^2 of the fertile deltaic plain of the mighty rivers – the Ganges, the Brahmaputra, and the Meghna, and their tributaries, was considered as a granary for centuries. However, the scenario of Bangladesh agriculture has changed in recent decades making it a country of recurring deficits since her food production fails to keep pace with human growth of about 1.9 percent (BER, 2011) per annum. Since liberation in 1971, Bangladesh has been trying hard to improve this situation, making considerable stride to attain food self – sufficiency, but still it remains an elusive goal.

Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2007) published in early 2007 leaves no doubt that the Earth’s climate is changing in a manner unprecedented in the past 400,000 years. The report corroborated previous scenarios that by 2100 mean planet-wide surface temperatures will rise by 1.4 to 5.8 °C, precipitation will decrease in the sub-tropics, and extreme events will become more frequent (IPCC, 2007). However, changes in climate are already being observed—the last 60 years were the warmest in the last 1000 years and changes in precipitation patterns have brought greater incidence of floods or drought globally. In quantitative terms, IPCC estimates that, by 2050, changing rainfall patterns with increasing temperatures, flooding, droughts and salinity (in coastal belt) could cause decline in rice production in Bangladesh by 8 per cent and wheat by 32 per cent, against 1990 as the base year (MoFE, 2008). The recent estimates using different models with changed assumptions predicts reduction in production by 1.5-25.8 per cent for aus rice, and 0.4-5.3 per cent for aman due to the effect of high temperature for 2050. For boro rice, production could be increased by 1.2-9.5 per cent, assuming the temperature would not exceed the 35 C threshold limit for rice production (Karim, Hussain, and Ahmed, 1996,).

Bangladesh Climate Change Strategy and Action Plan (BCCSAP, 2009) reveals, rainfall will increase resulting in higher flows during the monsoon season in the rivers, which flow into Bangladesh from India, Nepal, Bhutan and China. Global warming will result in mean sea level rises between 0.18 and 0.79 meters, which could increase coastal flooding and saline intrusion into aquifers and rivers across a wide belt in the south of the country, although most of the area is protected by polders. Rainfall is predicted to become both higher and more erratic, and frequency and intensity of droughts are likely to increase, especially in the drier northern and western parts of the country. Bangladesh is ranked as one of the most vulnerable countries to tropical cyclones and sixth most vulnerable country to floods (MoEF, 2008). The BCCSAP report says that there will be increasingly frequent and severe floods, tropical cyclones, storm surges, and droughts, which will disrupt and displace millions of people from coastal regions, making them 'environmental refugees', unless existing polders are strengthened and new ones are built.

Negative impacts of climate change on Bangladesh agriculture as reported in various documents can be summarized as follows; (i) extended flooding of arable land narrows scope for crop production, especially in the vast low land areas; (ii) increased temperature leads to increased evapotranspiration and droughts, causing water scarcity for irrigation and domestic uses in north-west Bangladesh; (iii) increased inundation and salinity intrusion limit crop cultivation with the existing varieties, especially in the coastal regions. Loss in terms of land degradation and arsenic contamination of soil and water becomes a major concern (Heikens, 2006; Ahmed, 2007); (iv) increased intensity of flush floods in Meghna basin and north eastern Haor region damages standing boro rice crop; (v) increased loss of land to river erosion reduces land-based livelihood opportunities, and increased drainage congestion and water logging due to sedimentation of rivers limit production options for the char dwellers.

These changes are driven by increasing concentrations of greenhouse gases, namely CO, CH and N2O, and will also affect agro-climatic conditions for food production systems. The potentially beneficial effects of increases in CO may be offset by concomitant temperature stress and other factors such as the increases in ground level (tropospheric) ozone concentrations. Most developing countries are not well prepared to deal with the negative impacts to be expected as a result of climate change and are therefore most vulnerable to its consequences.

Agriculture is always vulnerable to unfavorable weather events and climate conditions. Despite technological advances such as improved crop varieties and irrigation systems, weather and climate are important factors because these play significant role to agricultural productivity. The impacts of climate change on agricultural food production are global concerns and concerns specially for Bangladesh, where lives and livelihoods depend mainly on agriculture, and Bangladesh is one of the most vulnerable countries due to these change.

Bangladesh has a large agrarian base with 76 percent of total population living in the rural areas and 90 percent of the rural population are directly related with agriculture. Increasing food production and attaining food security in Bangladesh require sustainable growth in agricultural sector. The agriculture's contribution to gross domestic product is about 20 percent to Gross Domestic Product (BER, 2011). In the agricultural sector 48.1 percent of the country's labor force are engaged, who are always vulnerable to changing climate conditions and unfavorable weather events. The sector is already under pressure for increasing food demand, problems associated with agricultural land and water resource depletion. The issues of climate change make the pressure more acute for the sector (BER, 2011).

Rice is the staple food for above 150 million people. Total population will become 233.2 million by 2050. Therefore, it is imperative to increase rice production in order to meet the growing demand for food emanating from population growth. The diverse climatic phenomena like cyclone, drought, changing rainfall patterns and temperature cause a significant loss 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. Therefore, the challenges faced by the agricultural sector from the climatic conditions require systematic integration of environmental and economic development measures for a sustainable agriculture growth.

With more than sixty percent of its labour force dependent on climate sensitive activities such as agriculture, the impacts of climate change on agriculture assume significant importance for Bangladesh. Sustainability of agricultural production systems in Bangladesh are already challenged by declining land and water resources, high input and energy costs, increasing food prices, depressing effective demand by the poor, slow technology generation and so on. On top of all these, challenges of climate change as indicated by floods, droughts, cyclones etc. are superimposed, meaning that the country will be exposed to a range of disaster risk and vulnerability and that the ongoing efforts to reduce poverty and hunger might be slowed to some extent. Therefore, it becomes imperative to assess the effects of agro-climatic factors on rice production in western Bangladesh, Rajshahi district.

2. Data and Theoretical Framework

Estimation of the model requires crop- yield data and data on a number of agro-climatic variables. While yield data are data of different varieties of rice and total production of rice, agro-climatic data include data on maximum and minimum air temperature, rainfall, humidity, sunshine and wind speed. Yield data are collected from Bangladesh Statistical Yearbook, Bangladesh Bureau of Statistics. Data of agroclimatic variables are obtained from the Bangladesh Meteorological Department.*

The variable of yield of rice and the agro-climatic variables are conceptually related as follows:

$$Y = f(MAX, MIN, AAR, AAH, ASH, AWS) \quad (1)$$

Where, Y = Yield of the rice crop; MAX= Maximum Temperature; MIN= Minimum Temperature; AAR= Annual Average Rainfall; AAH= Annual Average Humidity; ASH= Annual Average Bright Sun-shine Hour; AWS= Annual Average Wind Speed.

3. Empirical Model

There are many empirical studies on the relationship between rice production and climatic variables. In this study, multiple regression model is used to evaluate the relationship between rice production and climatic variables. The explanatory variables included in the model were maximum temperature (MAX), minimum temperature (MIN), annual average rainfall (AAR), annual average humidity (AAH), Annual average sun-shine hour (ASH) and average wind speed (AWS). The yield forecasting model used in this study is specified as:

$$\gamma_i = \beta_0 + \sum_{i}^{n} \sum_{j}^{k} + \beta_j \; w_{jj} 1, 2, 3, \ldots, \; n \text{ and } j = 1, 2, 3, \ldots, k$$

Where, is the yield of the rice crop, w is the agro-climatic variables, b are the coefficients of the relevant variables, is the constant and is the disturbance term.

Rice production depends on the agro-climatic factors. In this model, we show the influence of explanatory variables on rice production.

* The nature of data obtained from the BMD constrains estimation of the model in both spatial and temporal dimensions. As for the spatial dimension, BMD does not have its weather stations in all the district locations. Again, while a given set of districts are covered in recording data with respect to some variables, other districts are not covered for recording data for the same variables. A preliminary assessment revealed that while data on rainfall, temperature and sunshine hours are recorded at 23 stations, information on evaporation is available from 12 stations and those for solar radiation is recorded at only 7 stations. On the temporal dimension, it is revealed that data on all the variables were not available for the same length of periods. These circumstances required a great deal of adjustment in the estimation of the model, particularly in respect of incorporation of variables in the model.

4. Descriptive Statistics of the Variables Used in the Model

The variables included in the model are presented in Table 1, together with their descriptive statistics. We use secondary data for Rajshahi district from 1972 to 2010. These include maximum and minimum values of all variables, their mean and standard deviation.

Table 1: Descriptive Statistics of the Variables

Variable	Mean	Maximum	Minimum	Standard.Deviation
Yield (Aus)	133385.03	196795	84331	29604.116
Yield (Amon)	544425.69	853070	142351	202951.002
Yield (Boro)	474595.51	1274843	63020	386799.053
Yield (Total)	13821769	3050000	545000.00	698235.8394
Maximum temperature	35.94	39.20	32.20	1.69282
Minimum temperature	10.90	13.80	8.40	1.20110
Annual average rainfall	126.35	186.75	70.25	23.45899
Annual average humidity	77.1026	82.00	72.00	2.60359
Annual average sun-shine hour	6.9308	8.00	5.30	.51817
Annual average wind speed	2.4051	5.40	.90	.97978

From Table 1, it is found that average yield of Aus rice is 133385.03 metric tonnes with the maximum yield of 196795 metric tonnes and minimum of 84331 metric tonnes. Average yield of aman rice is 544425.69 metric ton with the maximum and minimum yield of 853070 and 142351 metric tonnes, respectively. The average yield of Boro rice is 474595.51 metric tonnes with the maximum yield of 1274843 and 63020 metric tonnes, respectively. It is also evident that the average yield of aus, aman and boro aggregately (total rice) is 13821769 metric tonnes with maximum and minimum yield of 3050000 and 545000.00 metric tonnes, respectively. Average maximum temperature is 35.94C with the maximum of 39.20C and minimum of 32.20 C. The average value of minimum temperature is 10.90C with the maximum value of 13.80C and minimum value of 8.40C. The average value of yearly rainfall is 126.35 millimeter with the maximum value of 186.75 millimeter and minimum value of 70.25 millimeter. The average value of yearly average humidity is 77.10 percent with the maximum value of 82.00 percent and minimum value of 72 percent. The average value of yearly bright sun-shine hour is 6.93 with the maximum value of 8.00 and minimum value of 5.30. The average value of yearly average wind speed is 2.41 knots with the maximum value of 5.40 knots and minimum value of .90 knots.

5. Regression Results

Estimation results of the regression equation for aus rice, aman rice, boro rice and total rice production are presented in Table 2. These results provide the estimated coefficients of the explanatory variables, each of which explains the climatic impact of the concerned explanatory variable on rice production expressed in terms of rice yield. The coefficients give elasticity of climatic impact with respect to the individual explanatory variables.

Table 2: Estimated Regression Results of the Crop Yield -Weather Regression Model

Aus Rice		Amon Rice		Boro Rice		Total Rice	
640775.63	2.8390	-3348541.48	-2.0040	-5149223.91	-1.7590	-5954753.08	-1.2760
-151.19	-0.0500	-5623.77	-0.2520	35851.26	0.8980	49010.91	0.7860
-383.03	-0.0930	9694.78	0.3200	-43791.81	-0.7870	-24135.52	-0.2850
91.83	0.4640	869.18	0.5930	1048.98	0.4060	-4183.48	-1.0220
-6169.61	-3.2070	42235.49	2.9660	57113.02	2.2780	109812.34	2.7610
-8879.71	-0.9800	81042.29	1.2090	101519.56	0.8470	-200654.73	-1.0710
11580.36	2.6680	25548.16	0.7950	-170303.99	-2.8260	-294554.74	-3.2820
R^2	F	R^2	F	R^2	F	R^2	F
0.382	3.291	0.279	2.067	0.407	3.199	0.525	5.895

From Table 2 it is evident that maximum temperature has negative and insignificant impact on Aus rice production at 5% significance level. Minimum temperature has also negative and insignificant impact on Aus rice production. Annual average rainfall has positive but insignificant impact on Aus rice production. Annual average humidity has negative but significant impact on Aus rice production. Annual average bright sun-shine hour has negative and insignificant impact on Aus rice production. Annual average wind speed has positive and significant impact on Aus rice production at 5% significance level. It is also evident from Table 2 that both maximum and minimum temperatures have negative impacts on Aus yield, although the coefficients were not statistically significant. The R and F values of the equation were relatively lower indicating that the agro climatic variables in the model may not have been adequately explained.

Aman rice includes local, transplanted aman and HYV aman. It is evident that high day temperature and low night temperature contribute to yield of aman rice. Table 2 shows that, maximum temperature has negative and insignificant impacts on aman rice production at 5% significance level. Minimum temperature and annual average rainfall has positive but insignificant impacts on aman rice production. But annual average sun-shine hour has positive and significant impacts on aman rice production. On the other hand, annual average wind speed has positive but insignificant impacts on rice production at 5% significance level.

Boro production is influenced by climatic variables, such as, maximum and minimum temperature, rainfall, humidity, bright sun-shine hour and wind speed. Regression results of Boro rice are also represented in Table 2. Among the climatic variables, maximum temperature has positive and insignificant impact on boro rice production. But minimum temperature has negative and insignificant impact on boro rice production at 5% significance level. Annual average rainfall has positive and insignificant impacts on boro rice production. On the other hand, annual average humidity has positive and significant impact on boro rice production. Annual average bright sunshine hour has positive and insignificant impacts on boro rice production. Annual average wind speed has negative but significant impacts on boro rice production.

In order to assess the impacts of climatic variables on rice productivity, regression is run between total rice production and those variables and results are presented in Table 2. The results indicate that the explanatory variables have differential impact on rice production. Results show that all the six variables have significant estimated coefficients. Maximum temperature has positive and insignificant impacts on total rice production at 5% significance level. Minimum temperature has negative and insignificant impact on total rice production. Annual average rainfall has negative and insignificant impacts on total rice production. Annual average humidity has positive and significant impacts on total rice production. Annual average sunshine hour has negative and insignificant impact on total rice production. Annual average wind speed has negative but significant impacts on total rice production. The R and F values of the equation are relatively lower indicating that the agro-climatic variables in the model may not have sufficient explanatory power.

6. Conclusion

The study evaluates the impact of climate change on rice production in western Bangladesh using secondary data from 1972 to 2010 for Rajshahi district and applying a Crop Yield -Weather Regression model. In depicting the climate change impact, the rice productions are investigated in terms of maximum and minimum temperature, average rainfall, sunshine hour, average humidity. We investigate the impact on aus, aman, boro rice production separately and on total rice production. Results reveal that the climatic factors have mixed and varying effects on aus, aman, boro rice production and on total rice production.

References

1. Ahmed, I., 2007, Bangladesh: Problems of Global Warming, Land Inundation and Arsenic Poisoning, Paper presented at Ohio State University, Ohio, New Orleans, 02-05 November 2007.

2. BCCSAP, 2009, Bangladesh Climate Change Strategy and Action Plan, Ministry of Environment and Forests, Government of the People's Republic of Bangladesh, Dhaka, Bangladesh.

3. BER, 2011, Bangladesh Economics Review, Finance Divison, Ministry of Finance, Government of the People's Republic of Bangladesh.

4. Heikens, A., 2006, Arsenic Contamination of Irrigation Water, Soil and Crops in Bangladesh: Risk Implication for Sustainable Agriculture and Food Safety in Asia. FAO Regional Office for Asia and Pacific, Bangkok.

5. Hussain, Sk. G., 2008, Assessing impacts of climate change on cereal production and food security in Bangladesh, Paper presented at the International Conference on Global Climate Change and its Effects, held in Dhaka on August 25-30, 2008.

6. IPCC, 2007, Climate Change 2007, Synthesis Report, An Assessment of the Intergovernmental Panel on Climate Change (IPCC), IPCC Plenary XXVII, Valencia, Spain

7. Karim, Z., Hussain, S.G. and Ahmed, M., 1996, Assessing impacts of Climatic Variations on Foodgrain Production in Bangladesh, Water Air and Soil Pollution, 92, 53-62.

8. MoEF (Ministry of Environment and Forest), 2008, Bangladesh Climate Change Strategy and Action Plan, Government of the People's Republic of Bangladesh, Dhaka, Bangladesh.