CLIMATE CHANGE, FOOD SECURITY, NATIONAL SECURITY and ENVIRONMENTAL RESOURCES

GLOBAL ISSUES & LOCAL PERSPECTIVES

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Preface

This book adopts an exegetical approach as well as a pedagogic model, making it attractive agriculture and environmental economics teachers, professional practitioners and scholars. It is eschews pedantry and lays bars the issues in such clarity that conduces to learning. The book elaborates on contemporaneous climate change, food security, national security and environmental resources issues of global significance and at the same time, is mindful of local or national perspectives making it appealing both to international and national interests. The book explores the ways in which climate change, food security, national security and environmental resources issues are and should be presented to increase the public's stock of knowledge, increase awareness about burning issues and empower the scholars and public to engage in the participatory dialogue climate change, food security, national security and environmental resources necessary in policy making process that will stimulate increase in food production and environmental sustainability.

Climate Change, Food Security, National Security and Environmental resources: Global issues and Local Perspectives is organized in four parts. Part One deals with Climate Change with Six Chapters, Part Two is concerned with Food Security with Nine chapters, Part Three deals with National Security with Five Chapters, while Part Four pertains Environmental Resources, has Five Chapters.

Ahmed Makarfi / Eteyen Nyong

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CHAPTER 15

Effect of Carbon Dioxide (Co_2) Emission on Rice Production in Nigeria

Ibrahim Mohammed Kebiru, Husseini Salihu, Shaibu Ufedo Monday

Abstract

Since the onset of the Industrial Revolution in 1750, fossil fuel combustion has released significant amounts of carbon dioxide into the atmosphere, contributing to the greenhouse effect and causing global temperatures to rise. Climate change has had far-reaching consequences, including sea-level rise and flooding, which have negatively impacted key economic sectors such as agriculture and water resources. Given these concerns, this study aims to assess the effect of carbon dioxide (CO2) emissions on rice production in Nigeria from 1970 to 2020. The data used in this study were obtained from the Food and Agriculture Organisation Statistics (FAOSTAT) and the Nigerian Meteorological Agency. Descriptive and inferential statistics were used to analyze the data. Our results show an increasing trend in CO_2 emissions, which confirms the growing evidence of climate change. The Autoregressive Distributed Lag Model (ARDL) estimates revealed a statistically significant negative relationship (-186.65) between carbon dioxide emissions (CO_2) and rice yield, indicating that CO_2 emissions over several years can reduce rice output, regardless of the short-term impact. Our study recommends policy actions that reduce greenhouse gas emissions and promote Climate Smart Agriculture (CSA) practices to mitigate the negative impacts of Climate Change on agriculture.

Keywords: Climate Change, Carbon dioxide (CO_2) emission, Agriculture, Rice, Nigeria.

Introduction

Since the beginning of the Industrial Revolution in 1750, people have burned large amounts of coal, oil, and natural gas to power their homes, vehicles and factories. Today, most of the world relies on these fossil fuels for their energy needs and burning the fossil fuels releases CO_2, a heat-trapping gas, into the atmosphere, which is the main reason why the Earth's climate is getting

warmer. Heat-trapping gases are also called greenhouse gases. They exist naturally in the atmosphere, where they help keep the Earth warm enough for plants and animals to live-a phenomenon called the greenhouse effect (U.S Environmental Protection Agency, EPA, 2023). By adding more greenhouse gases to the atmosphere, however, people are contributing to an enhanced greenhouse effect and causing the atmosphere to trap more heat than it otherwise would (U.S. EPA, 2013)

Fossil-fuel combustion resulting in CO_2 emissions is the dominant human activity (driving force) causing the enhanced greenhouse effect. Other activities that add to greenhouse gas emissions are agriculture and land-use changes including deforestation, certain industrial processes such as cement production, landfilling of wastes, foam blowing and solvent use (Intergovernmental panel on Climate Change, IPCC, 2018). Climate change resulting from the enhanced greenhouse effect is expected to have widespread penalty, causing; sea-level rise and possible flooding of low-lying areas; melting of glaciers and sea ice; changes in rainfall patterns with implications for floods and droughts; changes in the incidence of climatic extremes, especially high-temperature extremes, these effects of climate change will have impacts on ecosystems, health, key economic sectors such as agriculture, and water resources (IPCC, 2018). According to the IPCC, an increase in the average global temperature is very likely to lead tochanges in precipitation and atmospheric moisture. Increased temperatures cause changes inatmospheric circulation and increase evaporation and water vapor, resulting in precipitation increases, more storms and sea level rise and hence flood in the 21st century (IPCC, 2018), although changes in precipitation will vary from region toregion. The frequency of heavy precipitation events has increased over most land areas, consistent with warming and observed increases of atmospheric water vapor and also Tropical storms and hurricanes are likely to become more intense, produce stronger peak winds, and produce increased rainfall over some areas due to warming sea surface temperatures (IPCC, 2018).

Carbon dioxide emissions (CO_2) and climate change are topical issues in all spheres of society, with nations striving to reduce the adverse effects of industrialization on climate (Mabutho and Hlengiwe, 2019). Over the last couple of decades, on one hand, the global economy has witnessed massive industrialization and urbanization (Gollin, Jedwab & Vollrath, 2016); on the other hand, there have been calls for efficient food production to meet the increasing demand for

food globally amid recurrent droughts and adverse weather patterns in the form of flood and others (Clark & Tilman, 2017; Bai *et al.*, 2018).

Among rice importing countries in the world, Nigeria still ranks third with Iraq (after the Philippines and China). There have been concerted research and policy discussions around the world supporting adaptation as a way of minimizing adverse climate change impacts in agriculture production in developing nations such as Nigeria (Ojo and Baiyegunhi, 2020). One food that has been identified in both national and global food security is rice (*Oryza sativa* or *Oryza glaberrima*) (Nwachukwu *et al.*, 2015). Importantly, it is a staple food with rich cultural identity. In Thailand, rice is described as the essence of life; In China, it is referred to life and generally the root of Asian civilization (Gomez, 2001). Rice is an important staple crop that plays an important economic role and feeds approximately half the world's population (Fahad *et al.*, 2019). Global rice consumption in 2018 was estimated at more than 488 million tons (MT) (USDA, 2019), with Asia accounting for 90% of the production and consumption. However, rice consumption is increasing rapidly in sub-Saharan Africa (SSA) (Aminou, Irene, Kazuki & Koichi, 2021). In Nigeria, rice is one of the few food items whose consumption has no cultural, religious, ethnic or geographical boundary (Ibitoye *et al.*, 2014). Rice is one of the food security crops in the continent of Africa, Nigeria inclusive, but its production is not growing fast enough in relation to the available potentials in the country (Clark and Tilman, 2017). Rice (*Oryza sativa* L.) production is greatly dependent on environmental factors provided by nature and the optimum combination of these factors, and production inputs determines yield. Rainfall characteristics (intensity and duration), relative humidity and temperature and flood constitute some environmental factors that affect rice yield and its variability and drastic changes in rainfall patterns and rise in temperatures introduces unfavourable growing conditions into the cropping calendars thereby modifying growing seasons which could subsequently reduce crop productivity (Clark & Tilman, 2017).

Climate change is a growing threat to the agriculture sectors. The negative effects on agricultural production and livelihoods of farmers, foresters and fisher folk are already being felt in many places, more especially in the area under study; they will only get worse overtime. Unless climate change and its resultant adverse effectsin the form flood is addressed, agricultural productivity will decline with serious implications on food security. Based on this background, this study assessed the effects of Carbon dioxide (CO_2) Emissionon rice yield in Nigeria, 1970 – 2020.

*Statement of the Problem***:** Great impacts of climate change associated with natural disasters such as severe floods, prolonged droughts, landslides, ice melting, storms and hurricanes usually lead to a massive loss of human life, agricultural and livestock production losses, soil degradation, and affect people's livelihood negatively (Rwanyirizi and Rugema, 2013). According to Intergovernmental Panel on Climate Change (IPCC) (2001), global warming and precipitation patterns have gradually affected crop productivity and finally resulted in food insecurity of ever increasing population across the globe. In developing countries where the majority of people reside in rural areas, climate change is having a continuous and serious detrimental impacts on agriculture on which most of people rely on especially for food and employment (FAO, 2017). The effect of interrelationship between the climatic factors like temperature, rainfall, and CO_2concentration on crop yield are researched but that of the effect of CO_2 on rice yield are studied a little, for instance Nwalieji and Uzuegbunam (2012) investigates Effect of Climate Change on Rice Production in Anambra State, Mbah, Ezeano, and Saror (2016) Analysises climate change effects among rice farmers in Benue State, Nigeria, Happiness, Catherine, Andrew, Donatus, Simeon and Johnny (2016) investigates Perceptions of climate change and variability, impacts and adaptation strategies by rice farmers in south east Nigeria. Adedeji, Tiku, Waziri-Ugwu and Sanusi (2017) studied the effect of climate change on rice production in Adamawa State, Nigeria, Onyegbula (2017) studied Rice farmer's perception of effects of climate change on rice development stages in Niger State, Nigeria and Abu, Okpe, and Abah, (2018) investigates effects of climate and other selected variables on rice output Response in Nigeria etc from the literature review its obvious that majority of studies are aimed at studying the effect of climate change generally on rice production with little emphasis on the effect of carbon dioxide (CO_2) emissionon rice yield in Nigeriaand that makes it more important for more researches to be done in order to unearth the effect of Carbon dioxide (CO_2) emission specifically on rice production. Itis against this background that the study seeks to provide evidence based answers to the following research questions:What is the trend of carbon dioxide emission in the study area from 1970 to 2020, What is the rice production trend in Nigeria during the study period and What is the effect of climate change variables on rice production within the study period?

Objectives of the Study: The broad objective of this study is to assess the effect of Carbon dioxide (CO_2) emissionon rice production in Nigeria from 1970 to 2020. The specific objectives are to:

examine the trend of carbon dioxide emission in the study area from 1970-2020. describe the rice production trend in Nigeria during the study period. And analyze the effect of climate change variables on rice production within the study period.

Methodology

This study was carried out in Nigeria. Nigeria is the most populous African country south of the Sahara (Worldometer, 2023). It is a geo-political and sovereign entity that is composed of 36 states and the Federal Capital Territory (FCT-Abuja). Nigeria is situated along the coast of WestAfrica between latitudes 4^0 and 14^0N and longitudes $3^0$and 15^0E. It shares a common boundary with Niger onthe West, Cameroun Republic on the East, and Gulf ofGuinea on the south. Nigeria occupies a land area of 923,769 km^2, of which only about 34.2 millionhectares are actually being cultivated and less than onepercent of the arable land is irrigated (Akinola, Adedeji & Oluwagbenga, 2020). Its terrain ranges from southern coastal swamps to tropical forest, open woodlands, grasslands and semi-desert in the far North. The country enjoys an annual rainfall ranging from 381cm along the coast to 64cm or less in the far North. Agriculture used to be the principal foreign exchange earner of Nigeria. Major crops include beans, sesame, cashew nuts, cassava, cocoa beans, groundnuts, gum arabic, kolanut, maize (corn), melon, millet, palm kernels, palm oil, plantains, rice, rubber, sorghum, soybeans and yams.

Method of Data Collection: Data for the study was obtained from secondary sources. The sources include the Production Yearbook published by the Food and Agriculture Organisation (FAO), FAOSTAT website and Nigerian Meteorological Agency as reported in the annual abstract of the Central Bank of Nigeria Statistical Bulletin. The study covers a fifty year period of 1970 to 2020.

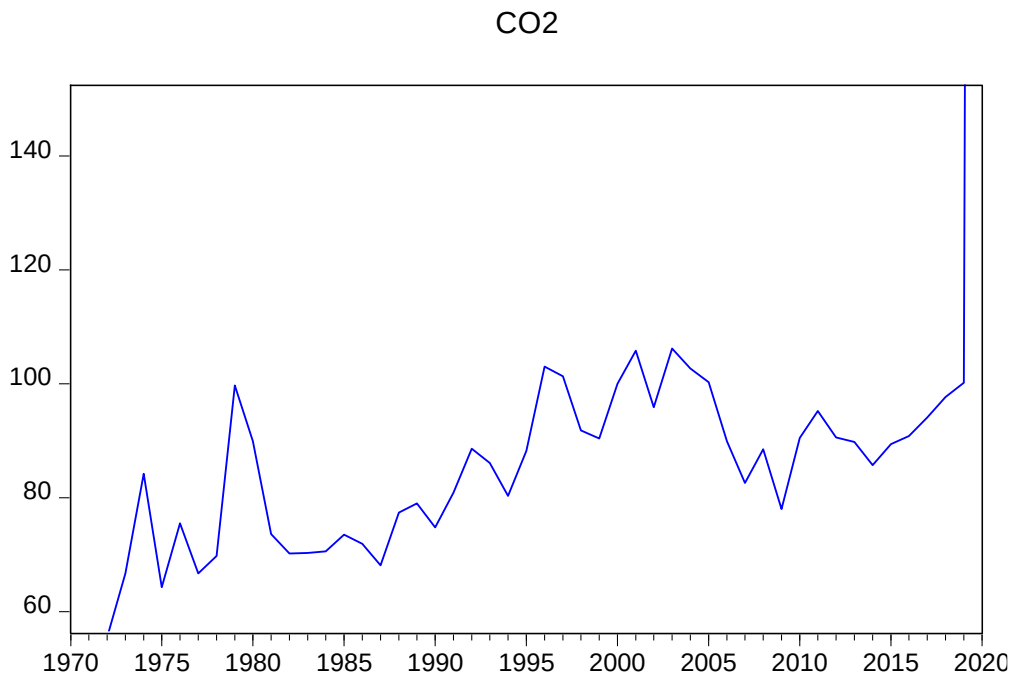
Method of Data Analysis: Both descriptive and inferential statistics was used to analyze the data for this study. The descriptive statistics involves the use of graphs to examine the movement and trend of various components of rice production. In addition, the production trend (yield) of rice in Nigeria was described through the graph. Unit root or stationary test was conducted to make decisions on whether the variables are stationary; the Augmented Dickey-Fuller (ADF) test was used for this test. The ADF F-ratio critical value was used to make decision on the unit root of the

variables while Auto-regressive Distributed Lag (ARDL) was used to examine the various climatic component on rice productivity in Nigeria.

Results and Discussion

This section presents the results and the discussion of the research findings.

The trend of CO_2 emissionin the study area from 1970-2020.



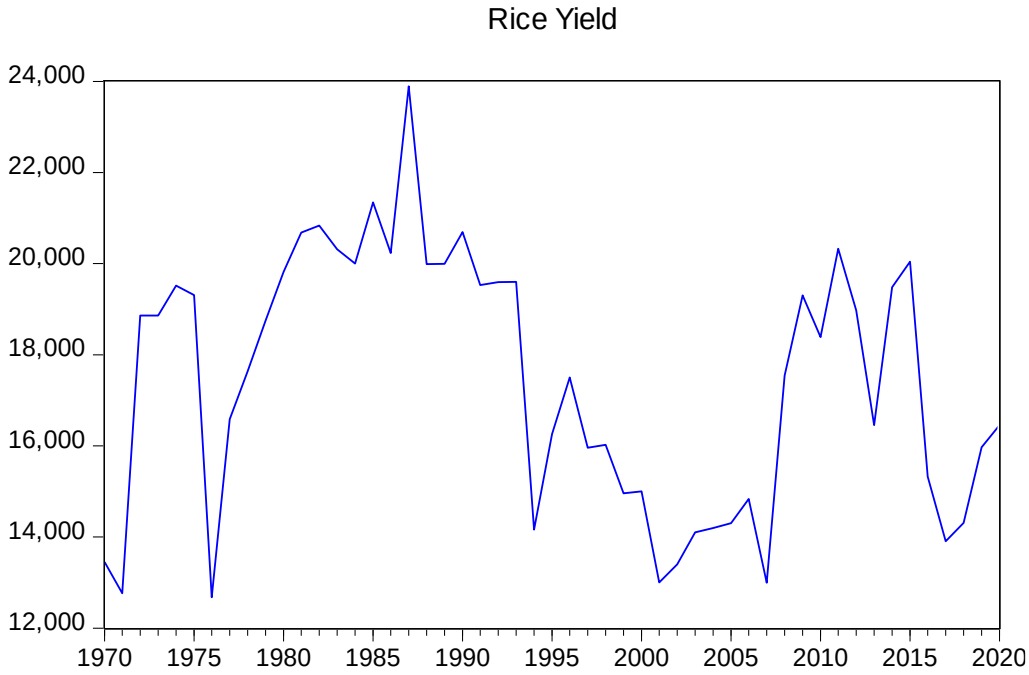
Graph 1: Graphical Representation of CO_2 emission trend in Nigeria.

Source: FAO Survey Data (1970-2020) and Own Calculation.

The Graph 1 above shows carbon dioxide emission trend in Nigeria from 1970 to 2020. The graph shows that there was a significant increase in CO_2 emission between 1970 and 1973 before a sharp decline in 1975. The next significant high emission of $CO_2$was recorded between 1978 and 1980. Between 1985 and 1997 there was a steady increase in CO_2 emission before declining to the last low in around 2009. CO_2 emission found another base in 2014 after a short increase in its emission before skyrocketing to this present level from 2015. The findings show that, there's truly an evidence of increasing emission of CO_2 in the atmosphere, and this implies that if CO_2 emission continues like this unchecked it may lead to decrease in the production of rice as excess CO_2 in the atmosphere tamper with the smooth growth of crops and the environment in general. Adeyemi *et al.* (2019) reported thatthere is a relationship between fossil fuel consumption and carbon

emissions, that is, CO_2emissions responds positively to fossil fuel consumption in Nigeria. This implies that fossil fuel combustion is a major driver of carbon emissions and impediment to the quality of life and environment in Nigeria.

Rice production trend in Nigeria during the study period.



Graph 2: Graphical Representation of rice yield trend in Nigeria.

Source: FAO Survey Data (1970-2020) and Own Calculation.

Graph 2 above shows rice yield trend in Nigeria from 1970 to 2020. The graph shows that after being at a certain level in 1970, there was a significant decline in rice yield from 1973 to 1976 before going to another significant high in around 1983. After a consolidation for a short period in rice yield, it reaches a new high in the year 1987. Between 1987 and 1994 there was a significant decline in rice production before a little jack up through 1996 followed by a fall in 2000. The graph also shows that, there was an increase in rice yield from 2007 to 2011. The graph shows a rapid decline in rice yield from 2015 through 2017 before it's trying to find its way back up the chart again and this could be attributed to current policy of the Federal government which encourages local production of rice and banning its importation. It is possiblethat the inconsistency in the growth rate of riceproduction in some of those years could be due to unfavourable weather conditions across the country's ecological zones and the lack of implementation of the various

intervention programmes targeted at developing rice production. This findings goes closely with the findings of Onu, Obike, Ebe, & Okpara (2015) who reported that, between 1980 and 2013, a total of 60,111,000 thousand metric tons of rice was domestically produced in Nigeria. Quantity of rice production in Nigeria varied from a maximum of 12,454,000 thousand metric tons from 2010-2013 to a minimum of 2,936,000 thousand metric tons from 1980-1984. The quantity of rice production increased from 2,936,000 thousand metric tons between 1980 and 1984 to 9,517,000 thousand metric tons between 1995 and 1999 and subsequently decline to 9,257,000 thousand metric tons between 2000 and 2004. It again increased from sum total of 11,560,000 thousand metric tons between 2005 and 2009 to 12,454,000 thousand metric tons from 2010-2013.

Effect of climate change on rice production within the study period

Stationarity Test Results

Table 1: Augmented Dickey-Fuller (ADF) Unit Root Test Results.

	At level		At first Difference	
Variables	**t-statistics**	**Prob.**	**t-statistics**	**Prob.**
Rice Yield	-3.251879*	0.0227	-8.675215**	0.0000
CO2	0.846697	0.9939	-0.427709**	0.0260
Rainfall	-5.603670*	0.0000	-12.36257**	0.0000
Temperature	-1.376079	0.5862	-9.636916**	0.0000

(*) Stationary at level. (**) Stationary at first difference

The variables of the studywere subjected to a unit root test by Augmented Dickey-Fuller (ADF) test in order to determine the stationarity condition of the variables. The level of probability at both level and first difference were compared. Any variable whose probability level is less than 5% is tagged stationary and reverse is also true. The result indicates that two of the series are stationary at both level and at first difference (i.e Rice yield and Rainfall) while two variables (CO_2 and Temperature) were stationary at first difference. Therefore, the order of Stationarity is mixed and this made Auto-regressive Distributed Lag (ARDL) an appropriate modelling technique (Emeka and Aham, 2016).

ARDL Short-Run Test

Table 2: ARDL short-run test result

VARIABLE	COEFFICIENT	STD. ERROR	T-STATISTIC	PROB.
CO_2	4.592039	1.107345	4.146892	0.0032
TEMPERATURE	1762.924	583.0621	3.023562	0.0165
RAINFALL	-0.750380	2.925463	-0.256500	0.8040

Dependent Variable: Riceyield. R-Square: 0.994316

Table 2 present the short-run form of the ARDL model used for the analysis of this study. The short-run model revealed that in the short run there is a direct positive and statistically significant relationship between carbon dioxide emission and rice yield in Nigeria with a coefficient of 4.59 which means that if CO_2 is increased by 1, rice yield will be increased by 4.59. This could mean that in the short run increase in CO_2 doesn't have any negative effect on rice yield. This result substantiates the findings of Alkhathlan and Javid (2013) who reported monotonically positive relationship between CO_2emissions and crops growth in the short in the case of Saudi Arabia.The result also revealed that in the short run, there is a statistically significant positive relationship between temperature and rice yield and the coefficient depicts that if temperature is increased by 1^0c, rice yield will be increased by 1762 kg/ha. This result in a way stresses the importance of temperature to crop production as this could mean that the photosynthetic ability of rice is enhanced as a result of the temperature and this would translate to higher yield. However there is a negative relationship between rainfall and rice yield which is not statistically significant in the short run and this could mean that even as rice is a water loving plant, it can be detrimental when it becomes excess in the event of water logging or flooding.

ARDL Bound Test

Table 3: ARDL Bound Test result

Test Statistic	Value	Signif.	I(0)	I(1)
			Asymptotic: n=1000	
F-statistic	20.79358	10%	2.37	3.2
K	3	5%	2.79	3.67
		2.5%	3.15	4.08
		1%	3.65	4.66

From the bounds test result on table 3, it could be seen that the F-statistics value is 20.79358. This value is greater than the lower bound critical values I(0) and the upper bound critical values of I(1) at all levels of significance. This result therefore showed that there is a long-run relationship in the model and that ARDL is an appropriate estimation method for the study and this necessitate the need to get long run form of the equation.

ARDL Long-Run Test

Table 4: ARDL long-run test result

Variable	Coefficient	Std. Error	t-Statistic	Prob.
CO2	-186.6525	51.16445	-3.648089	0.0065
Rainfall	0.338977	8.141119	0.041638	0.9678
Temperature	-1223.871	1780.329	-0.687441	0.5112
C	66234.54	43514.04	1.522142	0.1665

The long-run estimates of the ARDL revealed a negative relationship between carbon dioxide emission (CO_2) and rice yield, this impact is statistically significant. In the long-run a unit change in CO_2 will be accompanied by 186.65 kg/ha decrease in rice yield and this means that as long as CO_2 emission continue to accumulate in the atmosphere, it will adversely affect crop productivity (rice in this case) which makes food security which the country is striving at threatened. This finding is not consistent with Sulaiman, Abdulsamad, Salisu, Wong & Abdulfatah (2015) who reported that CO_2 emissions has significant positive impact on economic growth, that is to say, higher CO_2 emissions accelerates economic growth in the long run. This finding is also contrary to the findings of Nnaji *et al*. (2013) and Akpan (2012) in the case of Nigeria. According to the findings of Dawit, Zerayehu and Tsegaye (2016) in a research titled The Impact of CO2 Emissions on Agricultural Productivity and Household Welfare in Ethiopia: *A Computable General Equilibrium Analysis*, the reported that, the Simulation results indicated that a CO2 emissions-

induced decline in agricultural total factor productivity has an adverse impact on agricultural productivity and agricultural real GDP decreases from baseline 144.64 to 135.86 billion Birr, which is 6% lower by 2030 under the scenario without Climate Resilient Green Economy (CRGE) and on the other hand, under the scenario with CRGE, agricultural real GDP decreases by approximately 4.6%, from baseline 144.64 to 137.87 billion Birr by 2030.

The result also revealed that, there is positive relationship between rainfall and rice yield in the long run but not statistically significant, with the coefficient showing that a unit increase in rainfall will lead to a 0.33 kg/ha increase in rice yield. This findings stresses the importance of rainfall to agricultural production and rice as a water loving plant. This contradicts the findings of Abu *et al.*, (2018) who reported that, the coefficient of rainfall was negatively related to rice output in the short-run.This showed that rainfall had an adverse effect on rice output during the period studied. This result isconsistent with the findings Sowunmi and Akintola (2010) and Abu (2015) who found that rainfallnegatively affected maize output and sorghum yield, respectively.Also in the long run, the result indicates that, there is anegative relationship between temperature and rice yield with the coefficient showing that a unit increase in temperature will lead to 1223 kg/ha decrease in rice yield but not statistically significant. This depicts that, though temperature is a very important climatic element to crop production if it is in excess it will have an adverse effect and this negative relationship between temperature and rice yield could be as a result of global warming which further stresses the effect of climate change on agricultural production. This is consistent with Adedeji *et al.*, (2017) who reported that1% increase in minimum temperature will cause 3.715% reduction in rice production in Adamawa State, this shows a negative impact.

Conclusion and Recommendations: This study examined the effect of Carbon dioxide emission on rice yield in Nigeria from 1970 to 2020. The study reveals that, there is a positive and statistically significant relationship between carbon dioxide emission and rice yield in Nigeria in the short-run but, the long-run estimates of the ARDL revealed a negative relationship between carbon dioxide emission (CO_2) and rice yield with the impact statistically significant. Also, there is an increasing emission of CO_2 in the atmosphere in recent years which confirms the increasing evidence of climate change and its repercussions in the form of flood.

Based on findings from the study, it is recommended thatpoliciesor measures aimed at reducing carbon dioxide emission or to maintain optimal value should be formulated by both the Federal and State government in order to help curb the looming danger on food security pose by climate change through CO_2emission in Nigeria and the world at large. Also,farmers should be enlightened about Climate Smart Agriculture (CSA) in order for them to boost their farm productivity amidst the ever changing climate and its adverse effect in the form of flooding etc

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