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Climate Change Impact on Rice Production in Bangladesh: An Econometric Analysis

Md. Nur Islam & Md. Abdul Wadud

Abstract

Bangladesh's main grain is rice, but rising climate change vulnerabilities and global warming are reducing yields of various rice crops, jeopardizing the country's food security. As a result, the goal of this research is to see how climate change affects the production of three rice types farmed in Bangladesh (Boro, Aus, and Aman). The climate-crop yield connection is assessed using a multiple regression technique employing country-level time series data from 1972 to 2019. The results reveal that all climatic conditions had a significant influence on rice yield during the course of the study, while the affects varied between the three rice yields. Rainfall is critical for all rice crops, with benefits for Aus and Aman rice and drawbacks for Boro rice. Humidity, on the other hand, affects Aman and Boro rice yields in a statistically significant way. Nonetheless, in Bangladesh, the impacts of maximum temperature and rainfall on rice yield are stronger than the effects of lowest temperature and humidity. Our findings emphasize the need of developing temperature-tolerant rice cultivars and suggest that long-term agricultural expansion might help alleviate climate change's detrimental effects.

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About Author (s)

Md. Nur Islam (Corresponding author), Assistant Professor, Economics, OSD, Ministry of Education, Bangladesh & PhD Research Fellow, Institute of Environmental Science (IES), University of Rajshahi, Rajshahi 6205, Bangladesh.

Dr. Md. Abdul Wadud, Professor, Department of Economics, University of Rajshahi, Rajshahi 6205, Bangladesh

1.1 Introduction

Global climate change and unpredictability may have evolved as a complete phenomena in the last three decades as a result of human and non-human activities. Increasing flood frequency, shifting rainfall patterns, rising sea levels, rising temperatures, and increasing the intensity of extreme weather events are all disrupting ecosystems, agriculture and food security, infrastructure, and human health (IPCC, 2014). Bangladesh is one of the world's most vulnerable countries to climate change's severe consequences (According to the Global Climate Risk Index -GCRI, 2017). It is now the world's sixth most susceptible country due to climate change (Kreft et al. 2017). Climate change would have a significant influence on agricultural productivity and competence, leading to significant changes in agricultural production (IPCC, 2014; Arshad et al., 2018). Developing countries are more exposed to climate change's harmful consequences (Wheeler and Von Braun, 2013; Ruamsuke et al., 2015). As a result, the most significant predictor of agricultural productivity is climatic change. It's a big problem, particularly in poor nations like Bangladesh, where agriculture is based mostly on natural occurrences rather than the regulated environmental conditions of rich countries. Bangladesh is a developing country with a large population and a 20.5 percent poverty rate. (BBS, 2019). Rice has been grown in this area from the dawn of time, and it is our people's staple food. It produces approximately 92 percent of the country's total food grain and covers around 77 percent of the country's agricultural acreage. Bangladesh produces the fourth most rice in the world (DAE, 2013).

Climate change's effects on crop production are a global issue, but they're especially critical for Bangladesh's long-term agricultural development (Hossain, A., 2013). In certain circumstances, the relationship between these important ingredients and production losses is obvious, but this is not always the case. Despite recent progress in the direction of sustainable development, Bangladesh's capacity to recover from these losses is impeded by considerable obstacles, which are compounded by climate change (Ahmed and Haque, 2002). Temperatures in Bangladesh have risen during the previous three decades (Sarker et al., 2012). Furthermore, yearly mean temperatures are expected to climb by 1.0°C by 2030, 1.4°C by 2050, and 2.4°C by 2100. By 2030, the average winter temperature will have increased by 1.1 degrees Celsius, 1.6 degrees Celsius by 2050, and 2.7 degrees Celsius by 2100. By 2030, 0.8 °C, 1.1 °C, and 1.9 °C are expected during the monsoon months, with 1.9 °C by 2100. (Ahmed, A.U., 2006; Agrawala, et al., 2003). Data from the Global Climate Model (GCM), on the other hand, predicted a warmer winter than a warmer summer (FAO, 2007). According to estimates, Bangladesh would see more hot days and heat waves, longer dry periods, and a greater danger of drought. The monsoon season, on the other hand, delivers around 80% of the rain in Bangladesh (June-September). The remaining 20% covers an eight-month period, including the winter-grown high-yielding rice Boro. While rainfall is likely to rise throughout the monsoon season, rainfall variability is expected to increase significantly, resulting in more powerful showers and/or longer dry spells. During the summer monsoon, most climate models expect an increase in rainfall (GOB and UNDP, 2005). Extreme occurrences such as floods and droughts are caused by this erratic and unevenly dispersed pattern, which have a significant negative impact on the output of vital food crops, particularly Aman rice. Rice output is expected to fall by 8%–17% by 2050 as a result of this (IPPC, 2007; Sarker et al., 2012). Food security is defined as ensuring that everyone has access to sufficient and safe food at all times in order to maintain an active and healthy lifestyle. Food security is a serious problem in Bangladesh, which is mostly an agrarian country with a dense population. However, the country's aggregate domestic output and per capita availability of food grains have increased during the previous few decades. Regardless, the country continues to rely on imported food grains (Rahman and Pervin, 2009). In 2007–2008, it imported 11.5 percent of total availability, and the annual demand for basic food is predicted to exceed supply through 2021, indicating that demand is stronger than supply (Begum and Hases, 2010). Climate science research at the national level is crucial for resolving agricultural difficulties brought on by climate change. Climate data not only provides the optimal periods for planting and harvesting, but also acts as a guide for selecting the best places for a particular crop (Amin, et al., 2014). Most studies on the consequences of climate change have previously focused on the United States (Moorthy, et al., 2016; Zhang, et al., 2015). However, all of these studies have found that agriculture in developing countries is extremely vulnerable to climate change. Despite Bangladesh's reputation as a climate-vulnerable country, little scientific study on the impact of climate change on the country's primary food crops has been conducted (Rashid and Islam, 2017). As a result, the study's main purpose is to figure out how climate change would affect rice production in Bangladesh. Determine the climatic elements that are likely to affect rice yield using national level time series data from 1972 to 2019. The remainder of the paper is arranged as follows: The study on climate change's diverse implications on food security and agricultural output in poor countries is examined in the second part. Materials and Methods (Section 3) Conclusion and discussion in Section 4. Finally, the paper concludes with a discussion on future research.

1.2 Climatic Character of Key Food Crops in Bangladesh

There are three types of rice in Bangladesh: boro, aus, and aman. These are collected at different times throughout the year. Planting occurs in March and April, with harvest occurring in July and August. Aman is typically planted from June to August and harvested from November to December. Boro is planted in the months of December and January and harvested in the months of April and May. (GOB, 2017; Sarker et al., 2012). The calendar for these important crops is determined by edaphic and climatic circumstances, which differ greatly from place to place. Surprisingly, three meteorological seasons—hot summer (March–May), monsoon (July–October), and winter (December–February)—are virtually equal to these growth seasons. Aus rice, according to BRRI (2019), requires supplemental water during the early stages of its growing season, whereas Aman rice is completely rain-fed and grows during the monsoon months, though it does require supplementary irrigation during transplanting and, depending on precipitation availability, occasionally during the flowering stage. Boro rice is an irrigated rice that thrives in hot summers and dry winters (Mahmud, 2013).

2. Review of Literature

In recent years, a growing body of work has examined the impact of climate change on agricultural output. Changes in environmental factors such as temperature and rainfall have long been claimed to have a substantial influence on agricultural yields by scientists. Because of Bangladesh's agricultural sector's importance, the research of climate change consequences on Bangladesh agriculture has gotten a lot of interest recently.

Ahmed et al. (2019) investigated an important research issues of climate change and vulnerability of two coastal villages in Bangladesh that are environmentally vulnerable. The study revealed that climate change and vulnerability produced an important negative effect on public health, reducing agricultural yields, salinity intrusion, rising sea level and increasing temperature. The finding just shows the negative impact of climate variation on agriculture and environment. Hossain et al. (2018) did a study in Bangladesh to demonstrate the economic impact of climate change on yield farming. The link between net crop income and long-term climatic factors is revealed by the Ricardian model. According to the study, rising rainfall and mild temperatures boost net crop revenue. The finding of the research just shows the positive economic impact of climate change but it is not a negative impact identified. Rahman et al. (2018) investigated a review article to exhibit the impact of climate variation on temperature, frequency of flood, salinity intrusion, and storm surge and river bank erosion on crop production in Bangladesh. The study shows that the climate variation plays a negative role in crop production and environmental balance. The researcher gives some suggestions for policy makers that would help reduce adverse impact on human and natural environment. FAO, UN. (2018) conducted an annual report to reveal the implications of climate variation on agricultural small farming and livelihood, poverty reduction, livestock and adaptation. The study shows that the climate variation plays an important negative role on economic growth, reducing productivity, livestock and forestry, fisheries, global warming, and food safety. The risk of animal food security, infection and disease has decreased animal productivity. Hossion et al. (2018) conducted a review study to express the impact of climate variation on agricultural productivity, food safekeeping, livestock, fisheries and coastal livelihood, which are affected by global warming and adverse impact of climate variation. The study exhibits that the implication of global climate effects on vulnerable agricultural productivity, creates food insecurity, destroying coastal livelihood, food safekeeping, fisheries and livestock. The researchers found that climate change plays an important negative role on agricultural production and food safekeeping. Maniruzzaman et al. (2018) explained a study to reveal the impact of utmost temperature on agricultural production, increasing global warming and rice yields enhancing various seasons of Bangladesh. The paper shows that moderate temperature performs a significant negative role in decreasing rice yields. The research's outcome just demonstrates the negative and positive impact of climate variation on agricultural productivity in three different seasons without being numerical. Richard et al. (2017) have conducted a review article to reveal the consequence of global climate variation on agricultural yielding, livestock and economic influence of the U.S.A and Latin America. The research's outcome reviews that the effects of economic calculation is a bit positive on U.S. agriculture and predicted that the next century would see decreased food production, economic losses, imposition of huge cost, enhancing temperature, carbon dioxide doubling and need to assess the magnitude of global warming for livelihood policy as it is highlighted. Kabir et al. (2016) have focused on their study to show the influence of climate variation on coastal areas of Bangladesh, experienced cyclones Sidr and Aila. Implication of climate variation has adversely influenced on global weather and so, heat weave, cyclone, drought, flood, heavy rainfall and natural disaster are going to enhance seriously. The study reveals that climate change plays an important negative role on socio economic condition of individuals and the health status of people are more vulnerable to coastal belt of the country.FAO, UN. (2016) have investigated a study endeavor to show that the implications of climate change on agricultural yielding, food safe keeping, poverty reducing, global warming and sustainable development. The study shows that the climate variation plays an important negative role on economic growth, sustainable development, poverty reduction, and productivity of yielding, livestock, forestry, and fisheries, global warming and food safe keeping. The UN research's outcome just exhibits the negative impact of climate variation on living earth without being numerical result. Amin et al. (2015) have conducted an important study to exhibit the effect of climate variation on crops production, food security and major agricultural yield. The study shows that climate variation has a positive contribution of major food yield. Aus rice is benefited by rainfall but then again Amon rice is affected significantly. The role of humidity positively contributed to Amon and Aus rice, whereas Aus rice is negatively affected. Only Boro rice is significantly promoted by sunshine. Most of the food crops are adversely affected by higher temperature and only Amon rice is severely affected by the rainfall. Iqbal and Siddique (2014) have conducted a discussion paper to express the strong implication national and international perspective of climate variation on agricultural efficiency, food safekeeping, and poverty. The study exhibits that climate variation plays an important negative role on agricultural productivity, compared with unobserved and observed variables, food security and poverty reduction. There is no robust estimate which found the impact of climatic variables of the paper that could be adverse impact on living and non-living beings. However, there have been few researches in Bangladesh that have looked at the pattern and temperature, energy balance, solar radiation, relative humidity, heat budget and trend of rainfall on distinct ecosystems, and meteorological application on rice production. Nonetheless, earlier research in Bangladesh revealed that just a handful of them have thoroughly investigated the link between climate change and agricultural productivity (Ferdous and Baten, 2011). As a result, crop-specific research will be done (especially on main staples) in order to provide better policy recommendations for long-term development. Given the reliance of rice yields on climatic elements (i.e., change), assessing the impacts of climate change (i.e., lowest temperature, humidity, rainfall, and maximum temperature) on different types of rice yields is critical (productivity). Because predicting the consequences of future climate change on the country's food security may need a better understanding of the national repercussions of existing climatic patterns on important food crops.

3. Data Description and Methodology

3.1 Data Description

From 1972 to 2019, national yield data for Bangladesh's principal food crops (Boro rice, Aus rice, and Aman rice) were gathered from several editions of the country's agricultural statistics yearbook. The yield data is organized by fiscal year, such as 1971–1972, 1972–1973, and so on. The data from these fiscal years is then transformed to annual data, such as 1971–1972 being treated as 1972. The Bangladesh Meteorological Department (BMD, 2021) released monthly data on meteorological factors at the aggregate level for all (35) weather stations during the same time period, covering the whole country. These monthly data were then transformed to seasonal data depending on the crop's growing season year after year. Because the growth seasons for Aus and Aman rice differ from April to August and July to December, respectively, climatic variables have been specified for the whole time period. Boro rice, on the other hand, has a growth season that runs from December to May. With the exception of rainfall, the life span average has been taken into account for all meteorological characteristics. Rainfall totals for the whole production period have been calculated. As a consequence, the research recommended that climate data from 1971 be compared to yield (as well as cropping area) data from 1972, particularly for Aus and Aman rice, in order to demonstrate consistency between climatic factors and yield (as well as cropping area) data. Similarly, for the production and cropping area for the Boro rice growing season in 1972, climate data from the previous year (1971) and the following year (1972) were merged. The World Bank are also consulted (WB, 2020), the Department of Agricultural Extension, the Ministry of Agriculture, (DAE, 2020), the World Development Indicator (WDI, 2021), and the Bangladesh Economic Review (BER, 2020).

3.2 Methodology

Empirical Model Specification:

The goal of this research is to look at the relationship between three different rice crops (Aus, Aman, and Boro) and meteorological variables (rainfall, lowest humidity, temperature, and maximum temperature) in order to assess the impacts of climate change on rice crop output. The dependent variable in this study is yield of several rice crops (such as Aus, Aman, and Boro), and the independent factors are rainfall, lowest humidity, temperature, and maximum temperature, as described by (Lobell et al., 2007; Almaraz et al., 2008) and Sarkar et al (2012). To remove the trend and eliminate heteroskedasticity in a linear regression model, we can use a log-linear regression model. Because the log-transformation can change absolute discrepancies into relative ones. The log-linear version of our regression models is used in this example. The following regression models are utilized based on the distribution of yields of three rice crops and other features:

Aus Rice Model

The following is the link between rice production and variable:
f (MaxT, MinT, Rain, Humidity) = (1)
In comparison to the simple liner model, this linear combination is changed into a log-liner model, which produces appropriate and proficient results. $lnAP_t = \alpha_0 + \alpha_1 \, lnmaxT_t + \alpha_2 \, lnminT_t + \alpha_3 \, lnrain_t + \alpha_4 \, lnhumi_t + \varepsilon_t$ (2)
Where, $lnAP_t$ represents the logarithm function of the Aus production; lnmaxT represents the logarithm function of the average maximum temperature (ºC) from April to August; lnminT represents the logarithm function of the average minimum temperature (ºC) from April to August; $lnrain_t$ = represents the logarithm function of the average total rainfall (millimeter) from April to August; LnHumi represents the logarithm function of the average humidity (%) from April to August; $\mathcal{E}_t$= is the error term and't' is the time (i.e., year).

Aman Rice Model

The following is the link between rice production and variable:
f (MaxT, MinT, Rain, Humidity) (3)
In comparison to the simple liner model, this linear combination is changed into a log-liner model, which produces appropriate and proficient results. $lnAP_t = \beta_0 + \beta_1 \, lnmaxT_t + \beta_2 \, lnminT_t + \beta_3 \, lnrain_t + \beta_4 \, lnHumi_t + \varepsilon_t$ (4)
Where, $lnAP_t$ represents the logarithm function of the Amon production (in kg per acre), $lnmaxT_t$ represents the logarithm function of average maximum temperature (ºC) from July to December; $lnminT_t$ represents the logarithm function of average maximum temperature (ºC) from July to December; lnTrain represents the logarithm function of average total rainfall (millimeter) from July to December; $lnHum_t$ represents the logarithm function of average humidity (%) from July to December; $\mathcal{E}_t$ is the error term of Aman rice model and't' is the time (i.e., year).

Boro Rice Model

The following is the link between rice production and variable:
Boro Production= f (MaxT, MinT, Rain, Humidity) (5)
In comparison to the simple liner model, this linear combination is changed into a log-liner model, which produces appropriate and proficient results. $lnBP_t = \gamma_0 + \gamma_1 \, lnmaxT_t + \gamma_2 \, lnminT_t + \gamma_3 \, lnrain_t + \gamma_4 \, lnHumi_t + \varepsilon_t$ (6)
Where, $lnBP_t$ represents the logarithm function of the Boro rice production (in kg per acre);$lnmaxT_t$ represents the logarithm function of average maximum temperature (ºC) from December to May; $lnminT_t$ represents the logarithm function of average maximum temperature (ºC) from December to May; $Lnrain_t$ represents the logarithm function of average total rainfall (millimeter) from December to May; $lnHum_t$ represents the logarithm function of average humidity (%) from December to May; $\mathcal{E}_t$ = is the error term of Boro production and 't' is the time (i.e., year). Table 1 shows the descriptive statistics for all of the data series utilized in this investigation. The fundamental features of the variables under inquiry are also shown in this table1 for three rice growing seasons in Bangladesh.

3.3 Descriptive statistics

Table 1 presents the descriptive statistics, which are used to characterize the fundamental characteristics of all the variables studied.In terms of yield, it was revealed that Boro rice has the highest mean yield of the three principal crops, which is two times higher than Aus rice.

The observed mean yield of the three crops under investigation was as follows, in descending order: Boro > Aman > Aus. In terms of climatic characteristics, the Aus growing season has the greatest average maximum temperature and average lowest temperature. The Boro season, on the other hand, experienced the coldest maximum and lowest temperatures. Boro rice had the least amount of total rainfall throughout the growth season, whereas Aus and Aman received more than twice as much.However, the Aus rice growing season receives the greatest rain, followed by the Amon rice growing season. The Aman growth season has the highest humidity content, while the Boro growth season has the lowest.

Table1: Descriptive statistics for the data series from 1972 to 2019.

Variables	Rice Varieties	Statistics						
		Mean	Median	Std.Dev.	Maximum	Minimum	Kurtosis	Skewnes
Yield (kg/acre)	Aus	564.86	460.21	197.24	1012.15	363.90	-0.16	1.06
	Amon	704.09	659.91	171.95	1012.15	445.34	-1.19	0.34
	Boro	1194.81	1084.83	286.47	1625.16	728.27	-1.35	0.23
Maximum Temperature (C^0)	Aus	32.26	32.30	0.55	33.59	31.15	-0.08	0.28
	Amon	30.20	30.18	0.39	31.18	29.52	-0.08	0.48
	Boro	29.69	29.72	0.49	30.77	28.55	-0.07	-0.03
Minimum Temperature (C^0)	Aus	24.40	24.28	0.61	25.88	23.47	-0.13	0.81
	Amon	22.38	22.39	0.32	23.23	21.70	0.08	0.37
	Boro	16.38	15.84	1.38	20.52	14.97	1.46	1.57
Average Total Rainfall (mm)	Aus	1848.72	1819.27	237.37	2226.09	1324.37	-0.75	-0.17
	Amon	1530.39	1536.23	231.22	1975.61	1018.38	-0.46	0.09
	Boro	479.87	446.21	132.78	808.69	212.30	-0.33	0.55
Average Humidity (%)	Aus	82.63	82.64	0.92	84.26	80.55	0.33	-0.40
	Amon	83.58	83.50	0.59	84.62	81.94	0.59	-0.35
	Boro	76.13	76.06	1.10	78.00	72.79	1.81	-0.79
Observations (N)	48	48	48	48	48	48	48	48

N.B. MaxT= Average maximum temperature (^{0}C) in growing season; MiniT= Average minimum temperature (^{0}C) in growing season; kg/acre= kilogram per acre, mm=millimeter.
Source: Authors' own calculation based on BBS, DAE, BRRI and BMD.

3.4 Trend Analysis

Figures 1–5 show how variances and changes in trend (upward or downward) among the five climatic variables evolved over time (1972–2014) using time (t) as an explanatory variable.

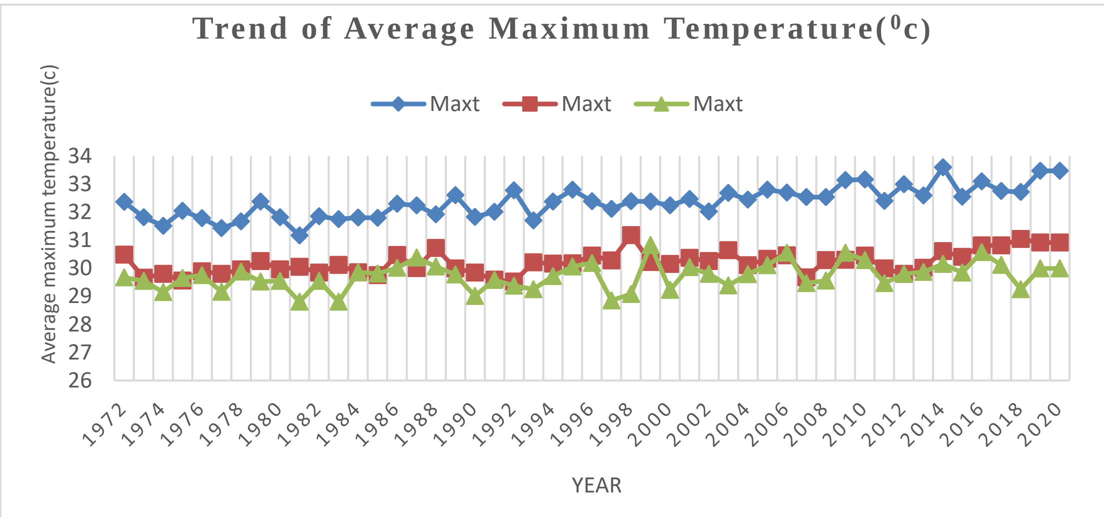

Figure1: Trend and variation in seasonal average maximum temperature (^{0}c) for 1972-2019

The mean maximum temperature varied widely, although the overall tendency for all rice growing seasons is to improve.

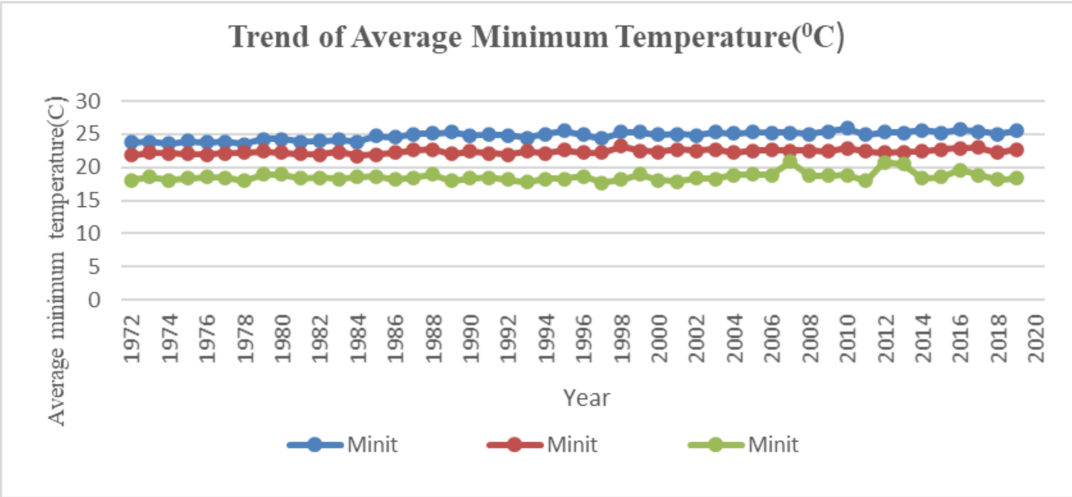

Figure2: Trend and variation in seasonal average minimum temperature (0c) for 1972-2019

In the case of the average lowest temperature, there are minor variances; nonetheless, the tendency appears to be growing.

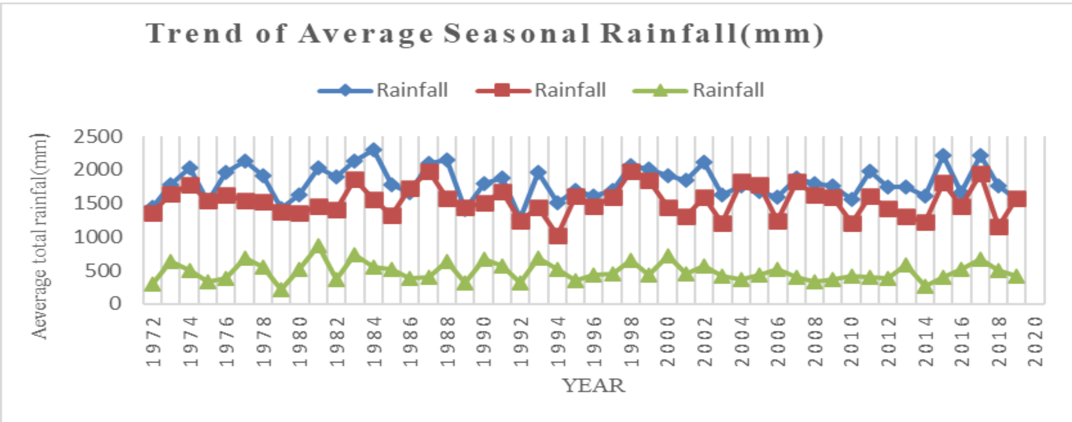

Figure3: Trend and variation in seasonal average total rainfall in(mm) for the period 1972-2019

Average rainfall rose with diverse and biggest fluctuations throughout the Aus and Aman rice growing seasons. Although there is no clear pattern in the Boro rice season over time, changes in the Aus and Aman crops would be adversely impacted.

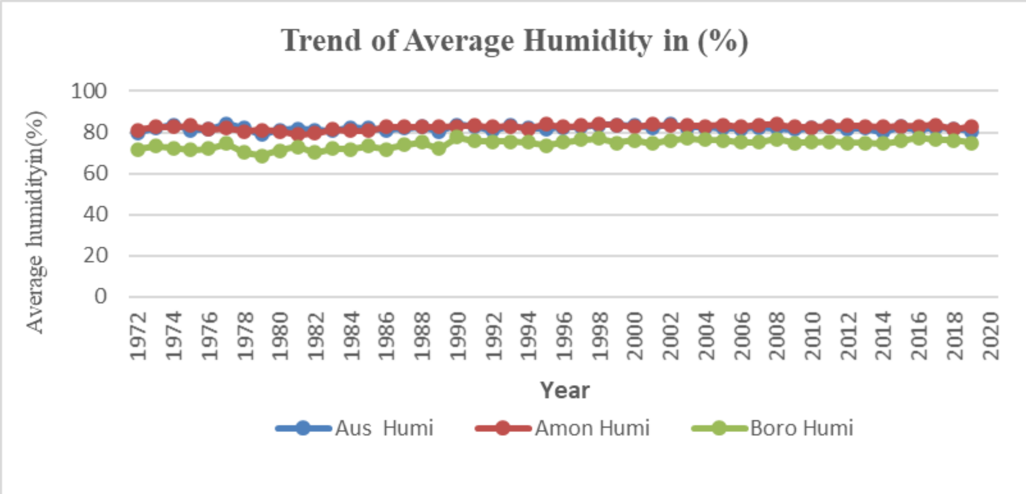

Figure 4: Trend and variation in seasonal average humidity in (%) for the period 1972-2019

With small changes, the average seasonal humidity likewise exhibited a rising tendency.

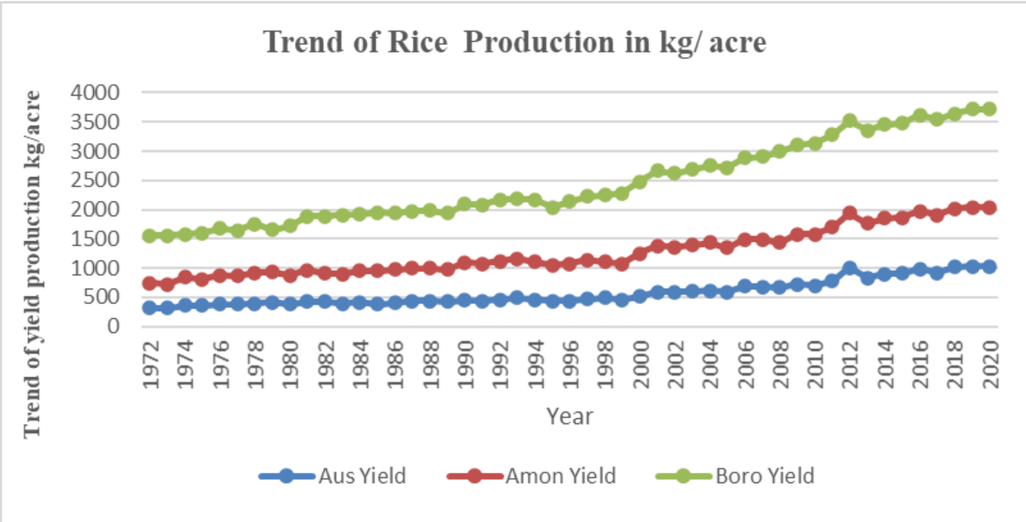

Figure5: Trend and variation in average yield(kg/ acre) of different rice production for 1972-2019

In contrast to Aus and Aman rice yields, Boro yields showed a rising (upward) tendency across the seasons, with bigger variations.

3.5 Stationarity and Unit Root Tests:

We need to validate zero degree of integration for each variable under examination since the current research report emphasizes a model to analyze the influence of climatic fluctuation on varied rice crops. Otherwise, if the variables represent different degrees of integration, they can't be utilized for correlation, causality, or OLS estimates. To ensure that all discoveries are genuine and all estimations are consistent, we must first check that the data series are free of unit roots, i.e. that the series are stable (Enders, 1995). The presence of unit roots in the data series was checked using the Phillips-Perron (PP) test (Phillips and Perron, 1988), and the Augmented Dickey-Fuller (ADF) test and the results are presented in table 2. If all variables are confirmed to be stationary, we can run our whole regression model.

Table 2: Augmented Dickey-Fuller (ADF) & Phillips-Perron (PP) Tests for checking the stationarity of the data series.

Variables	Integration of order for **Aus**	Integration of order for **Amon**	Integration of order for **Boro**
lnYield	I(1)	I (1)	I (1)
$\ln maxT_t$	I(0)	I(0)	I(0)
$\ln miniT_t$	I(0)	I(0)	I(0)
lnrain	I(0)	I(0)	I(1)
lnhumi	I(0)	I(0)	I(0)

Note: MacKinnon (1996) one-sided p-values (at 1%, 5% & 10% level is -3.605, -2.936& -2.606 respectively) is used.

Source: Authors own estimation based on BMD, BBS and DAE.

Table 2 shows that Aus, Aman, and Boro rice yields are integrated of order one, i.e., I(1), indicating that the three data series have a unit root. However, when it comes to explanatory variables, rainfall has an integration order of I(1), whereas the rest of the climatic variables have an integration order of zero, i.e., I(0), resulting in stable data series in their level form. The variables with I(1) must be differenced first, according to McCarl et al., (2008), before estimating. We can't do a Johansen co-integration test since most of the variables in each model aren't integrated in the same order. Instead, we use the OLS approach to do a multiple regression analysis with the differenced variables (Gujrati, 2004). Furthermore, rather than the other way around, climatic factors are thought to be the source of yield difference in various rice harvests (Lobell and Field, 2007). As a result, no causality test is carried out.

4. Result and Discussion

4.1 Regression Results for Aus Rice Model

Table 3 shows the findings of using the OLS technique to categorize the effects of climatic change (i.e., lnmaxTt, lminiTt, lnrain, and lnhumi) on Aus rice yield (LYield). The empirical findings show that Aus rice yield is statistically significant, implying that climatic factors can explain part of the variance in Aus rice output. The corrected R2 value implies that our climate variables (i.e., climatic change) in the model can explain 68.55 percent of the overall variance in Aus rice production. The results also show that the maximum temperature, lowest temperature, and rainfall (seasonal average) are statistically significant at the 1%, 1%, and 10% levels, respectively.

Table 3: Estimated Results of Aus Rice Model

Dependent Variable: LNYIELD				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Probability**
$\ln maxT_t$	-9.618339***	3.097156	-3.105539	0.0034
$\ln miniT_t$	6.172641***	1.925080	3.206433	0.0025
lnrain	0.526025*	0.317463	1.656966	0.0998
lnhumi	2.388275	3.160280	0.755716	0.4539
Constant Term	-61.31864***	15.24259	-4.022851	0.0002
R-squared	0.712335	Mean dependent var		6.271300
Adjusted R-squared	0.685575	S.D. dependent var		0.339141
S.E. of regression	0.190168	Akaike info criterion		-0.383482
Sum squared resid	1.555052	Schwarz criterion		-0.188565
Log likelihood	14.20356	Hannan-Quinn criter.		-0.309822

F-statistic	26.61983	Durbin-Watson stat		1.507582
Prob(F-statistic)	0.000000***			

Note: ***, **, and * denotes significance at 1%, 5% and 10% correspondingly.
Source: EViews 10 output

The results show that Aus yield is inversely related to maximum temperature, implying that every unit increase in average maximum temperature reduces Aus rice output by 9.618339 unit kg(kilogram) per acre. The results also show that average minimum temperature and rainfall have a positive relationship with Aus rice yields that is significant at the levels of 1% and 10%, respectively. Finally, because the coefficient of humidity is minimal, dampness has no effect on the production of Aus rice.

4.2 Regression Results for the Amon Rice Model

The Amon rice is a mostly rain-fed crop that is cultivated during the monsoon season.
The impact of climatic factors (lnmaxTt, lnminiTt, lnrain, and lnhumi) on Amon rice yield is calculated using the OLS technique and shown in table 4.

Table 4: Estimated Results of Amon Rice Model

Dependent Variable: LYIELD				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Probability**
$lnmaxT_t$	-3.999542*	3.132838	-1.276652	0.0986
$lnminiT_t$	5.020846	3.334129	1.505895	0.1394
lnrain	0.568458***	0.208680	-2.724071	0.0093
lnhumi	7.225035***	2.595143	2.784061	0.0079
C	-50.44846***	11.14273	-4.527479	0.0000
R-squared	0.481317	Mean dependent var		6.498948
Adjusted R-squared	0.433067	S.D. dependent var		0.262279
S.E. of regression	0.197483	Akaike info criterion		-0.307998
Sum squared resid	1.676977	Schwarz criterion		-0.113081
Log likelihood	12.39194	Hannan-Quinn criter.		-0.234338
F-statistic	9.975551	Durbin-Watson stat		0.957456
Prob(F-statistic)	0.000008***			

Note: ***, **, and * denotes significance at 1%, 5% and 10% correspondingly.
Source: EViews 10 output

Table 4 shows that seasonal average total rainfall and humidity are statistically significant and have a beneficial affect on Aman rice output at the 1% significance level. On the other side, average maximum temperature has a negative impact on Amon rice yield and is statistically significant at the 5% level. The lowest temperature, on the other hand, is statistically negligible and has no influence on the Aman yield. Furthermore, the environmental characteristics (i.e., variation) employed in the study may explain around 43.30 percent of the total variance in Aman rice yield, according to the computed value of modified R2.

4.3 Regression Results for the Boro Rice Model

Table 5 shows the results of using the OLS technique to estimate the influence of climate change on Boro rice yield.

Table 5: Estimated Results of Boro Rice Model

Dependent Variable: LNYIELD				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Probability**
$lnmaxT_t$	-1.630001*	1.430644	-1.139348	0.0995
$lnminiT_t$	1.687947***	0.285282	5.916765	0.0000
lnrain	-0.105681*	0.080513	-1.312598	0.0963
lnhumi	4.400100***	0.761939	5.774876	0.0000

C	-21.50634***	5.361046	-4.011594	0.0002
R-squared	0.766526	Mean dependent var		7.036433
Adjusted R-squared	0.744808	S.D. dependent var		0.256022
S.E. of regression	0.129333	Akaike info criterion		-1.154514
Sum squared resid	0.719266	Schwarz criterion		-0.959597
Log likelihood	32.70834	Hannan-Quinn criter.		-1.080855
F-statistic	35.29375	Durbin-Watson stat		0.908720
Prob(F-statistic)	0.000000***			

Note: ***, **, and * denotes significance at 1%, 5% and 10% correspondingly.
Source: EViews 10 output

The findings revealed that average maximum temperature and rainfall were both inversely connected to Boro rice output, with the latter being highly significant at the 10% significance level. As a result, increases in maximum temperature and rainfall may have a negative impact on Boro yield. On the other hand, average minimum temperature and humidity have a direct impact on Boro rice output and are statistically significant at the 1% level. Furthermore, the corrected R2 value indicates that the long-run overall model with well-fitting explanatory variables can explain about 74.48 percent of the entire variance in Boro rice yield. According to the findings, a 1% rise in average growing season maximum temperature and rainfall reduces Boro rice output by 1.63 percent and 0.10 percent kg (kilogram) per acre, respectively. On the other hand, a 1% rise in minimum temperature and humidity might boost Boro rice yields by 1.68 percent and 4.04 percent, respectively, with a 1% increase in minimum temperature and humidity.

5. Conclusion

The goal of this research is to look at the influence of climate change on three rice crops in Bangladesh: Boro, Aus, and Amon, using time series data from 1972 to 2019. To do this, regression techniques are employed. Climate conditions have a substantial influence on Boro, Aus, and Amon rice yields, according to the study's findings. In the case of Aus rice, average maximum and lowest temperatures, as well as rainfall, have been shown to be statistically significant and closely associated to Aus yield. Three climatic parameters, average maximum temperature, rainfall, and humidity, are statistically significant for Aman rice. Amon rice farming is said to benefit from average rainfall and humidity. As we all know, average maximum temperature has a detrimental impact on Aman rice production since Aman rice requires supplemental watering during plantation, which is weather dependent. The impact of average maximum temperature on Boro rice yield is also shown to be the same, with an inverse connection. Despite this, there is a positive relationship between Boro rice yield and average minimum temperature and humidity. Furthermore, the results demonstrate that maximum temperature and rainfall have a statistically significant negative influence on Boro rice productivity. The R2 and F-values for all three rice models were statistically significant, and the overall goodness of fit findings were consistent with Lobell's (2010). Crop output fluctuates dramatically as temperature rises above the higher limit, falls below the lower limit, or humidity rises above the upper limit. Furthermore, severe rainfall can result in water logging and flooding, which can wreak havoc on agricultural productivity. Given Bangladesh's high sensitivity to climate change, several adaption techniques should be implemented to mitigate the negative consequences of climate change. Climate change is a big worry in Bangladesh since it has a negative impact on agriculture, the country's most vital sector. As a result, the relevant authorities should adopt appropriate measures to combat the impact of climate change on rice production in order to provide food security for the country's ever-growing population by implementing sustainable agricultural development. As a result, future research in this area should focus on regional data analysis to capture regional variations in climate change and offer a more comprehensive picture of climate change and its implications on rice yield in

Bangladesh. In addition, the government may urge academics in this field to perform more research on the adaptation of temperature-tolerant rice cultivars to Bangladesh's particular environment.

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