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EXPLORING THE CLIMATE CHANGE IMPACT ON MAJOR FOOD CROPS OF BANGLADESH - A TIME SERIES ANALYSIS

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ABSTRACT

This paper tries to explore the dynamic relationship between the yield of major crops in Bangladesh (aus, amas, boro, wheat and potato) and climate change (average rainfall, average maximum temperature and average minimum temperature). Graphical visualization shows that, there is increasing trend in average annual minimum temperature and average annual minimum rainfall, while there is decreasing trend of average annual maximum temperature. We applied autoregressive distributive lag (ARDL) cointegration method in order to study the dynamic relationship. The paper finds long run dynamic link between yield of aus rice and average rainfall and average minimum temperature. We have found short run dynamic relationship for yield of aman rice, boro rice and potato. However, we do not find any dynamic relationship has been found for yield of wheat with the variables of climate change. After estimation the dynamic relationship, we ensure there is no serial correlation among residuals using Breusch-Godfrey test and models are normally distributed using histogram and Jarque-Bera test. Finally, we ensure the stability of the models applying CUSUM test.

Contribution/Originality: This study contributes to the existing literatures of climate change and its impact on yield of major food crops in Bangladesh with more recent and extended dataset and more logical statistical analysis based on global literatures. This is our original work.

1. INTRODUCTION

World's climate is changing. It is experiencing era of global warming (IPCC). The average temperature of the world is rising and 2016 is the warmest year in last 70 year (NASA). Changing climate has impact in many aspects, environment, agriculture, health, natural resources, eco system and most commonly weather. Nonetheless, climate change is the threat on global food security (Easterling, 2007). Study shown that, global top four produced food's (rice, maize, wheat, soybean) yield is affected through climate change since 1980 (Lobell, Wolfram, & Justin, 2011). Climate change affects Global food security in four dimensions, availability, stability, utilization and security (Schmidhuber & Tubiello, 2007).

There are many empirical evidences of relationship between different crop production and different variables of climate. They are mainly considering change in temperature and rainfall. Considering temperature change, Kalra et al. (2008) studies the consequence of increasing temperature in Northwest India on yield of wheat, mustard, barley and chickpea. Schlenker and Roberts (2009) shows the impact of US crops yield due to temperature. There are some other evidences, which consider rainfall is the one of the determinant of crops yield.

There are few studies on Bangladesh about rice yield and climate change. Sarker, Khorshed, and Jeff (2012) consider three variables of climate change; maximum temperature, minimum temperature and rainfall. They use ordinary least square (OLS) method. Tesso, Emana, and Ketema (2012) uses Johansen cointegration approach to assess the impact of climate change on crops yield. In their paper, considering cointegration approach, they tried to observe long run relationship of climate change with yield of most three important food; rice wheat and potato of Bangladesh. To estimates three variables of climate change; maximum temperature, minimum temperature and rainfall are taken under concern (Lobell & Field, 2007). The later parts are background of the study, reviewing the existing literature, methodology, result and at the end the paper is concluded.

2. TREND OF CLIMATE CHANGE

The mean temperature in Bangladesh varies from 7.2 degree Celsius to 12.8 degree Celsius throughout the winter and 23.9 degree Celsius to 31.1 degree Celsius throughout the summer.

Trend of annual average temperature (degree celcius) from 1988-2015

Trend of annual average rainfall (mm) from 1988-2015

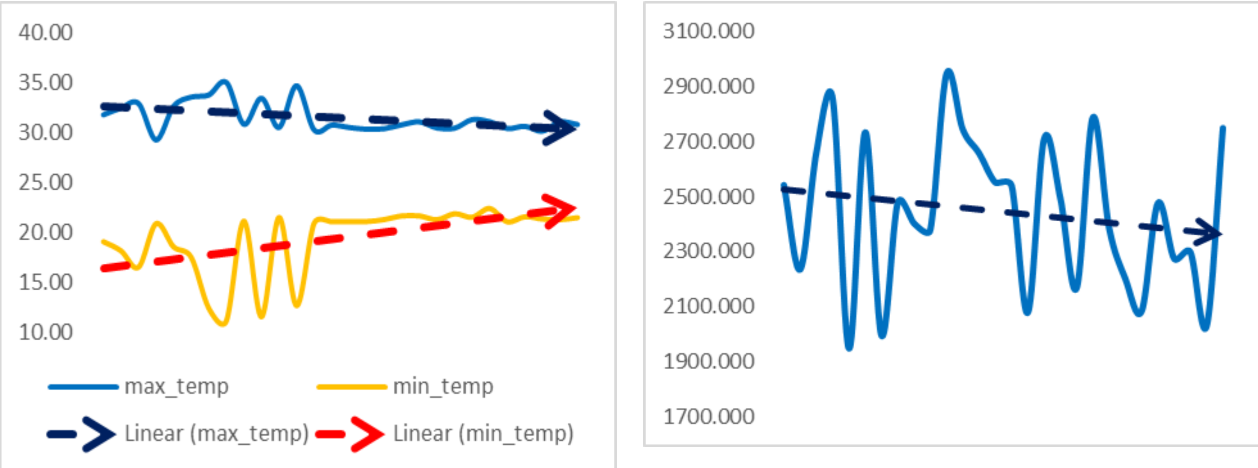


Figure-1. Trend of climate change.

Source: BBS statistical yearbook.

Moreover, there is an increase in trend of the average minimum temperature and a decrease trend of the maximum temperature over the period 1988-2015 Figure 1 In winter and pre monsoon season minimum temperature is increasing rapidly than the maximum temperature. But maximum temperature of monsoon and post monsoon season are expanding faster. The mean temperature is increased by 0.64 degree Celsius in last 64 years (Van Scheltinga & CTHM Terwisscha, 2015).

Temperature has a notable impact on the productivity, growth duration and pattern of the rice crops. In every growth stage of rice production, it needs proper temperature for development. Deviation of temperature will affect the rice production. According to Bangladesh National Adaptation Program of Action 2000 a hike of 10C to 20C, in combination with lower solar radiation, causes sterility in rice spikelet, and excessive temperature was found to reduce yields of HYVs of Aus, Aman and Boro rice in all study locations and in all seasons in Bangladesh (Talukder, 2007). Higher temperature can deteriorate the grain quality. 10% increase in peak temperature can decrease the Aman rice production by 2.94, 53.06 and 17.28 tons in three growth stage Bangladesh (Islam, Baten, Hossain, & Islam, 2008).

Bangladesh receives plenty of rainfall, but it is not evenly distributed across region or season. In our country rainfall differs from 1400 mm in the west to more than 4400 mm in the east. The rainfall pattern has been changed over the years. Though the annual rainfall is increased by 6%-11% last 50 years (Shelley, Takahashi-Nosaka, Kano-Nakata, Haque, & Inukai, 2016).

In recent years annual rainfall has a decreasing trend with very narrow margin Figure 1. But during the monsoon there are back-to-back 8-10 rainy days in West and 30-40 day to Northeast (Ahmed & Kim, 2003).

Rainfall is one of the key factors that determine the agronomy of Bangladesh. Bangladesh is a flood prone country. On the other hand, drought is a frequent phenomenon in the Northwest region. Both are the result of rainfall. Heavy rainfall in monsoon of 2007 destroyed the 2.47 million of hectares of agricultural land. On the other hand, in 1994-1995 drought led to a reduction in rice and wheat yield by 3.5×10^6 MT (Rahman & Biswas, 1995). In addition, during the winter season less rainfall will decrease the moisture content in topsoil and it will lead to less recharging in ground water. It adversely affects the agricultural production of Bangladesh (Talukder, 2007).

3. LITERATURE REVIEW

There is extensive literature by many researchers about the dependency of agriculture on the climate. Most of literature is focused on the food sufficiency rather than the food security which is the emerging problem in our country.

Gregory, Ingram, and Brklacich (2005) linked the climate change with food system in several ways from food production to adjustments in market, prices of food and supply cycle framework. A study of Campbell et al. (2016) suggest that the climate change has far reaching impact on crop yield as well as livestock and fisheries. We are interested to assess the current scenario of climate change and food availability, accessibility, stability and utilization for reducing the risk to food supply from climate change in the context of Bangladesh.

Schmidhuber and Tubiello (2007) considered the notability of the different measurements and the comprehensive effect of climate alter on food supply will vary over districts and over time and will depend on the generally socio-economic status. This finding of the studies indicates that changes in climate will increase the dependency of food import of emergent nations. In this study, there is lack of empirical analysis and mainly dependent on theoretical analysis. So, we want to conduct a research to find an empirical relationship between climate change and food security.

Lobell and Field (2007) showed the measure of harvesting season temperature and precipitation spatial average based on the location of crops for the period 1961 to 2002. They took climate variables like temperature and rainfall and used distinct econometrics tools i.e. first difference time series, multiple linear regression and causality test. Climate is inversely related with wheat, maize and barley. They also found that warming temperature trends had significant effect on yield rather than precipitation. Schlenker and Roberts (2009) conducted a research pairing a group of state-level production for corn, soybeans and cotton with a weather dataset of United State for 1950 to 2005. They found that temperature up to 29° C for corn, 30° C for soybeans, and 32° C for cotton helped to increase but that temperatures above these thresholds are very deleterious. Precipitation for corn and soybeans has a statistically significant inverted-U shape but not statistically significant for cotton.

Climate change and agriculture is related in two way relationship for developing countries as they are dependent on agriculture mostly and they have lack of infrastructure for adaptation than developed country. Yohannes (2016) stated in his paper that agriculture in developing country affected due to direct dependency on climate. Actually they are interrelated, using fertilizer in agriculture affects climate through emission of greenhouse gases on the other hand widespread adaptation of mitigation and adaptation actions can be solutions climate change. De (2017) analyzed the impact of climate on the agricultural output using panel data of last six decades for ten zones of Assam. They have used various econometrics tools (panel Co-integration and VECM) and found the long run correlation among CPI, Khariff/Rabi maximum temperature, Fertilizer, GCA and annual rainfall. It also exhibits that negative relationship of Khariff/Rabi maximum temperature on agriculture productivity and positive relationship with rainfall.

Tesso et al. (2012) analyzed the climate fluctuation and its impact on food production of New Shewa area in Ethiopia over three decades. For estimating the impact of climate variability on food production they used VAR and VECM and showed that co integration technology, manure usage, Meher rain and temperature have significant impact and fertilizer and Belg rain has less significant impact on food production. They also used Johannes' approach to show the dependency of dependent variable on the independent variables.

Various strategy can be taken for the susceptibility of Bangladesh's agriculture due to the climate change. Participating in the international negotiations process for realization of the objectives under the Bali Action Plan (2007) and planning itself at home for fundamental domestic action-these two approaches will help Bangladesh to deal with the climate issues (Sikder & Xiaoying, 2014). Islam, Tasnuva, Sultana, and Rumana (2014) carried out their research based on local perception of climate change and food production in Khulna district for the year 2013. They observed that high temperature, rainfall and disaster and low food production affect the food supply in the study area. According to their study that the higher knowledge vulnerability is presented for who have US $ 340-390 and US $280-$330 per capita income. They also divided the people who have US $100- $ 270 per capita income into 3 groups and from their perception climate change and food production are negatively correlated. So we can say perception from different people can give us different results.

Numerous studies have investigated the climate change-food production nexus in Bangladesh. Sarker et al. (2012) scrutinized that climate variable have had cogent effects on the rice yield for the period of 1972-2009 years in Bangladesh using the ADF test, OLS and QR models. Though these effects varied among three types of rice. Highest & lowest temperature and rainfall are the climate variables. Highest temperature has impacted positively on Aus and Aman rice but negatively on Boro rice. Opposite is true for the minimum temperature. Finally rainfall has statistically significant effect on Aus and Aman rice. Mamun, Ghosh, and Islam (2015) examined and found significant effect of climate variables on production of rice using time series data from 1972-2010 for Rajshahi. Three climate variables: - Temperature, Humidity and Rainfall have significant effect on three different rice varieties (Aus, Aman, Boro). In their empirical analysis, they found that temperature has inverse correlation with Boro and rainfall has negative correlation with Aman and Aus. About 23%,91% and 89% variance of Aus,Amna and Boro respectively can be explained by the climate variables. Chowdhury and Mohammad (2015) observed the relationship of climate vulnerability and yield of rice crops. They used OLS method for the period 1972-2014 on the basis of country level and the outcomes of the study shows that all four climate variables have substantial effects on the yields of Aus, Aman and Boro rice. In their study they have evaluated the relationship of climate change and yield of rice crops but every year yield of rice is increasing whether climate change or not. Basak (2009) analyzed the effects of climate change on production of Boro rice using DSSAT (Decision Support System for Agro-technology Transfer), for six major rice-growing locales in Bangladesh in 2008. The production varied place to place because of climate condition and hydrological properties of the region. Rajhshahi has the lowest production due to the inconsistency of day and night temperature in winter. Because of 2 degree increase in temperature Boro production can decline by 2.6 % to 13.5%. Minimum temperature affect the Boro production as well. So, from this study we can't find the accurate dependency of food production on climate change. So, we will conduct this research from another dimension that is growth of yield of crops.

Many researchers have found that fluctuation of climate has most devastating effect on the Coastal area of Bangladesh. Ismail (2016) and Dasgupta, Hossain, Huq, and Wheeler (2014) both proclaimed in their study that because of rise in sea levels and tidal flooding, soil salinity has been rapidly expanded and it will affect the agriculture production. Scientists predict that sea levels could rise 50 to 130cm by 2100 which is a threat for coastal population as two third of Bangladesh is less than 5 meters above sea levels. Hossain and Noman (2018) examined the impact of climate factor in agriculture transformation and food security in Northern Bangladesh. They have shown how rice cultivation land has been transformed into mango and guava orchard because of climate change and economic factor. As production of our major crops is decreasing it is a threat for our food security.

On the other hand, Kabir, Ahmed, and Khan (2016) investigated and found that climate change doesn't have significant effect on food availability and food security. Which is contradictory with other literature. They worked on the Patuakhali district and demonstrated recent climate change scenarios for Kalapara, analyzed the relationship between climate change scenarios and adaptation of relevant measures and strategies by the cultivators which adequately helps in eliminating the risks of climate change and progresses vocations. As different school of thought have different opinion so we will conduct our research to find out the relationship of climate change with growth of yield of food crops (rice, wheat and potato). To overcome the above mentioned shortcomings of the literature, we will analyze the relation between climate change and food production system from another dimension.

4. METHODOLOGY

We try to identify the long relationship between three major food crops (Rice, Wheat, Potato) and three important indicators of climate (Rainfall, Maximum Temperature, Minimum Temperature).

4.1. Data

As our research area is Bangladesh, annual data of from 1987 to 2015 are collected from Bangladesh Bureau of Statistics (BBS).

4.2. Model Specification

The selected crops sowing to harvesting time are (Yearbook of Agricultural Statistics-2017).

- Aus – March to August.
- Aman – June to November.
- Boro – December to May.
- Wheat – November to April.
- Potato – September to March.

So, models are

$$aus_t = \alpha + \beta_1 rainfall_t + \beta_2 min\_temp_t + \beta_3 max\_temp_t + u_t$$

$$aman_t = \gamma + \beta_1 rainfall_t + \beta_2 min\_temp_t + \beta_3 max\_temp_t + u_t$$

$$boro_t = \emptyset + \beta_1 rainfall_t + \beta_2 min\_temp_t + \beta_3 max\_temp_t + u_t$$

$$wheat_t = \delta + \beta_1 rainfall_t + \beta_2 min\_temp_t + \beta_3 max\_temp_t + u_t$$

$$potato_t = \omega + \beta_1 rainfall_t + \beta_2 min\_temp_t + \beta_3 max\_temp_t + u_{t-1}$$

Where,

$\beta = coefficient$

$subscript\ t = 1,2, \ldots\ldots T\ (time\ period)$

$aus_t = yield\ of\ aus\ at\ t\ period$

$aman_t = yield\ of\ aman\ at\ t\ period$

$boro_t = yield\ of\ boro\ at\ t\ period$

$wheat_t = yieald\ of\ wheat\ at\ t\ period$

$potato_t = yieald\ of\ potato\ at\ t\ period$

$rainfall_t = annual\ average\ rainfall\ at\ time\ t$

$\max\_temp_t = annual\ average\ maximum\ temperature\ at\ time\ t$

$\min\_temp_t = annual\ average\ minimum\ temperature\ at\ time\ t$

$\alpha, \gamma, \emptyset, \delta\ and\ \omega\ are\ constant$

We use Eviews10 and Excel 2016 software.

4.3. Unit Root Test

To examine data are stationary or not we checked the unit root of data. Non-stationary contains unit root. To check the unit root, we apply Augmented Dickey-Fuller (ADF) and Phillips Perron (PP) ADF model with intercept and no trend:

$$\Delta y_t = \alpha + \gamma y_{t-1} + \sum_{s=1}^{m} a_s \Delta y_{t-s} + v_t$$

PP model with intercept and no trend –

$$y_t = c + \delta t + a y_{t-1} + e(t)$$

Where hypotheses are,

$H_0: \rho = 1\ (varbale\ has\ a\ unit\ root)$

$H_1: \rho < 1\ (variable\ has\ no\ unit\ root)$

4.4. Co-Integration Test

To examine cointegration we apply Autoregressive Distributed Lag (ARDL) method. ARDL incorporate both lag value of regressand and regressors (Greene, 2008). It is a cointegration method when variables are stationary at both; level and first difference (Pesaran, Shin, & Smith, 2001). To estimates the models, we use maximum lag 1 for both regresands and regressor as we take only 28 years data. Moreover, we take constant as trend specification. We consider automatic selection process in order to select model.

After performing ARDL, we check the significance of the estimated model by Bound test (Pesaran et al., 2001). If the test statistics of bound test (F statistics and t statistics) are significant, model will be considered as long run cointegrated. If the test statistics are insignificant, model will be considered as not long run cointegrated. If model is long run cointegrated, we estimate error correction model (ECM), where we check the speed of adjustment of both short run and long run to on another. Before checking the ECM, we identify lag length criteria following Schwarz information criterion (SIC). To do so, we adopt vector autoregressive (VAR) method. Later, we identify the residual series for the long run cointegrated model and ECM model. We use ordinary least square (OLS) method.

For not significant long run cointegration, short run ARDL is estimated using OLS method.

4.5. Diagnostic Test

We check the diagnostic of residuals of estimated model. To study the normality, we observe the histogram and apply Jarque-Bera test. Moreover, to examines the autocorrelation we apply Breusch-Godfrey Serial Correlation LM test. In case of ECM and short run ARDL model we also check the stability of the model using Cusum test.

5. RESULT

5.1. Unit Root Test

Addressing level of significance 5%, yield of Aman, Aus, Boro, Wheat and Potato are stationary at first difference, which means integrated order 1 (I (1)), Rainfall and Min_temp are stationary at level and Max_temp is stationary at first difference Table 1

Table-1. Unit root test result (ADF & PP).

Variables	Level				First Difference			
	t stat (ADF)	p value (ADF)	t stat (PP)	P value (PP)	t stat (ADF)	p value (ADF)	t stat (PP)	p value (PP)
aman	-0.784029	0.8076	-0.324044	0.9087	-5.358397	0.0002	-6.893000	0.0000
aus	0.773477	0.9915	-1.841660	0.3534	-9.452017	0.0000	-10.49737	0.0000
boro	-0.249541	0.9198	-0.464847	0.8835	-8.625585	0.0000	-8.625585	0.0000
wheat	-1.558606	0.4893	-1.459260	0.5384	-5.681142	0.0001	-6.140013	0.0000
potato	0.495467	0.9830	0.447217	0.9813	-9.352221	0.0000	-13.16608	0.0000
rainfall	-6.156032	0.0000	-6.142354	0.0000	-6.716668	0.0000	-26.81666	0.0001
max_temp	-2.000072	0.2850	-4.445422	0.0016	-11.11705	0.0000	-15.54201	0.0000
min_temp	-1.521472	0.5072	-4.260515	0.0026	-12.71418	0.0000	-15.35659	0.0000

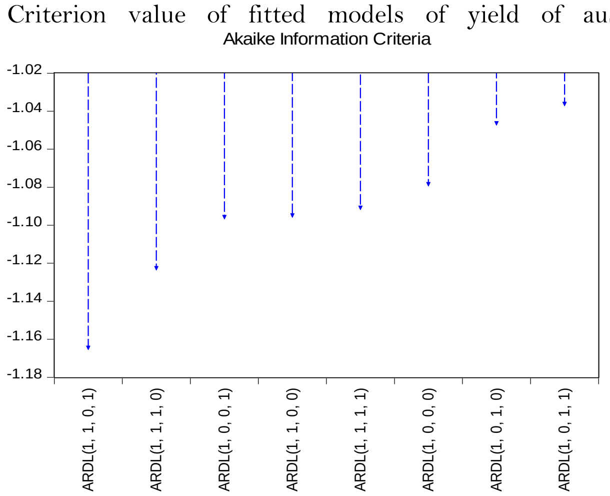
5.2. Best Fitted ARDL Model Selection

By evaluation 8 models, the best fitted ARDL model for yield of Aus rice is (1,1,0,1), which provides the lowest criterion value and ranks highest Figure 2. This means, 1 lag for Aus, 1 lag for Rainfall no lags for Max_temp and 1 lag for Min_temp

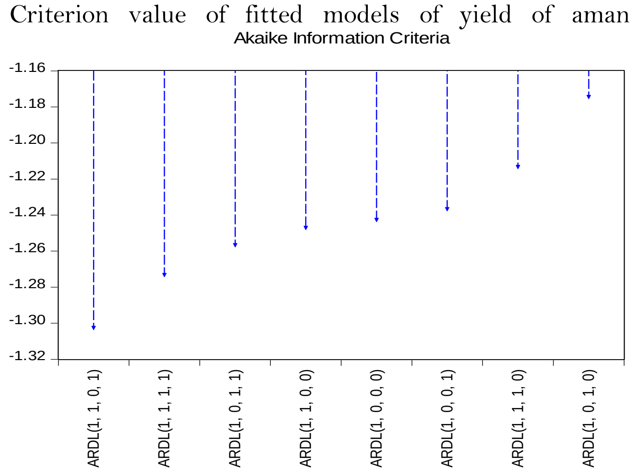
One same basis (1,1,0,1) is the best fitted model for Aman and (1,1,1,1) is the best fitted model for Boro rice. Meanwhile, (1,0,0,0) is the best fitted model for both yield of Wheat and Potato.

Best fitted ARDL model according to Akaike Information Criterion (AIC)

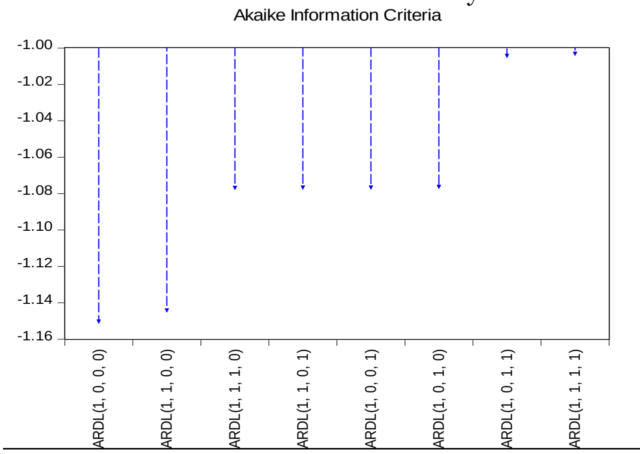
Criterion value of fitted models of yield of aus



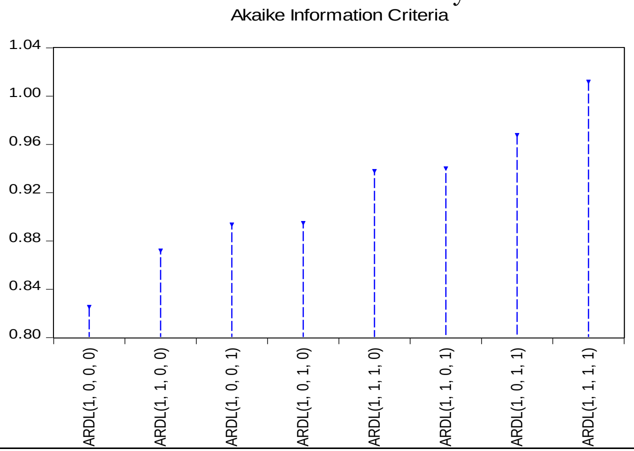
Criterion value of fitted models of yield of aman



Criterion value of fitted models of yield of boro



Criterion value of fitted models of yield of wheat



Criterion value of fitted models of yield of potato

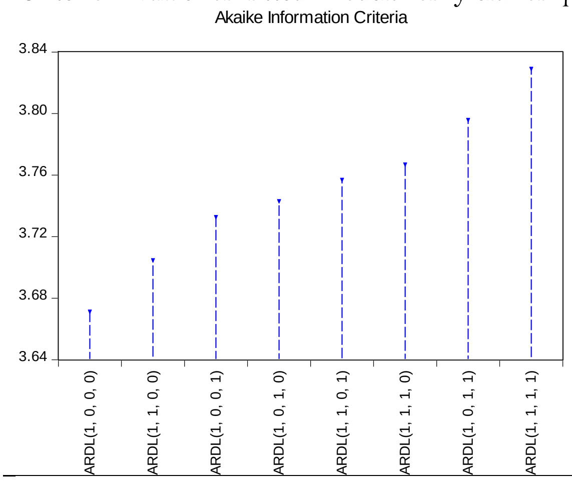


Figure-2. Best fitted model for dependent variables.

5.3. Aus Rice

So, the estimated equation for yield of Aus –

$$aus_t = 0.999812 + 0.667491 aus_{t-1} - 0.000152 rainfall_t - 0.000174 rainfall_{t-1} - 0.008989 \max\_temp_t + 0.016774 \min\_temp_t + 0.014939 \min\_temp_{t-1} + \varepsilon_t$$

Bound test-

Considering the test statistics value (F statistics and t statistics) at 10% level of significant, the null hypothesis is rejected at I(1), which means, long run cointegration relationship exists Table 2.

Considering the significance of coefficients, the estimated model-

$$aus_t = 0.667491\, aus_{t-1} - 0.000174 rainfall_{t-1} + 0.014939 \min\_temp_{t-1} + \varepsilon_t$$

So, in the long run, the yield of Aus rice will increase by .66749 unit in current year if the yield of Aus rice increases by .1 unit in previous year, average annual Rainfall decreases by 1 unit in previous year causes increase the yield of Aus rice by .000174 unit and average annual Minimum Temperature increases by 1 unit in previous year causes .014939 unit increase in the yield of Aus rice in current year.

Estimation of ECM- The lag length is identified and the estimated model is Table 2.

$$\Delta aus_t = 0.053351 + -0.000063\, \Delta rainfall_{t-1} + 0.534851 u_{t-1}$$

The coefficient of ECM indicates, correction of a year lead error, in the current year.

Table-2. Estimation for dependent variable Aus.

Long run ARDL model for yield of Aus rice

Variable	Coefficient	t-stat	Probability
Aus(-1)	0.667491	7.665745	0.0000
Rainfall	-0.000152	-1.608862	0.1233
Rainfall(-1)	-0.000174	-1.752608	0.0950
Max_Temp	-0.008989	-0.220259	0.8279
Min_Temp	0.016774	0.961372	0.3478
Min_Temp(-1)	0.014939	1.757831	0.0941
C	0.999812	0.564839	0.5785
R-squared	0.919113		
F-statistic	37.87655		0.000000
DW statistics	1.286575		

Bound test result for ARDL model of yield of Aus rice

	Test statistics	Significant value (10%) I(0)	Significant value (10%) I(1)
F-Bound test	4.080808	2.72	3.77
t-Bound test	-3.818677	-2.57	-3.46

Lag length identification of yield of Aus rice

Lag	SIC
0	0.829026
1	-1.578743*
2	-1.565932
3	-1.570548
4	-1.441893

Note: *Indicate selected lag length.

ECM model of yield of Aus rice

Variable	Coefficient	t-Statistic	Prob.
C	0.053351	3.636690	0.0016
Δ(Aus(-1))	-0.060980	-0.654174	0.5205
Δ(Rainfall(-1))	-6.33E-05	-1.918655	0.0694
Δ(Max_Temp(-1))	-0.006467	-0.453210	0.6553
Δ(Min_Temp(-1))	-2.18E-05	-0.003431	0.9973

5.4. Aman Rice

The estimated equation-

$$aman_t = 2.293591 + 0.689239\, aman_{t-1} - 0.000102\, rainfall_t - 0.000169\, rainfall_{t-1} - 0.039847\, \max\_temp_t - 0.002104\, \min\_temp_t + 0.013909\, \min\_temp_{t-1} + \varepsilon_t$$

Bound test-

Considering the test statistics value (F statistics and t statistics) at 10% level of significant, we do not reject the null hypothesis, indicating no cointegration relationship in the long run Table 3. So, we estimate short run ARDL.

Short run ARDL-

The appropriate lag length is 1 and the estimated model is Table 3.

$$\Delta aman_t = 0.044026 - 0.000104\, \Delta rainfall_{t-1} \varepsilon_t$$

So, average rainfall significant for yield of Aman in the short run. Change in yield of Aman rice will increase by .044026 unit if there is no change in average yearly rainfall in previous year meanwhile if change in average annual rainfall increase by 1 unit in the previous year the change in yield of Aman rice will be -.000104 unit.

Table-3. Estimation for dependent variable Aman.

Long run ARDL model for yield of Aman rice

Variable	Coefficient	t-Statistic	Prob.*
Aman(-1)	0.689239	5.430356	0.0000
Rainfall	-0.000102	-1.129192	0.2722
Rainfall(-1)	-0.000169	-1.733215	0.0984
Max_Temp	-0.039847	-1.028399	0.3160
Min_Temp	-0.002104	-0.129090	0.8986
Min_Temp(-1)	0.013909	1.663201	0.1119
C	2.293591	1.329778	0.1986
R-squared	0.892894		
F-statistic	27.78838		0.00000
Durbin-Watson stat	1.895409		

Bound test result for ARDL model of yield of Aman rice

	Test statistics	Significant value (10%) I(0)	Significant value (10%) I(1)
F-Bound test	1.689561	2.72	3.77
t-Bound test	-2.448410	-2.57	-3.46

Lag length identification of yield of Aman rice

Lag	SIC
0	0.245946
1	-1.113329*
2	-0.990323
3	-1.041080
4	-0.968001

Note: *Indicate selected lag length.

Short run ARDL model of yield of Aman rice

Variable	Coefficient	t-Statistic	Prob.
C	0.044026	1.885355	0.0733
Δ(Aman(-1))	-0.173676	-0.883917	0.3867
Δ(Rainfall(-1))	-0.000104	-1.899672	0.0713
Δ(Max_Temp(-1))	0.010207	0.420724	0.6782
Δ(Min_Temp(-1))	0.008746	0.811576	0.4261
R-squared	0.207407		
F-statistic	1.373829		0.276790
Durbin-Watson stat	1.870871		

Note: ** Dependent Variable: Δ(AMAN)

5.5. Boro Rice

The estimated equation:

$$boro_t = -1.787097 + 0.929771 boro_{t-1} + 0.000014 rainfall_t + 0.045050 \max\_temp_t + 0.031471 \min\_temp_t + \varepsilon_t$$

Bound test-

Considering the test statistics value (F statistics and t statistics) at 10% level of significant, we can reject the null hypothesis, so, there is no long run cointegration relationship Table 4. So, like the case of Aman rice we estimate the short run ARDL for Boro rice.

Short run ARDL- The appropriate lag length is 1 Table 4. So, the estimated model is Table 4.

$$\Delta boro_t = 0.093900 + -0.5337014 \Delta boro_{t-1} \varepsilon_t$$

So, only yield of Boro itself is significant in the short run for yield of Boro. Change in yield of Boro rice will increase by .0939 unit if there is no change in yield of Boro rice in previous year and if change in yield of Boro rice increase by 1 unit in one year lag the change in yield of Boro rice would be -.5337014 unit in current year.

Table-4. Estimation for dependent variable Boro.

Long run ARDL model for yield of Boro rice

Variable	Coefficient	t-Statistic	Prob.*
Boro(-1)	0.929771	16.43755	0.0000
Rainfall	1.40E-05	0.152617	0.8801
Max_Temp	0.045050	1.118386	0.2755
Min_Temp	0.031471	1.754183	0.0933
C	-1.787097	-1.076539	0.2934
R-squared	0.956741		
F-statistic	121.6404		0.000000
Durbin-Watson stat	2.758056		

Bound test result for ARDL model of yield of Boro rice

	Test statistics	Significant value (10%) I(0)	Significant value (10%) I(1)
F-Bound test	1.008663	2.72	3.77
t-Bound test	-1.241582	-2.57	-3.46

Lag length identification of yield of Boro rice

Lag	SIC
0	1.404424
1	-1.331337*
2	-1.275219
3	-1.177557
4	-1.061960

Note: *Indicate selected lag length.

Short run ARDL model of yield of Boro rice

Variable	Coefficient	t-Statistic	Prob.
C	0.093901	3.872709	0.0009
Δ(Boro(-1))	-0.533701	-2.885924	0.0088
Δ(Rainfall(-1))	8.54E-05	1.581778	0.1286
Δ(Max_Temp(-1))	0.017662	0.740187	0.4674
Δ(Min_Temp(-1))	0.009216	0.844685	0.4078
R-squared	0.363689		
F-statistic	3.000681		0.041828
Durbin-Watson stat	1.606948		

Note: ** Dependent Variable: Δ(Boro).

5.6. Wheat

The estimated equation:

$$wheat_t = -6.426551 + 0.809729 wheat_{t-1} + 0.000270 rainfall_t + 0.141894 \max\_temp_t + 0.090399 \min\_temp_t + \varepsilon_t$$

Bound test-

Considering the test statistics value (F statistics and t statistics) at 10% level of significant, the null hypothesis cannot be rejected), which means, long run cointegration relationship does not exists Table 5.

Short run ARDL- The appropriate lag length is 1 Table 5 and the short run ARDL model is insignificant. So, no short run cointegration exists.

Table-5. Estimation for dependent variable Wheat.

Long run ARDL model for yield of Wheat

Variable	Coefficient	t-Statistic	Prob.*
Wheat(-1)	0.809729	5.844071	0.0000
Rainfall	0.000270	1.096746	0.2846
Max_Temp	0.141894	1.300154	0.2070
Min_Temp	0.090399	1.929035	0.0667
C	-6.426551	-1.415960	0.1708
R-squared	0.648132		
F-statistic	10.13084		0.000083
Durbin-Watson stat	1.829913		

Bound test result for ARDL model of yield of Wheat

	Test statistics	Significant value (10%) I(0)	Significant value (10%) I(1)
F-Bound test	2.120446	2.72	3.77
t-Bound test	-1.373249	-2.57	-3.46

Lag length identification of yield of Wheat

Lag	SIC
0	1.904740
1	1.141363*
2	1.253283
3	1.379750
4	1.404417

Note: *Indicate selected lag length

Short run ARDL model of yield of Wheat

Variable	Coefficient	t-Statistic	Prob.
C	0.065670	0.759388	0.4561
Δ(Aus(-1))	-0.286002	-0.525026	0.6051
Δ(Rainfall(-1))	-0.000137	-0.707200	0.4872
Δ(Max_Temp(-1))	0.026366	0.314088	0.7566
Δ(Min_Temp(-1))	0.009252	0.247482	0.8069
R-squared	0.041770		
F-statistic	0.228853		0.919111
Durbin-Watson stat	2.164674		

Note: ** Dependent Variable: Δ (WHEAT).

5.7. Potato

The estimated equation-

$$potato_t = 6.853697 + 0.909199 potato_{t-1} - 0.000273 rainfall_t - 0.171262 \max\_temp_t + 0.039042 \min\_temp_t + \varepsilon_t$$

Bound test- Considering the test statistics value (F statistics and t statistics) at 10% level of significant, the null hypothesis cannot be rejected), which means, long run cointegration relationship does not exists Table G2.

Short run ARDL-The appropriate lag length is 2 and the estimated model is Table 6.

$$\Delta potato_t = 0.794245 + -0.688477 \Delta potato_{t-1} \varepsilon_t - 0.001482 \Delta rainfall_{t-2}$$

So, average rainfall and yield of Potato has impact on yield of Potato in the short run. Change in yield of potato will increase by .794245 unit if there is no change in yield of Potato in previous year and no change in average annual rainfall in two years lag. If change in yield of Potato increase by 1 unit in previous year the change in yield of Potato will be -.688477 unit in current year. The change in average annual rainfall is two years lag increases by 1 unit will cause change in yield of Potato in current year by -.001482.

Table-6. Estimation for dependent variable Potato.

Long run ARDL model for yield of Potato

Variable	Coefficient	t-Statistic	Prob.*
Potato(-1)	0.909199	9.165206	0.0000
Rainfall	-0.000273	-0.268212	0.7910
Max_Temp	-0.171262	-0.381917	0.7062
Min_Temp	0.039042	0.197401	0.8453
C	6.853697	0.372281	0.7132
R-squared	0.858370		
F-statistic	33.33357		0.000000
Durbin-Watson stat	2.788806		

Bound test result for ARDL model of yield of Potato

	Test statistics	Significant value (10%) I(0)	Significant value (10%) I(1)
F-Bound test	0.418736	2.72	3.77
t-Bound test	-0.915321	-2.57	-3.46

Lag length identification of yield of Potato

Lag	SIC
0	5.204510
1	3.840328
2	3.645734*
3	3.693741
4	3.800531

Note: *Indicate selected lag length.

Short run ARDL model of yield of wheat

Variable	Coefficient	t-Statistic	Prob.
C	0.794245	3.006572	0.0084
∆(Potato(-1))	-0.688447	-3.180771	0.0058
∆(Potato(-2))	-0.264921	-1.296555	0.2132
∆(Rainfall(-1))	-0.000769	-1.027108	0.3196
∆(Rainfall(-2))	-0.001482	-2.001961	0.0625
∆(Max_Temp(-1))	-0.324831	-1.181716	0.2546
∆(Max_Temp(-2))	0.076785	0.289634	0.7758
∆(Min_Temp(-1))	-0.060624	-0.505106	0.6204
∆(Min_Temp(-2))	0.097437	0.788224	0.4421
R-squared	0.510748		
F-statistic	2.087875		0.100015
Durbin-Watson stat	2.004180		

Note: ** Dependent Variable: ∆(POTATO).

5.8. Diagnostics Test

We first check the srial correlation of the residuals. For all the residuals of respective models, excluding Boro rice, LM test is not significant and we can not reject the null hypothesis of residuals are not being serially correlated. However, in case of Boro rice residuals are seems serilally correlated Table 7.

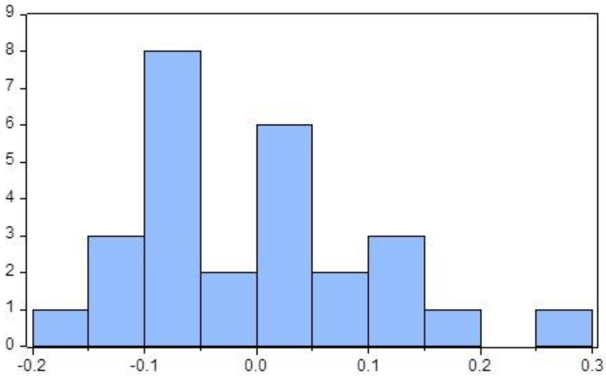
Table-7. Breusch-Godfrey Serial Correlation LM Test for Residuals.

long run ARDL of yield of aus rice			
F-statistic	0.315595	Prob. F(1,19)	0.5808
Obs*R-squared	0.424811	Prob.Chi-Square(1)	0.5145
ECM model of yield of Aus rice			
F-statistic	0.315595	Prob. F(1,19)	0.5808
Obs*R-squared	0.424811	Prob.Chi-Square(1)	0.5145
Short run ARDL model of yield of aman rice			
F-statistic	0.003734	Prob. F(1,20)	0.9519
Obs*R-squared	0.004853	Prob.Chi-Square(1)	0.9445
Short run ARDL model of yield of Boro rice			
F-statistic	0.526686	Prob. F(1,20)	0.4764
Obs*R-squared	0.667123	Prob.Chi-Square(1)	0.4141
Short run ARDL model of yield of Potato			
F-statistic	0.053083	Prob. F(2,14)	0.9485
Obs*R-squared	0.188156	Prob.Chi-Square(2)	0.9102

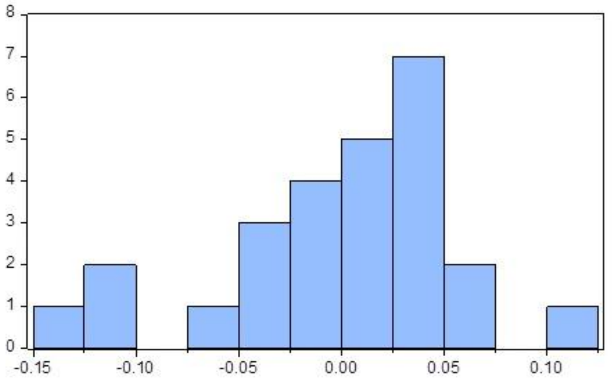
Histogram chart and Jarque-Bera test confirm that models are normally distributed Figure 3 & Table 8. Meanwhile CUSUM test ensure the stability of the models Figure 4.

Histogram for Normality

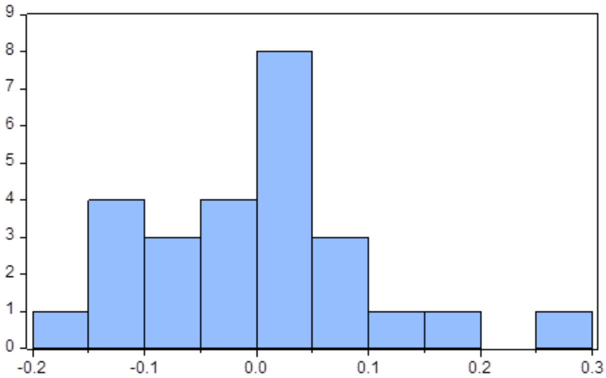
long run ARDL of yield of Aus rice



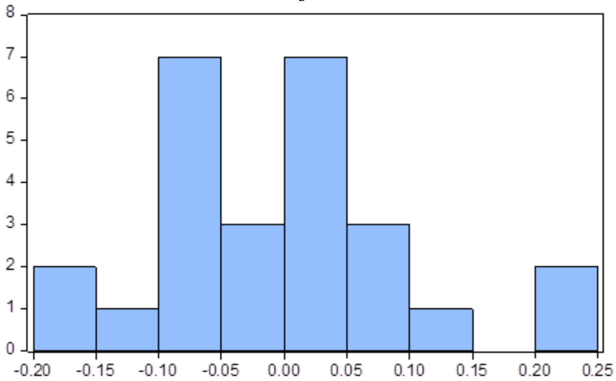
ECM model of yield of Aus rice



Short run ARDL model of yield of aman rice



Short run ARDL model of yield of boro rice



Short run ARDL model of yield of potato

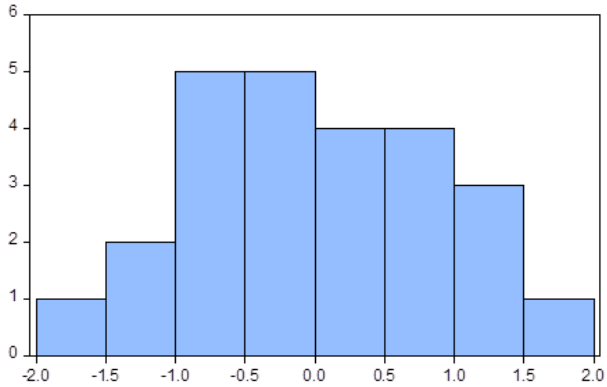


Figure-3. Histogram chart.

Table-8. Jarque-bera test for normality.

long run ARDL of yield of Aus rice

Jarque-Bera	2.131017
Probability	0.344553

Short run ARDL model of yield of Aman rice

Jarque-Bera	3.259808
Probability	0.195948

Short run ARDL model of yield of Potato

Jarque-Bera	0.492780
Probability	0.781617

ECM model of yield of Aus rice

Jarque-Bera	2.385837
Probability	0.303335

Short run ARDL model of yield of Boro rice

Jarque-Bera	2.011438
Probability	0.365781

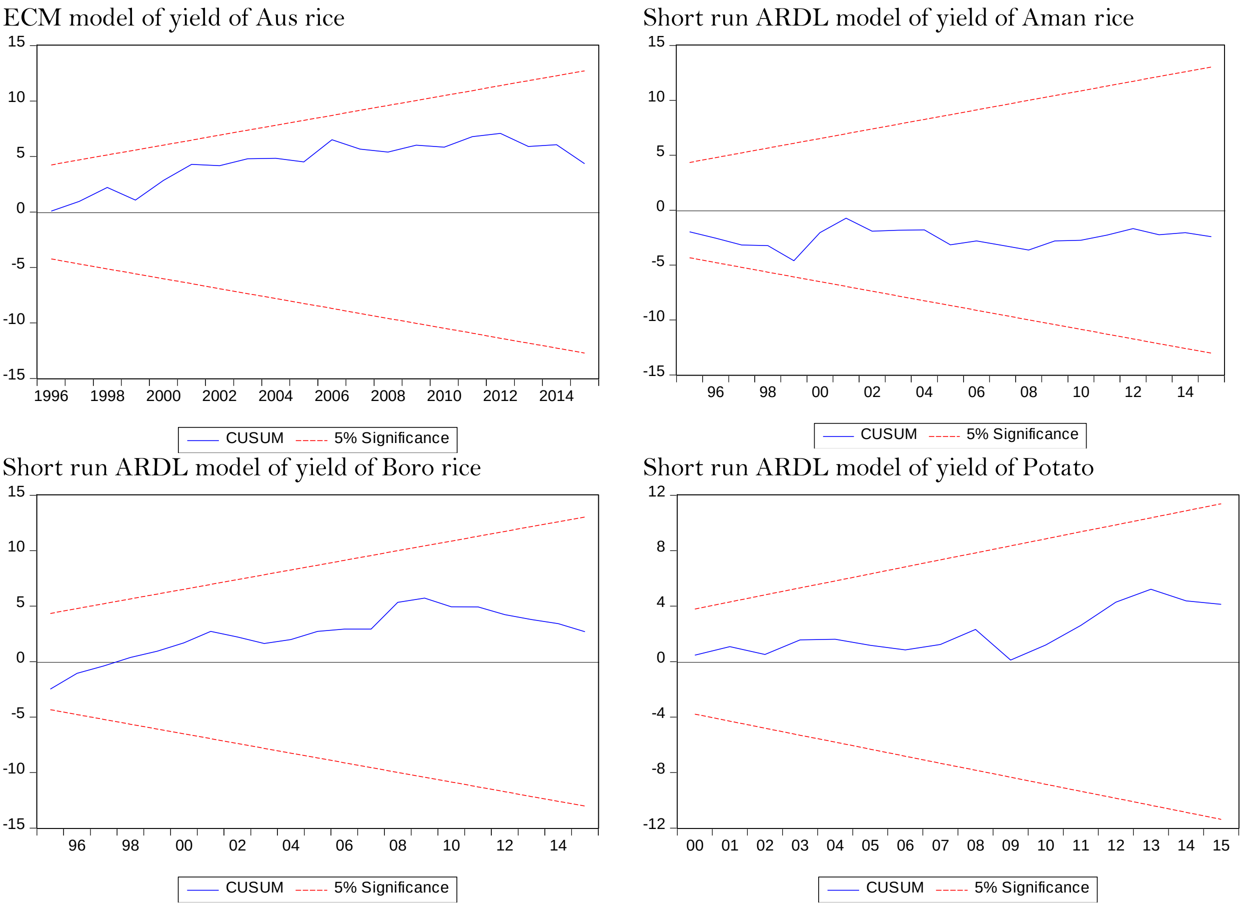


Figure-4. Stability Test (CUSUM).

6. CONCLUSION

After completing estimation, yield of aus rice is long run cointegrated with one lag of average annual rainfall and average minimum temperature, which supports many empirical evidence, discussed earlier. Yield of aman rice, yield of boro rice and yield of potato are not long run cointegrate with the climate variables. But yield of aman rice has short run cointegration with one lag of average annual rainfall. Yield of boro rice has short run cointegration with the one lag of yield of boro rice. Yield of potato has short run cointegration with one lag of yield of potato and two lags of average annual rainfall. Yield of wheat does not have any cointegration. The result shows us that the impact of climate on crops production is still not much noticeable. In defense we assume that improved technology, soil fertility and fertilizer can be good reason behind this. However, the narrow impact of climate on production may suggest a greater magnitude impact in the long run.

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