Analysis of the Effects of Climate Change on *Jamila* Rice Output in Kaduna-Nigeria

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Abstract - **The effect of climate change factors and non-climate change factors on *Jamila* Rice output have been investigated, using secondary sources of time series annual data obtained from Zaria and Rumi area of Kaduna State for the period of 1980-2013. The error correction mechanism was analyzed, and it was shown that in the short run, only rainfall tested significantly positive to rice output among the climate change factors. In the long run, temperature, carbon dioxide emission, carbon emission and rainfall tested significantly to rice output. There is a need to formulate policies that will aid farmers towards adaptation practices to mitigate the effects of climate change and motivate them to increase their involvement in rice production.**

Keywords-*Climate Change, Agriculture, Jamila Rice Output, Cointegration, Error Correction Models, Zaria, Rumi.*

I. INTRODUCTION

Human activities have contributed substantially to an increase in atmospheric concentration of greenhouse gases that emitted into the atmosphere, gases such as, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), Hydrofluorocarbons (HFCs), Perfluorocarbons (CF_6). This increase in atmospheric concentration of gases has led to increased warming of the earth's surface and atmosphere, causing climate change.

According to the Intergovernmental Panel on Climate Change [1], climate change is emerging as one of the cardinal challenges of the 21st century, AFP [2].

The climate system is complex, interactive, and consists basically of the atmosphere, snow and ice, oceans and other bodies of water, land surface, and living things all of which are powered by solar radiation. The climate evolves over time due to internal dynamics or external factors. Some of such dynamics or factors are volcanic eruptions, solar variations, anthropogenic (man-made) changes that alter the balance between incoming (solar) shortwave solar radiation and outgoing long wave radiation.

In recent times, warming of the climate system is increasing and the earth's temperature is highly variable. According to [3], over the last 50 years, warming trend is nearly twice that of the last 100 years, and even higher over the past twenty-five years.

Increasing global temperature is likely to boost agricultural production in the temperate regions, while reduced yield is expected in the tropical regions of the world, [4].

IPCC [1] projected that many African regions will suffer from drought and floods with greater frequency and intensity in the nearest future. Crop production is a significant part of agricultural production in Nigeria. Rice in particular is a major food crop that aids the economical growth of Nigeria. Nigeria's wide range of climate variation allows it to produce a wide variety of cash and food crops, [5]. Currently, the fluctuation in climate is putting Nigeria's agricultural system under serious threats and stress, thereby causing food insecurity.

II. LITERATURE

Jamila rice is a food crop grown in Kaduna State, Northern Nigeria. Its production falls under that part of agriculture that deals with crop production for food and not fiber. Many homes in Nigeria depend on rice for food. Most of the time, rice is imported into Nigeria and thus becomes too expensive to afford. It is therefore not a surprise that farmers seek and explore production of rice locally to meet the increasing demand at a reduced cost. Jamila rice among others, is one of such exploration. However, climate change may have some effects on the crop yield.

According to IPCC [6], climate change is a change in the state of climate that can be identified by changes in the mean and or the variability of its properties that persist for an extended period typically decades or longer.

Another theory of climate change is called Human Forcings spearheaded by IPCC [6], it holds that mankind's greatest influence on climate is not its greenhouse gas emissions, but its transformation on earth's surface by clearing forests, irrigating deserts, and building cities. According to [7], although the natural causes of climate variations and changes are undoubtedly important, the human influences are significant and involve a diverse range of first-order climate forcings, including but not limited to, the human input of carbon-dioxide (CO_2).

[8] have examined the impact of climate change on agriculture in India and Brazil. The methods they employed for the analysis are; the Ricardian method, Agro-economic model and agro-ecological zone analysis. In the model, the explanatory variables were; farm performance, land value, labour, infrastructure. The study pointed out the significance of adaptation. They argue that making production decisions of interest to the farmers is an adaptation skill that could combat the menace of climate change. In which case, farmers switch to the crop that will do better in certain temperatures.

[9] analysed climate change impacts on rice production in Bangladash using a simulation model. The model focused on Boro rice production which amounts to 58% of the total rice production during 2008 in Bangladash to estimate the effects of future climate change, soil and hydrologic characteristics of the locations, typical crop management practices and traditional in the simulation model called DASAT (Decision Support System for Agrotechnology Transfer). The results show that the yield of Boro rice varies in different climatic conditions. A rise in temperature causes damage to the Boro rice production.

[10] examined the impact of climate change in Ibadan, Nigeria. The study made use of the time series data on climate variables over 30 years. The study showed that reduction in rainfall, relative humidity and increased temperature accounted for reduced crop yield on food production.

Climate change factors affecting crop production have been limited in the models that have been adopted by past authors to at most three factors, such as, rainfall, temperature and carbon emission. In this study, nine explanatory variables have been included in the model. The models are; Rainfall, temperature, carbon emission, Gross Fixed Capital Formation, Agricultural machines and tractors, Economically Active Population in Agriculture, Land Area Equipped for Irrigation, Crop output (the dependent variable).

III. Research Methodology

Data on carbon-dioxide due to manufacturing and industrial activities in Nigeria was sourced from World Data Atlas [11]. Data on Gross Fixed Capital Formation, Agricultural machines and tractors, Economically Active Population in Agriculture, Land Area Equipped for Irrigation were sourced from African Development Indicator, crop production index and carbon-dioxide emissions were sourced from World Development Indicator [12]. Rainfall data was sourced from Central Bank Statistical Bulletin [13] and computed to arrive at annual averages. Data on temperature was sourced and extrapolated from the work of [14]. The data set used in this study ranges from 1980-2013.

The error correction model is the analytical technique used in this study,

$$CRPI = F(R, T, CA, C, E, L, G, AM) \quad (1)$$

where,
CRPI is Crop production index
R is Rainfall (cm)
T is Temperature (degrees)
CA is Carbon Emission due to manufacturing and industrial activities (MT per capital)
C is Carbon-dioxide emission (million MT)
E is Economically Active Population in Agriculture (Number)
L is Land Area Equipped for Irrigation (hectares)
G is Gross fixed capital formation (% of GDP)
AM is Agricultural Machines and Tractors (100 sq km of arable land)

The framework is derived from [15] and its theoretical explanation could be used for time series studies. Consider the simple economy model,

$$Y = e^{\beta T} AL \quad (2)$$

For the level effect of climate on production. The level effects of climate shocks on output and appear through β in equation (2),

and

$$\frac{\Delta A}{A} = g + \gamma \quad (3)$$

where,
Y -is aggregate output
L -measures population
A -measures labour productivity
T -measures climate

equation (3) captures the growth effect of climate. Taking log and differentiating with respect to time, we have the dynamic growth equation

$$g_t = g + (\beta + \gamma)T - \beta_{t-1} \quad (4)$$

The growth effect of climate shocks appears through γ in equation (3). The growth equation in (4) allows separate identification of level effects and growth effects through the examination of transitory weather shocks. The growth effect in (4) is a summation of the climate effect over time.

From equation (1), the short run version of the error correction model is,

$$\Delta CRPI = \alpha + \alpha_1 \Delta C + \alpha_2 \Delta E + \alpha_3 \Delta L + \alpha_4 \Delta CA + \alpha_5 \Delta G + \alpha_6 \Delta T + \alpha_7 \Delta R + \alpha_8 \Delta AM + eC_{t-1} + \mu \quad (5)$$

where,
µ - Error term
t - Time parameter
t-1 is the previous time periodic error correction term
Δ - difference operator
α - coefficients of independent variables

To test for the order of stationarity, the time series model used is the Augmented Dikey-Fuller test (ADF) to check the unit root properties of the series.
The Engle-granger cointegration method was used to test the presence of a long-run relationship among the variables.

IV. Results And Discussion

The 12th edition of Stata statistical package was used for the analysis of data. Table 1 illustrates the theoretical expectations of the coefficients of each of the variables. Table 2 illustrates the Augmented Dickey Fuller test for stationarity in the series.

Table 1: Theoretical expectations

Coefficient of variation	R	T	CA	C	G	AM	E	L
Expected Sign	>0	<0	<0	<0	>0	>0	>0	>0

Table 2: Unit Root Test (ADF) order of stationarity.

STATISTIC	C	T	R	CA	L	E	AM	G	C
ADF test	-2.912	-3.900	-4.800	-3.334	-4.722	-3.812	-5.001	-3.350	-3.211
1%	-2701	-3.696	-4.001	-2.911	-3.711	-3.200	-3.500	-3.702	-3.113
5%	-2.811	-2.978	-3.500	-3.001	-3.622	-3.110	-4.110	-2.980	-3.201
10%	-2.900	-2.620	-4.102	-3.101	-3.211	-3.602	-3.020	-2.662	-3.080
p-value	0.0012	0.002	0.0124	0.0101	0.0049	0.0003	0.001	0.0128	0.042
order of integration	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)

There is the need to carry out another test apart from the Augmented Dickey Fuller test to ensure the long-run relationship among variables. The results of these tests are presented in Tables 3, 4, and 5.

Table 3: Interpolated Dickey Fuller test with 33 observations.

	Test Statistic	1% Critical value	5% Critical value	10% Critical value
Z(t)	-5.366	-3.696	-2.978	-2.62

Table 4: Sort-run model of error correction mechanism.

Source	SS	DF	MS		Number of obs	33
Model	10381.83	9	1153.54		F(9,23)	61.17
Residual	433.76	23	18.86		Prob>F	0.00
Total	10815.59	32	337.99		R-squared	0.96
					Adj R-squared	0.94
					Root MSE	4.34

CRPI	Coef	Std. Err.	T	p>|t|	95% CI (LL)	95% CI(UL)
AM	-1.20	0.70	-1.74	0.095*	-2.70	0.20
C	-8.60	7.70	-1.11	0.28	-24.50	7.40
E	0.000008	0.0000004	18.98	0.000***	0.000007	0.000009
L	0.00003	0.00002	1.19	0.25	-0.00002	0.00007
R	0.20	0.08	3.01	0.006***	0.08	0.41
T	0.20	0.25	0.88	0.39	-0.30	0.70
CA	-0.08	0.11	-0.66	0.52	-0.30	0.20
G	0.00004	0.0001	0.35	0.732	-0.0002	0.0003
ect L1	-0.24	0.11	-2.10	0.047**	-0.50	-0.004
cons	2.04	0.84	2.41	0.024	0.30	3.80

NB: *, **, ***, indicate significance at $p<0.01$, $p<0.05$, and $p<0.1$ respectively.

Table 5: Long-run model of error correction mechanism.

Source	SS	DF	MS		Number of obs	33
Model	26074.10	8	3259.30		F(8,25)	17.70
Residual	4603.70	25	184.10		Prob>F	0.00
Total	30677.80	33	929.60		R-squared	0.85
					Adj R-squared	0.80
					Root MSE	13.57

CRPI	Coef	Std. Err.	T	p>|t|	95% CI (LL)	95% CI(UL)
C	-51.60	14.60	-3.54	0.002**	-81.60	-21.60
E	0.000008	0.000002	4.66	0*	0.000004	0.00001
L	0.0002	0.00006	3.98	0.001*	0.0001	0.0004
CA	-0.70	0.20	-3.86	0.001*	-1.09	-0.30
G	0.0007	0.0004	1.98	0.058**	-0.00003	0.002
T	1.40	0.80	1.75	0.092***	-0.30	3.10
R	0.50	0.30	2.08	0.048**	0.006	1.09
AM	-0.20	1.50	-0.12	0.909	-3.30	2.97
cons	-131.80	46.30	-2.85	0.009	-227.20	-36.47

NB: *, **, ***, indicate significance at $p<0.01$, $p<0.05$, and $p<0.1$ respectively.

The Engle-Granger Test of Cointegration investigates the long-run relationship among variables through unit root test of residuals. Table 3 shows a long-run relationship among variables hence the minimum condition for the use of the Error Correction Model is decided. Table 4 shows that in the short-run only agricultural machines and tractors (AM), economically active population in agriculture (E), rainfall (R), have indicated a significant influence on Jamila rice output (CPRI) at 95% confidence level. Table 5 shows that in the long-run model, almost all variables tested significant to Jamila rice output at 95% confidence level, while Gross capital formation (G) and Temperature (T) were significant at 90% confidence level within the period under investigation.

Table 6: Correlation of variables (obs = 34).

	CRPI	C	E	L	CA	G	T	R
CRPI	1							
C	-0.0848	1						
PE	0.4518	0.5509	1					
L	0.6263	0.4545	0.6888	1				
CA	-0.2645	-0.1192	0.1978	-0.0494	1			
G	-0.3228	-0.6224	-0.8679	-0.7968	-0.2075	1		
T	0.3840	-0.3567	-0.0974	-0.038	-0.0736	0.1741	1	
R	0.3345	-0.2343	-0.0057	0.1662	0.2681	-0.0313	0.2970	1
AM	0.3098	0.4378	0.4660	0.6034	0.1275	-0.5639	-0.5639	

Table 6 shows that the correlation between Crop Production Index (CRPI) and Temperature (T) and Rainfall (R) is 38% and 33% respectively. The respective relationships between CRPI and the other eight explanatory variables are strong and suggest careful monitoring of the effect of climate change on the production and output of Jamila rice.

Table 7: Summary Statistics of the explanatory variables.

Variables	Obs	Mean	Std. Dev	Min	Max
CRPI	34	60.99	30.49	0.00	105.31
C	34	0.54	0.26	0.00	0.90
E	34	1.18	3000171.00	0.00	1.29
L	34	226176.50	80710.28	0.00	293000.00
CA	34	52.29	16.48	31.24	82.12
G	34	5699.67	17683.66	8.80	89043.62
T	34	35.29	3.37	29.50	43.10
R	34	113.49	11.49	90.00	138.00
AM	34	4.31	2.33	0.00	6.97

Table 7 shows variability in the explanatory variables, farmers should be mindful of such variability to help mitigate the adverse effect of climate change on the crop production index.

V. Conclusion

In the short-run, rainfall has a significantly positive relationship on crop production index of Jamila rice while other variables such as carbon-dioxide, temperature, and carbon emission indicated an insignificant relationship during the period of investigation.

From the error correction model, in case of shock in the economy, there can be a recovery at 23% per annum in the long-run. Other determinants of Jamila rice production such as economically active population in agriculture, gross capital formation, and land area equipped for irrigation have a significantly positive influence in the long-run.

Policy makers should formulate policies that will aid farmer's adaptation to practices that mitigate the effects of climate change, improve involvement of the masses in crop production and encourage all season farming via irrigation, achieve food security, reduce food prices and imports in Nigeria.

References

[1] Intergovernmental Panel on Climate Change IPCC (2007a). Fourth Assessment Report, Climate change Cambridge UK. Cambridge University, Press for Intergovernmental Panel on Climate Change, Cambridge.

[2] African Partnership Forum (AFP) (2011). Climate Change and Africa. 8th Meeting of African Partnership Forum, Berlin, 22-23 May 2011, 22-23.

[3] Trenberth K.E., Jones P.D., Amberje P., Bojarin R., Easterling D., Klein Tank A., Parker D., Rahimzadeh F., Renwick J.A., Rusticucci M., Soden B. and Zhai P. (2007). Observations: Surface and Atmospheric Climate Change. In: Hoskins, B.J. Karl T.R., and Jallow B., Eds., Climate Change 2007: The Physical Science Basis, Contribution of Working Group 1 to the Fourth Assessment Report of the IPCC. Cambridge University Press, Washington, 235-236.

[4] WTO-UNEP (2009) World Trade Organization and the United Nations Environmental (WTO-UNEP). Report on Trade and Climate Change. www.Wt.org/English/res_../booksp_etrade_climatechange_e.pdf

[5] Tunde A.M., Usman B.A. and Olawapo V.O. (2011). Effects of Climate Change variables on Crop Production in Patigi LGA, Kwara State, Nigeria. *Journal of Geography and Regional Planning*, 36, 695-700.

[6] IPCC (2007b). Climate Change: Synthesis Report. Cambridge University Press, Cambridge.

[7] Pielke S.R. (2009). Climate Change: The Need to Consider Human Forcings besides Greenhouse Gases. *Earth Observation Satellite (EOS)*, 90, 413.

[8] Mendelsohn R. and Dinar A. (1999). Climate Change, Agriculture, and Developing Countries: Does Adaptation Matter? *The World Bank Research Observer*, 14, 277-293. https://doi.org/10.1093/wbro/14.2.277

[9] Basak J.K., Ali A., Islam N. and Rashid A. (2010). Assessment of the Effects of Climate Change on Boro Rice Production in Bangladesh Using DSSAT Model. *Journal of Civil Engineering*, 38, 95-108.

[10] Agboola T. and Ojeleye D. (2007). Climate Change and Food Production in Ibadan. *Nigeria Afi. Crop Sciconfer Prod*, 8, 1423-1433.

[11] World Data Atlas (2014) Nigeria: CO2 Emissions from Manufacturing Industries and Construction (Million Metric Tons). World Data Atlas. https://knoema.com/atlas/topics/Emissions/datasets

[12] World Development Indicator (2014). International Bank for Reconstruction and Development. The World Bank, Washington D.C. www.worldbank.org

[13] Central Bank of Nigeria Statistical Bulletin (2015). Domestic Production, Consumption and Prices. Central Bank of Nigeria, Abuja.

[14] Oyewole J.A., Thompson A.M., Akinpelu J.A. and Jegede O.O. (2014). Variation of Rainfall and Humidity in Nigeria. *Journal of Environment and Earth Science*, 4, 2224-3216.

[15] Bond S., Leblebicioglu A. and Schiantarelli F. (2010). Capital Accumulation and Growth. A New Look at Empirical Evidence. *Journal of Applied Econometrics*, 25, 1073-1099. https://doi.org/10.1002/jae.1163