Journal of Environmental Impact and Management Policy
ISSN: 2799-113X
Vol : 03 , No. 03 , April-May 2023
http://journal.hmjournals.com/index.php/JEIMP
DOI: https://doi.org/10.55529/jeimp.33.23.35

Influence of Climate Factors on Aman Rice Yield in Bangladesh: Co-Integration and Vector Error Correction Model Approach

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Received: 17 January 2023 **Accepted:** 06 April 2023 **Published:** 12 May 2023

***Abstract:** Climate factors' consequence on human performance has occurred as a worldwide apprehension in the earlier 30 years. This study explores climate factors' influence on Aman rice production in Bangladesh. Co-integration and Vector Error Correction Model approximation procedure is applied to measure the climate-crop harvest interrelation on the basis of country-level time series data for the time 1972-2019. Changing in mean maximum and minimum temperature, annual men rainfall, and average humidity are used as characteristic variables for climate factors. The result of the vector error correction model denotes that both in the long-run and short-run, average maximum temperature and average total rainfall inversely affect Aman rice yield in Bangladesh respectively. Average minimum temperature and average humidity positively affect Aman rice production in the short run respectively. Fertilizers and irrigation have a positive influence on Aman rice yield in the short-run correspondingly. Conversely, labor has a robust negative consequence on Aman rice yield in the short-run in Bangladesh agriculture. Policymakers would develop policies to control temperature and introduce heat-tolerant rice varieties and adaptation measures to sustain Aman rice production in Bangladesh.*

***Keywords:** Aman Rice, Climate Factors, Co-Integration, Food Security, Temperature, VECM.*

1. INTRODUCTION

Global climate change and inconsistency may have emerged from anthropogenic and natural activities as a comprehensive phenomenon in the past three decades. Rising temperatures,

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enhancing sea levels, changing rainfall patterns strength of extreme weather events, and increasing flood frequency are adversely distressing ecosystem performance, infrastructure, agriculture and food safekeeping, human health, and water resources [1]. Due to the increases in greenhouse gases (CO_2, CH_4, NOx, CFCs, etc.), atmospheric heat is trapped in the lower part of the atmosphere and the temperature rises. This rising average temperature (global warming) regulates climatic events. Bangladesh is one of the more susceptible countries to the adverse effects of climate alteration in the world (According to the Global Climate Risk Index-GCRI, 2017). It is the sixth most climate-vulnerable country in the world [2]. Climate variability would significantly affect agricultural productivity and capability and would lead to serious changes in agricultural yield [1]. Developing nations are more susceptible to the adverse impacts of climate variation [3]. Climate change, therefore, becomes a major determinant of agricultural production. This is a particularly important issue in developing countries like Bangladesh, where agriculture is heavily dependent on natural phenomena, as opposed to controlled environmental conditions in developed countries. As Bangladesh is a densely populated developing country, 20.5% of its total population lives in poverty [4]. Rice is our staple food and has been cultivated in this country since ancient times. It accounts for about 92% of all food grain yield in the country and approximately 80% of agricultural land and Bangladesh is the fourth highest rice producer in the world [5].

Bangladesh is one of the countries which is most susceptible to climate variation. The most reasons for its susceptibility are owing to (i) its area within the tropics, (ii) the effects of its floodplains, (iii) it has low elevation from ocean level, and (iv) its populace density is very high. Though, it has also inadequate technological capability and adaptive capacities because of its poor economic condition [6]. The adverse impact of climate events such as cyclones, floods, and drought happen more or less every year and sometimes occurs more than two or three times a year, the crop agricultural sector affecting extremely, especially rice production [7]. Most of the world's growing population is taken rice as a main crop to feed [8]. Rice is consumed daily by around 3 billion people which is one of the utmost common staple foods for human beings, it has more significant for feeding people than any other crop [9]. Bangladesh's rice yield is significant because it is the favorite and staple food of the Bangladeshi people and most of the rural population is engaged in its agricultural activities.

Though, all these investigations show that agricultural activities in developing countries are highly vulnerable to climate change. Bangladesh is a highly sensitive country to climate change, but there are few factual studies on the influence of climate change on the country's important food crops [10]. Therefore, the main objective of this study is to estimate the influence of climate factors on Aman rice yield in Bangladesh. To identify the climatic factors which are expected to affect Aman rice production utilizing national-level time series data over the span from 1972 to 2019.

Literature Review

In current years, a growing body of literature observes the effects of climate change on agricultural production. The scientific community has long claimed that changes in climatic variables such as temperature and precipitation have significant effects on crop yields. Due to

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the share of Bangladesh's agricultural sector, the study of climate change impacts on Bangladesh's agriculture has recently received a lot of attention.

Ahmed et al. [11] considered key research questions on climate change and the environmental vulnerability of two coastal villages in Bangladesh. The study found that climate change and fragility are leading to reduced crop yields, salinity intrusion, rising sea levels, and warmer temperatures, with significant negative impacts on public health. The findings just show that climate change will have a negative effect on agriculture and the environment.

Hossein et al. [12] conducted a study showing the economic impact of climate change on yield agriculture in Bangladesh. The Ricardo model shows the relationship between net crop income and long-term climate variables. This study shows that increased rainfall and moderate temperatures increase crop net income. The results of this study show only positive economic effects from climate change, and no negative impacts have been identified.

Maniruzzaman et al. [13] described a study aimed at showing the impact of extreme temperatures on agricultural production, increasing global warming, and seasonally increasing rice yields in Bangladesh. This paper shows that moderate temperatures have a substantial negative impact on rice yield reduction. The results of the study show only the negative and positive impacts of climate change on agricultural productivity in three different periods and are not numerical.

Richard et al. [14] wrote a review article showing the impact of global climate change on crop yields, livestock, and the economies of the United States and Latin America. The results of the study assume that the economic impact on U.S. agriculture is somewhat positive, resulting in reduced food production, economic losses, enormous costs, rising temperatures, and a doubling of carbon dioxide (CO_2) over the next century and need to estimate the degree of global warming for livelihood policies.

Nevertheless, few studies have been conducted in Bangladesh investigating patterns and trends of precipitation, temperature, heat budget, solar radiation, relative humidity, energy budget, and meteorological applications to rice production in various ecosystems. However, previous studies in Bangladesh reveal that few studies have focused on the relationship between climate factors and crop production.

2. MATERIALS AND METHODS

2.1 Data description

National production data for the major food crop Ammann rice from 1972 to 2019 are compiled from several versions of the Bangladesh Agriculture Sector Statistical Yearbook. Production data is recorded for each year, such as 1971-1972 and 1972-1973, and the statistical data for the current year has been converted to annual data. For instance, 1971-1972 was measured as 1972. Collective level monthly data on climatic events for all (35) weather stations are obtained from the Bangladesh Meteorological Department (BMD) [15], for the same period which

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covers the entire country are also collected from the Department of Agricultural Extension [16], the World Development Indicator [17], and the World Bank [18].

2.2 Unit Root

The unit root is a distinct case of the random walk model which is one kind of non-stationary series. Amplified Dickey-Fuller (ADF) and Phillips-Perron (PP) tests are employed in order to detect the problem of the unit root. If a variable data converts stationary at level, then it is said to be combined of order zero I (0) whereas I (1) denotes that the series convert stationary after its first difference [19]. We apply ADF and PP tests on series at level (without differencing).

ADF test is applied by the following Equations:

$$\Delta Y_t = \beta_1 + \beta_2 t + \delta Y_{t-1} + \sum_{i=1}^{p} \alpha_i \Delta Y_{t-i} + u_t \tag{1}$$

Where β is the intercept (constant value), β_2 is the coefficient of time series t, α, and δ are the parameter where, γ = p-1, Δ Y is the first variance of Y series, p is the number of insulated first differenced term, and u_t is the error term.

Phillips Perron (PP) test equation

$$\Delta Y_t = \alpha + \beta t + \gamma \Delta Y_{t-1} + \varepsilon_t \tag{2}$$

where, α = constant value
β = coefficient of time series t
γ = parameter, and
ε = error term

2.3 Model specification

In this study, it was considered seven independent variables include maximum and minimum temperature, humidity, rainfall, labor, fertilizer, and irrigation. The source of VECM is the Granger Depiction Theorem [20] which presented that if two variables are cointegrated, at that time there happens a uni-directional or bi-directional Granger interconnection between them an error correction model (ECM) association the long run connection with the short-run dynamics of the model. The Vector Error Correction Model (VECM) is applied to explore the run-short dynamics, long-run causality, and short-run to long-run dynamic modification of a system of cointegrated variables.

For the case of our 8 variables, the VECM is specified as:

$$\Delta LYIELD_t = \alpha_0 + \alpha_1 \; ECT_{t-1} + \sum_{i=1}^{n} \beta_1 \, \Delta LYIELD_{t\ -1} + \sum_{i=1}^{n} \delta_1 \;\; \Delta LMAXT_{t-1} + \sum_{i=1}^{n} \lambda_1 \; \Delta LMINIT_{t-1} + \sum_{i=1}^{n} \sigma_1 \, \Delta LRAIN_{t-1} + \sum_{i=1}^{n} \mu_1 \, \Delta LHUMI_{t-1} + \sum_{i=1}^{n} \pi_1 + \sum_{i=1}^{n} \varphi_1 \; \Delta LLABOR_{t-1} + \sum_{i=1}^{n} \eta_1 \, \Delta LFERTI_{t-1+} \sum_{i=1}^{n} \kappa_1 \, \Delta LIRRI_{t-1} + + \varepsilon_t \tag{3}$$

$$ECTt_{-1} = LYIELDt_{-1} - \gamma_0 - \gamma_1 LMAXT_{t-1} - \gamma_2 LMINIT_{t-1} - \gamma_3 LRAIN_{t-1} - \gamma_4 LHUMI_{t-1} - \gamma_5 LLABOR_{t-1} - \gamma_6 LFERTI_{t-1} - \gamma_7 LIRRI_{t-1} \quad (4)$$

The error correction term (ECT) re-counts to the fact that the last retro deviation from long-run equilibrium influences the short-run dynamics of the reliant-on variable. Consequently, the coefficient of ECT, α_1 is the speed of adjustment, for the reason that it calculates the speed at which yield returns to the equilibrium after a change in explanatory variables. The above-mentioned equation is error correction which indicates the changes in the variables, and α_1 is the adjustment parameter. Besides, in the equation, e is the base of the natural logarithm, u_t is the error term/random residual/stochastic disturbance term, β_0 is the intercept/slope coefficient, β_1 to β_{10} is the coefficient parameters to be assessed, and t is the time period (i.e., year).

3. RESULTS AND DISCUSSION

In this section, we investigate the data collected with the aim of defining the influence of climate factors on Aman rice yield involvement to the gross domestic product (GDP) of Bangladesh's economy. Climate factors accredited variables in temperature, long-term rainfall events, and humidity. The time series belongings of the data are applied in the investigation which is examined. Subsequently, the investigation of the influence of climate factors on the Aman rice yield Vector Error Correction Model (ECM) is conducted. Earlier running the Vector Error Correction Model, we run pre-estimation tests such as unit root and cointegration tests. To determine the stationarity of each variable, the unit root test is applied and the co-integration test is applied for determining the presence of long-run relationships among such variables.

3.1 Descriptive statistics

The descriptive statistics of the log value of the variables in the model which presented in Table 1. The result reveals that the maximum and minimum values of Aman LYIELD are 6.92 and 5.98 with 0.26 standard deviations. The largest mean value of irrigation is 8.17 and a standard deviation of about 1.35, the lowest mean value of labor is 2.68 with a standard deviation is 0.05. It can be exhibited that LYIELD, LMAXT, and LMINIT variables show positive Skewness, while LRAIN, LHUMIDITY, LLABOR, LFERTI, and LIRRI are negatively skewed. The excess kurtosis (kurtosis-3) of average humidity and land is greater than zero (positive) which denotes that this distribution is leptokurtic (peaked curve).

Table 1. Descriptive statistics of the data series for the period of 1972-2019

Measure	**LYIELD**	**LMAXT**	**LMINIT**	**LRAIN**	**LHUMI**	**LLABOR**	**LFERTI**	**LIRRI**
Mean	6.50	3.41	3.11	7.33	4.41	2.68	3.86	8.17
Median	6.48	3.41	3.11	7.34	4.42	2.69	4.04	8.68
Maximum	6.92	3.44	3.15	7.59	4.43	2.80	4.91	9.95

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Minimum	5.98	3.39	3.08	6.93	4.37	2.58	2.29	5.51
Std. Dev.	0.262	0.013	0.015	0.152	0.014	0.059	0.699	1.350
Skewness	0.01	0.44	0.36	-0.29	-1.23	-0.04	-0.41	-0.69
Kurtosis	1.86	2.70	2.89	2.69	4.13	2.05	2.23	2.26

3.2 Stationarity and Unit Root Test

The unit root examination is very significant to define the order of addition of the variables and avoiding the existence of spurious regression. To find the being of a unit root individually of the time series, the Augmented Dickey-Fuller (ADF) check is employed. The null hypothesis in the ADF test is the data series are non-stationary (unit root) against the alternate hypothesis of the fixed process. The ADF test result of both with and without trends is indicated in Table 2. The variables at the level are non-stationary and the first difference the variables are stationary. Consequently, the results of ADF and PP unit-root tests are observed to be non-stationary at a level while, after the first difference all the variables are stationary in the model.

Table 2. Augmented Dickey-Fuller (ADF) & Phillips-Perron (PP) Unit Root Test of variables

Variable	**Augmented Dickey-Fuller (ADF)**		**Phillips-Perron (PP)**	
	At level	**At first difference**	**At level**	**At first difference**
LAMAN	-2.925169	-1.948140**	-2.925169	-3.510740***
LMAXT	-3.508508**	-3.510740***	-1.947975	-1.948140***
LMINIT	-1.948313	-1.948313***	-1.947975	-3.510740***
LRAIN	-1.948140	-1.948140***	-1.947975	-3.510740***
LHUMI	-1.948313	-3.515523***	-1.947975	-1.948140***
LLABOR	-1.947975	-1.948140***	-3.508508	-1.948313***
LFERTI	-3.508508	-3.513075***	-3.508508	-2.926622***
LIRRI	-3.508508	-1.948140***	-2.925169	-2.926622***

Note: MacKinnon's [31] (1996) one-sided p-values (at 1%, 5% & 10% level is -3.605, -2.936& -2.606 respectively) are utilized (Source: Authors' own assessment based on BBS, BMD, and DAE)

3.3 Optimal Lag Length Selection Criteria for the Model

The next step after unit root testing is to determine the optimal delay for the VECM model. The optimal lag is determined using her VAR selection criteria of lag order. Optimal lags are important for validating cointegration between variables. Table 3 shows the criteria for choosing VAR lags. The Final Prediction Error (FPE) and the Hanan Quinn Information

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Criterion (HQ) selected two lags, indicating that two lags apply to the current multivariate model for empirical analysis.

Table 3. VAR Lag order selection measures for Aman rice yield model

Endogenous variables: LYIELD LMAXT LMINIT LRAIN LHUMI LLABOR LFERTI LIRRI						
Exogenous variables: C						
Lag	LogL	LR	FPE	AIC	SC	HQ
0	703.0559	NA	2.37e-27	-30.08939	-29.65210	-29.92558
1	990.3580	424.7074	1.97e-30	-37.31991	-32.07251*	-35.35420*
2	1141.529	151.1706*	1.37e-30*	-38.63168*	-28.57415	-34.86407

Note: * designates lag order selected by the measure

3.4 Result of co-integration test

We conduct the co-integration test in order to identify the presence of a long-term association amongst variables comprised in the model. Johansen test for co-integration was employed for this study. Subsequently, all the variables are non-stationary at the level and stationary at the first difference. The Johansen test denotes that the null hypothesis of a long-run association between the independent and dependent variables is tested against the alternative hypothesis. So, the null hypothesis is rejected and it would be decided that there exists a long-run association among the variables.

Table 4 Unrestricted cointegration rank test (Trace) for Aman rice yield model

Hypothesized No. of CE(s)	**Eigenvalue**	**Trace Statistic**	**Critical Value (at 0.05 level)**	**Probability**
None *	0.893686	407.9144	285.1425	0.0000
At most 1 *	0.798758	304.8121	239.2354	0.0000
At most 2 *	0.690322	231.0628	197.3709	0.0003
At most 3 *	0.630350	177.1407	159.5297	0.0038
At most 4	0.481024	94.96470	95.75366	0.0566
At most 5	0.444132	64.79342	69.81889	0.1179

Note: Trace test indicates 4 cointegrating eqn(s) at the 0.05 level

It is known that the Johansen test has two forms: (a) the trace test, and (b) the maximum eigenvalue test. We have taken the trace test. The result of the trace test (table 4) exhibits that the δ_{trace} value for r =0 is 407.9144 which surpasses its critical value of 285.1425 at a 5% level (p-value $0 < 0.05$). So, it can reject the null hypothesis of none cointegration equations at a 5% significance level. In the same way, the null hypothesis for $r \leq 1$ (at most 1 cointegration equation), $r \leq 2$ (at most 2 cointegration equations), and $r \leq 3$ (at most 3 cointegration equations) can be rejected. But $r \leq 4$, the δ_{trace} value is 94.96470 which is less than its critical value of 95.75366 at a 5% level (and also p-value $0.0566 > 0.05$) meaning that we cannot discard the null hypothesis of existing at most five cointegration equations.

3.5 Result of Vector Error Correction Model (VECM)

The existence of cointegration vectors between variables recommends a long-term association among the variables under consideration. To know the long-run and short-run connection between the variables, the vector error correction model (VECM) is designated. The output of the vector error correction model can be explained as follows:

$$ECT_{t-1} = 1.000000\ LYIELD_{t-1} + 11.483LMAXT_{t-1} - 10.773LMINIT_{t-1} + 0.0634LRAIN_{t-1} - 4.0602LHUMI_{t-1} + 0.6084LLABOR_{t-1} - 0.6551LFERTI_{t-1} - 0.0824\ LIRRI_{t-1} - 17.11129 \quad (5)$$

Where ECT Error Correction Term. The long-run equation can be formed as follows:

$$LYIELD_{t-1} = -11.483LMAXT_{t-1} + 10.773LMINIT_{t-1} - 0.0634LRAIN_{t-1} + 4.0602LHUMI_{t-1} - 0.6084LLABOR_{t-1} + 0.6551LFERTI_{t-1} + 0.0824\ LIRRI_{t-1} + 17.11129 \quad (6)$$

A one-unit increase in maximum temperature, rainfall, and labor leads to an 11.48-, 0.06-, and 0.60-unit reduction in Aman yield in Bangladesh respectively. Likewise, a one-unit increase in minimum temperature, humidity, irrigation, fertilizer, and fertilizer will enhance Aman yield by 10.77, 4.06, 0.65, and 0.082 units correspondingly.

3.6 VECM Coefficient with P-Value of the model

Johansen's co-integration test result exhibits that there exists a long-run association among variables. The error correction depiction of the VAR method is projected as the next step after the estimation of the long-run coefficients. The VECM indicates the long-run and short-run association between climate factors and Aman rice yield in Bangladesh.

In the first rows of Table 5, the error correction coefficient (ECTt-1) is adverse and statistically important at a 5% significant level. The coefficient of error correction should be negative and significant that how quickly a variable adjusts to equilibrium. The supplementary confirmation of the presence of a stable long-run association is highly significant in error correction terms. The ECT coefficient recommends that the speed of adjustment of any short-run disequilibrium to the long-run equilibrium is 17.98 % every year. The coefficient of error correction term of yield is 0.179819. Meaning that about 17.98% of disequilibrium is corrected each year by the change in yield. The explanation is that the earlier time's deviation from long-run equilibrium is corrected in the present period with an adjustment speed of 17.98%.

Table 5 displayed that average yearly temperature has a strongly substantial reverse relationship with Aman rice yield in the long run. This means a 1% increase in mean yearly temperature would lead to a decrease in Aman rice yield by 2.45% in the long term. It can be said that a 1% increase in average minimum temperature would lead to enhancing in Aman rice production by 9.65%. The impact of average total rainfall is found to be negative and strongly statistically substantial. The coefficient indicates that a 1% increase in average total rainfall on an average will reduce Aman yield by 10.95% per acre. The coefficient of average humidity has positive and it has a statistically insignificant influence on Aman rice yield it is

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indicating that with a one-unit increase in average humidity Aman rice yield would rise by 0.403573 times.

Labor of Aman season has a negative and significant relationship with Aman rice yield at a 5% significance level. It also indicates that an increase in labor could have an adverse effect on Aman yield. The result denotes that a one percent increase in seasonal labor on average will decrease the production of Aman by 0.31% kg (kilogram) per acre. In addition, the significance of the agricultural labor coefficient marks the incompetence of the excessive labor force in the agricultural sector in Bangladesh. Bangladeshi farmers depend on old methods of cultivation and are not well-equipped with new technology. This result is reliable with the findings of Janjua et al. (2014) and Mahrous (2018). It can be justified by the law of diminishing marginal productivity (excess labor used on a fixed land may enhance first output only up to the mark and decline thereafter).

Table 5. VECM coefficient with P-Value of the model

Dependent Variable: D(LYIELD)					
Method: Least Squares (Gauss-Newton/Marquardt steps)					
		Coefficient	**Std. Error**	**t-Statistic**	**Prob.**
ECT	C(1)	0.179819	0.069084	2.602894	0.0137**
D(LYIELD(-1))	C(2)	-0.379053	0.186479	-2.032679	0.0502**
D(LMAXT(-1))	C(3)	-2.454220	0.749712	-3.273552	0.0025***
D(LMINIT(-1))	C(4)	0.965533	0.805242	1.199059	0.2390
D(LRAIN(-1))	C(5)	-0.109572	0.049380	-2.218983	0.0335**
D(LHUMI(-1))	C(6)	0.403573	1.081855	0.373038	0.7115
D(LLABOR(-1))	C(8)	-0.314905	0.289635	-1.087249	0.0548**
D(LFERTI(-1))	C(10)	0.081391	0.066509	1.223761	0.2297
D(LIRRI(-1))	C(11)	0.043580	0.058366	0.746674	0.0505**
C	C(13)	0.012288	0.012306	0.998585	0.3253
R-squared		0.629877			
Adjusted R-squared		0.358923			
F-statistic		3.099527			
Prob(F-statistic)		0.004951			

The coefficient of Fertilizer consumption was positively associated with Aman yield and was statistically insignificant. From this result, it can deduce that a 1% increase in fertilizer consumption on average may cause to enhance the yield of Aman by 0.08% kg/acre. Fertilizer has a dual effect. At first, they increase the land fertility and secondly enhance the growth of plants. In the long-run fertilizers would raise the land fertility causing to increase the agricultural production. The empirical results reveal that irrigation is positively associated with Aman yield and highly significant at a 5% level which implies that a one percent enhancement in irrigation would lead to a 0.04% increase in Aman rice kg per acre in the short run.

Average temperature data were used to monitor temperature trends. They found that the average annual temperature has increased by 1.7 °C over the past 30 years. The average 10-

year increase was 0.64 °C. This indicates that temperatures are continuously rising crosswise the country. Mean annual temperatures continue to rise, leading to climate change and a deterioration in agricultural GDP. Thus, temperature fluctuation trends due to climate change had a negative impact on rice yields in Aman.

The p-value of R-square in the Aman rice yield model is 0.529877 which is a 52.98% variation in Aman yield that can be explained by explanatory variables jointly. The probability of Aman rice yield model, F-statistic is 0.004951 which is less than 0.05 (meaning that significant at 1% level) correspondingly. This means that expletory variables can jointly influence Aman rice yield. As a result, it can be summarized that the model has a very good fit.

3.7 Result of residual diagnostic test

It was performed diagnostic examinations in order to check the goodness of fit of the model. For this purpose, the normality test, autocorrelation or serial correlation test, and heteroskedasticity test are employed. Table 6 reveals that the p-value of Jarque–Bera is 0.347571 which is more than a 5% level of significance. Therefore, we cannot reject the null hypothesis which is that the residual is normally distributed. The p-vale Autocorrelation or serial correlation test and heteroskedasticity test cannot reject the null hypothesis meaning that there is no serial correlation or heteroskedasticity in the model. Consequently, the employ of the VECM is free from autocorrelation, normality, and heteroskedasticity problems in this study.

Table 6. Diagnostic test result

Jarque-Bera test	2.113
Probability (Jarque-Bera test)	0.347571
Breusch-Godfrey Serial Correlation LM Test (p-Value)	0.4739
Hetoroskedticity test	0.5245

Note: All the test of p-value is greater than 5% significant level

3.8 Granger causality test

We apply the Granger causality test that knows the causal direction among the variables. Granger causality test is applied to regulate the causal linkages amongst the main climate factors recognized variables (temperature and humidity) and Aman rice yield in Bangladesh. The null hypothesis of the causality test does not granger causality among climate factors variables and Aman rice yield.

Table 7 illustrates that in the case of MAXT↔YIELD, we can discard the null hypothesis that maximum temperature does not Granger Cause change in YIELD as the p-value is less than 5% (0.047). However, the inverse null hypothesis that YIELD does not Granger causality change in maximum temperature is rejected as the p-value is less than 0.05 < (0.015).

Table 7. Result of VEC Granger causality test

Null Hypothesis:	Chi-2	P-value	Decision
D(LMAXT)does not Granger Cause D(LYIELD)	3.922353	0.0476**	Rejected at 5%
D(LYIELD) does not Granger Cause D(LMAXT)	5.866111	0.0154**	Rejected at 5%
D(LHUMI) does not Granger Cause D(LYIELD)	6.232704	0.0125**	Rejected at 5%
D(LYIELD) does not Granger Cause D(LHUMI)	2.809599	0.0937*	Rejected at 10%

Note: ***, **, and * denote the significance level at 1%, 5%, and 10% respectively.

This result reveals that there occurs a bidirectional short-run Granger causality running from maximum temperature to Aman YIELD. In the same way, average humidity has a bidirectional short-run Granger causality running from average humidity to Aman YIELD.

4. CONCLUSION

This study investigates the influence of climate factors on Aman rice harvest in Bangladesh using time series data for the period 1972-2019 applying the Co-integration and Vector Error Correction Model which are used to satisfy this objective. The overall results of the vector error correction model denote that both in the long run and short run, climate factors have robust effects on Aman rice production in Bangladesh. For the Aman rice, maximum temperature and rainfall are found to be negative and statistically significant. Average minimum temperature and humidity are seen as positively distressing Aman rice production. Conversely, the average maximum temperature has an adverse effect on Aman rice yield, as we know Aman rice requires accompanying irrigation during plantation depending on the weather. The R^2 and F-values of the models have been found statistically substantial and the results of overall goodness of fit are consistent with the results of some relevant studies. When the temperature goes beyond the upper limit or falls below the range or humidity crossed the upper limit then crop production changes drastically. In addition, excess rainfall can cause inundation and flooding, which also damages crop yield. Given that rice yields are highly vulnerable to climatic factors in Bangladesh, different adaptation strategies need to be adopted to offset the adverse impacts of climate change. Climate factors in Bangladesh are of great concern as they adversely affect agriculture, an important sector of the country. Therefore, relevant authorities should take appropriate measures to address climatic factors affecting Aman rice production in order to ensure food security for the growing population through sustainable agricultural growth. Thus, future research in this area will focus on region-specific data analysis to capture regional differences in climate change and to obtain a more inclusive scenario of climate change and its impact on rice yields in Bangladesh.

Journal of Environmental Impact and Management Policy
ISSN: 2799-113X
Vol : 03 , No. 03 , April-May 2023
http://journal.hmjournals.com/index.php/JEIMP
DOI: https://doi.org/10.55529/jeimp.33.23.35

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