IMPACTS OF CLIMATE CHANGE, POLICIES AND ADAPTATION TECHNOLOGIES ON RICE PRODUCTIVITY ACROSS AGRO ECOLOGICAL ZONES IN NIGERIA

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ABSTRACT

African countries have the lowest food productivity compared to other regions of the world. Particularly important is Nigeria's rice sector, which although currently the largest producer in Africa yet it is still a major world importer. This is largely attributed to the low productivity of rice which varies across six Agro Ecological Zones (AEZs) that marks the boundaries in terms of climate, soil and vegetation types. In the phase of high food insecurity and environmental concerns, improving productivity is considered a more sustainable approach. This study assessed multiple dimensions of climate factors (carbon dioxide, rainfall, temperature and flood); adaptation of technologies (irrigation and dummy of National Adaptation Strategies and Plan of Action on Climate Change in Nigeria (DumNASPA)) and policies (trade policy, corruption and government stability) as rice productivity determinants across AEZs. Data collection covers six AEZs from 1980 to 2018. After a series of diagnostic test, the unit root test, the cross-sectional dependence test and the Hausman test, the panel Autoregressive Distributive Lag (ARDL) model particularly the pooled mean group (PMG) model was used to examine the long-run and short-run impact of factors in the model. The long-run result revealed that, three climate factors (carbon dioxide, temperature, and rainfall) and irrigation capacity have a positive and significant impact on rice productivity. Trade policies and corruption were also positive and significant. In the short run, the impact of the factors varies across AEZs in Nigeria. While, based on the long-run PMG result, the positive effect of climate change factors, irrigation capacity, and import tariffs supports the increase in rice productivity. Interacting corrupt practices with fertilizer usage indicated a positive effect on rice productivity. This practice will actually increase production costs and in turn reduce the profits of paddy farmers. Therefore, policy making should consider the significant factors in each AEZ.

Keyword: adaptation technologies, Agro Ecological Zones, ARDL, climate change, rice productivity

ABSTRAK

Negara-negara Afrika mempunyai produktiviti makanan yang rendah berbanding dengan kawasan lain di dunia. Yang paling penting ialah sektor padi di Nigeria di mana ia adalah pengeluar beras yang terbesar di Afrika namun pada masa yang sama adalah pengimport utama di dunia. Kepelbagaian kriteria seperti jenis cuaca, kesuburan tanah dan kesesuaian tanaman di enam Zon Ekologi Agro (AEZs) mempengaruhi kepelbagaian produktiviti beras. Langkah meningkatkan produktiviti padi dianggap sebagai pendekatan terbaik dalam memastikan keselamatan makanan dan kelestarian alam sekitar. Kajian ini menilai pelbagai dimensi faktor cuaca (karbon dioksida, taburan hujan, suhu cuaca, dan kejadian banjir), faktor adaptasi teknologi (sistem pengairan dan Strategi Adaptasi dan Pelan Tindakan Perubahan Iklim), dan faktor dasar kerajaan (dasar perdagangan, amalan rasuah dan kestabilan kerajaan) sebagai penentu tingkat produktiviti padi di setiap AEZs. Pungutan data merangkumi enam AEZ dari tahun 1980 hingga 2018. Pemilihan Model *Panel Autoregressive Distributive Lag* (ARDL) terutamanya *pool mean group* (PMG) bagi analisis jangka panjang dan pendek adalah berdasarkan kepada hasil beberapa ujian diagnostik seperti ujian *unit root*, ujian kerbergantungan keratan rentas dan ujian Hausman. Hasil analisis jangka panjang mendapati tiga pembolehubah bagi faktor cuaca (karbon dioksida, taburan hujan, dan suhu) dan keupayaan pengairan memberi kesan yang positif dan signifikan kepada produktiviti beras. Dasar perdagangan dan amalan rasuah juga memberi kesan yang positif dan signifikan kepada produktiviti beras. Dalam jangka masa pendek, terdapat kepelbagaian impak faktor bagi semua AEZ di Nigeria. Namun, berdasarkan hasil jangka panjang PMG, kesan positif faktor perubahan cuaca, keupayaan pengairan dan tarif import meningkatkan produktiviti beras. Hasil pembolehubah interaksi amalan rasuah serta pemberian baja turut memberi kesan positif kepada produktiviti beras. Amalan ini sebenarnya akan meningkatkan lagi kos pengeluaran dan seterusnya mengurangkan keuntungan pengusaha padi. Justeru, pembentukan dasar perlulah bersandarkan kepada pembolehubah yang signifikan di setiap AEZ tersebut.

Kata kunci: adaptasi teknologi, Zon Ekologi Agro, ARDL, perubahan iklim, produktiviti beras

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LIST OF ABBREVIATIONS

Abbreviation	Full Meaning
AAAE	African Association of Agricultural Economists
ABP	Anchor Borrowers Program
ADF	Augmented Dickey-Fuller
ADP	Agricultural Development Projects
AEASA	Agricultural Economists Association of South Africa
AEZs	Agro Ecological Zones
AGW	Anthropogenic Global Warming
AMRTI	Agricultural and Rural Management Training Institute
APP	Agricultural Promotion Policy
APSIM	Agricultural Production Systems Simulator Model
ARDL	Autoregressive Distributed Lag
ARMTI	Agricultural and Rural Management Training Institute
ATA	Agricultural Transformation Agenda
BIC	Bayesian information criterion
CAE	Country assistance evaluation
CCAFS	Climate Change, Agriculture and Food Security
CFTA	Continental Free Trade Area
CGE	Computable General Equilibrium
CO_2	Carbondioxide
CRIN	Cocoa Research Institute
CSD	Cross-Sectional Dependence
CSM	Crop Simulation Model
DF	Dickey-Fuller
DFE	Dynamic Fixed Effect
DS	Derived savanna
DSSAT	Decision Support System for Agro-technology Transfer
ECM	Error Correction Model
ECOWAS	Economic Community of West African States
ECT	Error Correction Term
EKC	Environmental Kuznet Curve
EPA	Environmental Protection Agency
EPPA	Emissions Prediction and Policy Analysis
FAO	Food and Agricultural Organisation
FEEM	Fondazione Eni Enrico Mattei
GCM	Global Climate Model
GDP	Gross Domestic Product
GESS	Growth Enhancement Support Scheme
GHGs	Greenhouse Gases
GMM	Generalized Methods of Moments
Ha	Hectare
HF	Humid Forest
IADP	Integrated Agricultural Development Projects

ICID	International Commission on Irrigation and Drainage
ICT	Information and Communication Technology
IFPRI	International Food Policy Research Institute
IGSM	Integrated Global Systems Model
IITA	International Institute for Tropical Agriculture
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
IPS	Im Pesaran and Shin
IRRI	International Rice Research Institute
LLC	Levin-Lin-Chu
MG	Mean Group
MPI	Multidimensional Poverty Index
MT	Metric Tonne
NAFPP	National Accelerated Food Production Programme
NASA	National Aeronautics and Space Administration
NASPA	National Adaptation Strategies and Plan of Action
NBS	National Bureau of Statistics
NCAM	National Centre for Agricultural Mechanization
NCCPRS	Nigeria Climate Change Policy Response and Strategy
NEPC	Nigerian Export Promotion Counsil
NEST	Nigerian Environmental Study/Action Team
NGS	Northern Guinea Savanna
NIMET	Nigerian Meteorological Agency
NIRSAL	Nigeria Incentive Based Risk Sharing for Agricultural Lending
NISER	Nigerian Institute of Social and Economic Research
OECD	Organisation for Economic Cooperation and Development
PDNA	Post Disaster Need Assessment
PEM	Partial Equilibrium Models
PMG	Pooled Mean Group
PP	Phillips-Perron
PTF	Presidential Task Force
RBDA	River Basin Development Authorities
RCM	Regional Climate Model
SDGs	Sustainable Development Goals
SSA	Sub Saharan Africa
SSL	Self-Sufficiency Level
TFP	Total factor productivity
UNDP	United Nations Development Programme
UNEP	United Nations Environmental Project
UNFCCC	United Nation Framework Convention on Climate Change
UNFPA	United Nations Population Fund
VIF	Variance Inflation Factor
WARDA	West African Rice Development Association
WB	World Bank
WDR	World Development Report
WGI	Worldwide Governance Indicators

CHAPTER ONE

INTRODUCTION

1.1 Research Background

Global food production has increased significantly since the 1960s, but widespread hunger and malnutrition have remained in many regions of the world (Lal, 2016; FAO, 2017; Mailumo & Okoh, 2019). There are 26.4 percent of the world's population who suffer from moderate to severe food insecurity, including approximately 0.8 billion who are chronically hungry and two billion who suffer from micronutrient deficiencies (FAO, 2017). As a result, the world's population continues to face chronic hunger and malnutrition. Additionally, research indicates that current levels of improvement in food production may fall short of the required capacity to end global hunger even by 2050. (Lal, 2016; Mailumo & Okoh, 2019; UN, 2019; Omar, Shaharudin, & Tumin, 2019). Thus, there is growing global concern about the current food system's ability to meet current and future demands in the face of numerous problems and uncertainties in the sector, such as the threat of climate change (Steffi, 2020; Intergovernmental Panel on Climate Change [IPCC], 2014).

The threats from climate change are felt across all aspects of human society, from the natural environment down to various sectors of the economy (IPCC, 2014). These threats varies from extreme weather events in the form of abnormal temperatures and unstable rainfall patterns, to changes in natural processes such as rising sea levels, El-Nino and La-Niña events (Organization for Economic Cooperation and Development

[OECD], 2008). Similarly, the US Environmental Protection Agency (EPA; 2017) reported an increased frequency of natural disasters such as hurricanes, floods and long drought spells across the world. These changes impact several sectors of the economy such as health, agriculture, forestry, water supply, trade and energy. While none among the sectors is more threatened or sensitive to the implications of climate changes as agriculture (Banna et al., 2016; Huber et al., 2014; Mulwa, Marenya, Rahut, & Kassie, 2017).

Every component of the agricultural sector from production to harvesting, marketing, value addition, storage, productivity, trade supply, prices and inputs will be affected by climate change (Maxwell et al., 2017; Kotir, 2011; Shiferaw et al., 2014). The high sensitivity of agriculture to climate change is due to it's over dependence on natural system. The agricultural sector accounts for 70% of global water use and 30% of global energy demand (OECD, 2016; FAO, 2015; FAO, 2011; World Bank, 2018). Consequent to the fact that some agricultural practices contribute to climate change and environmental damages, agriculture is currently linked to three most phenomenal challenges in the world today. These challenges are concerned with food insecurity, adapting to climate change and mitigating climate impact (FAO, 2017). Though climate change remains a global problem, the impact is dynamic and differences exists in the severity of impact between developed and developing regions (National Aeronautics and Space Administration [NASA], 2018). Thus, food related challenges have overwhelmed most developing regions of the world, especially Africa which have a large proportion of the world most vulnerable people.

Among the developing regions, Africa's agriculture is largely nature dependent, therefore it is considered to be more vulnerable to climate changes (Komba & Muchapondwa, 2012; Hatfield & Takle, 2014**)**. Furthermore, Africa is expected to surfer more pronounced impact as a result of low productivity in the agricultural sector and over dependence on import for its major food (Islam & Kieu, 2020; Masipa, 2017; de Graaff, Kessler, & Nibbering, 2011; International Institute for Tropical Agriculture (IITA; 2017); Costello et al., 2009). Somado et al. (2008) reported that Africa imported around 9 million MT of cereals in 2006, thus accounted for 23% of global cereal import while in 2018 its share of cereal import further increased to 28.9% (FAOSTAT, 2019). A major concern is that growing dependence on import have not resolved the existing food challenges (de Graaff, Kessler, & Nibbering, 2011). Incidence of severe food insecurity continues to persist among 21% of its population and moderate food insecurity still exist among 52.5% of Africa's population. Also, in 2019, FAO estimated the number of undernourished people in Africa to be about 19.1% of the population and 0.675 billion people are affected by moderate or severe food insecurity (FAO, 2017).

In addition to the persistent food related challenges highlighted and high import reliance (Islam & Kieu, 2020; Masipa, 2017; de Graaff, Kessler, & Nibbering, 2011), more complications are posed by climate change (Beddington, et al., 2012; Rakotoarisoa, Lafrate, & Paschali, 2011). That is, Africa's food sovereignty is further threatened as the export supply could be affected by climate challenge (Ahmed & Long, 2013; Kochy et al., 2017; Mirimo & Shamsudin, 2018; David Dawe, 2013). Consequently, to achieve food sovereignty there is a need for African countries to revamp the food production system specially to meet current and the projected increase in demand of major food crops (Steffi, 2020). Among the major food crops in Africa, rice is expected to experience higher growth in demand (6% per annum) as the world population increases (Roy-Macaulay, 2019; Krishnan, Ramakrishnan, Reddy & Reddy, 2011).

Rice accounts for the major share of food calories and food expenses, playing a vital role in the livelihoods of most farmers (Dawe, Jaffe & Santos, 2014). The regions of Africa and Asia have more than 100 million households that are dependent on rice as their primary source of nutrition, income and employment (Roy-Macaulay, 2019; FAO 2004). Thus, rice production contributes greatly to the economic structure of Asia and Africa. Whereby, nearly 200 million small farmers produce over 90% of rice across Asia (Tonini & Cabrera, 2011). Rice is therefore regarded as a priority and strategic crop for eradicating food insecurity, poverty and hunger across the world and especially in the case of Africa (Roy-Macaulay, 2019; FAO, 2016). Despite the economic importance, Africa's rice sector is characterised by existing deficit challenge and consequently heavy reliance on import (Islam & Kieu, 2020; Masipa, 2017; Ganpat, Dyer, & Isaac, 2016; Sasson, 2012; Rakotoarisoa, Lafrate, & Paschali, 2011).

For Africa to outlive these challenges, urgent research effort and actions are needed to support the emergence of a sustainable domestic food systems and overturn the rising import reliance in Africa (Steffi, 2020; GRAINS, 2019; Mailumo & Okoh, 2019). Especially as several studies have indicated that Africa has the potential to feed its region and also export rice to other parts of the world (Chivenge, Mabhaudhi, Modi &

Mafongoya, 2015). This food production potential of Africa has been undermined for a long period as acknowledged by many studies (Mabhaudhi, Chibarabada, Chimonyo, Murugani, Pereira, Sobratee, Govender, Slotow, & Modi, 2018; Chivenge, Mabhaudhi, Modi & Mafongoya, 2015; Chamberlin & Headey, 2014; de Graaff, Kessler, & Nibbering, 2011). One obvious challenge responsible for the inability to meet the growing rice demand in Africa is the issue of persistent low productivity (See Figure 1.1).

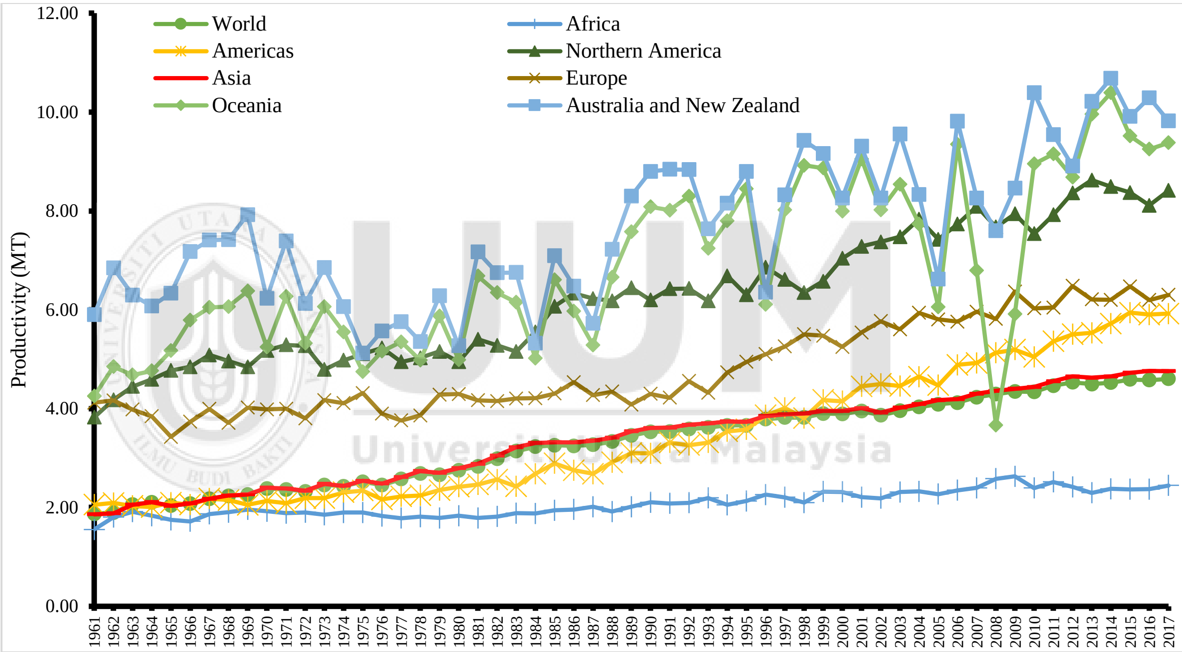

Figure 1. 1
Rice Productivity across Regions (1961- 2018)
Source: Constructed using Data from FAOSTAT.

As indicated in Figure 1.1, the growth in productivity of rice in Africa remains the lowest as compared to other regions. The productivity increase remains comparatively slow, currently stagnant at a value of 2.4 MT/ha indicating only slight improvement from initial value of 1.55 MT/ha in the early 1960s. Compared to Asia, where the value stand at an average of 4.6 MT/ha and even higher for the case of Australia and New Zealand with average productivity above 9.0 MT/ha. Thus, comparatively, Africa is recognized to have the lowest rice productivity as compared to that obtained in other regions of the world. This is further affirmed by the Food and Agricultural Organisation (FAO) where it highlighted that productivity in Africa is 46% lower than what is obtained in other countries of the world such as China, Malaysia, Thailand, the Philippines and Myanmar.

1.2 Rice Productivity Issues

The low rice productivity is a major factor threatening food self-sufficiency in Africa. The persistent low productivity trend in Africa as compared to other regions have consequently led to the long-term stagnation in growth of the rice sector (Chamberlin & Headey, 2014; David Dawe, 2013). Importantly, the low productivity situation cannot be dissociated with the long-term neglect of the sector by the government (Garba, 2013) and several other challenges identified in extant literature (Chamberlin & Headey, 2014). The most compelling among the challenges reported in extant studies across both developed and developing regions of the world is the issues of climate change (Tiamiyu et al., 2015; Ajetomobi, Joshua, Abiodun, Ajiboye & Hassan, 2011; Mariara & Karanja 2006; Seo *et al* 2005; Liu et al., 2004). While several existing studies have also emphasized the role of adaptation technologies (FAO, 2017; Shikuku, et al., 2017; Malawi, Mulwa, et al., 2017; Thamo, et al., 2016; Elizabeth, et al., 2012; Moser & Ekstrom 2010; Lal 2003; and IPCC, 2000).

Other factors indicated as critical determinants in the agricultural sector growth are instability in government policies (trade policies, subsidies and incentives policies) (Adesiyan et al., 2015; Abbas et al., 2018; Adedeji et al., 2016; Ajetumobi, 2015; Akande 2011; Emodi & Madukwe 2008; Stifel & Randrianarisoa, 2004). Political instability and corruption factors (Shumetie, & Watabaji, 2019; Kimenyi, Adibe, Djiré, & Jirgi, 2014; Galinato & Galinato, 2011; de Graaff, Kessler, & Nibbering, 2011; Morgan & Solarz, 1994). Whereas the most challenging of these factors is the threat from climate change (IPCC, 2014; Steynor & Pasquini, 2019).

1.2.1 Climate Change and Productivity

Among the threats to productivity, climate change presents the most complex and dynamic challenge across every part of the world. This is because every component of the agricultural sector is affected by climate change, from productivity, export market, inputs supply, production, harvesting, processing, value addition, prices to trade (Maxwell et al., 2017; Shiferaw et al., 2014; Kotir, 2011). A major concern is how this will disrupt the productivity of rice as a major food staple of the world. Consequently, leading to decline in export supply and other consequences. For example, rice export, productivity and prices have been deeply undermined by recent events that are attributed to climate change in major producing and exporting countries such as Thailand, India, China, Myanmar and Viet Nam.

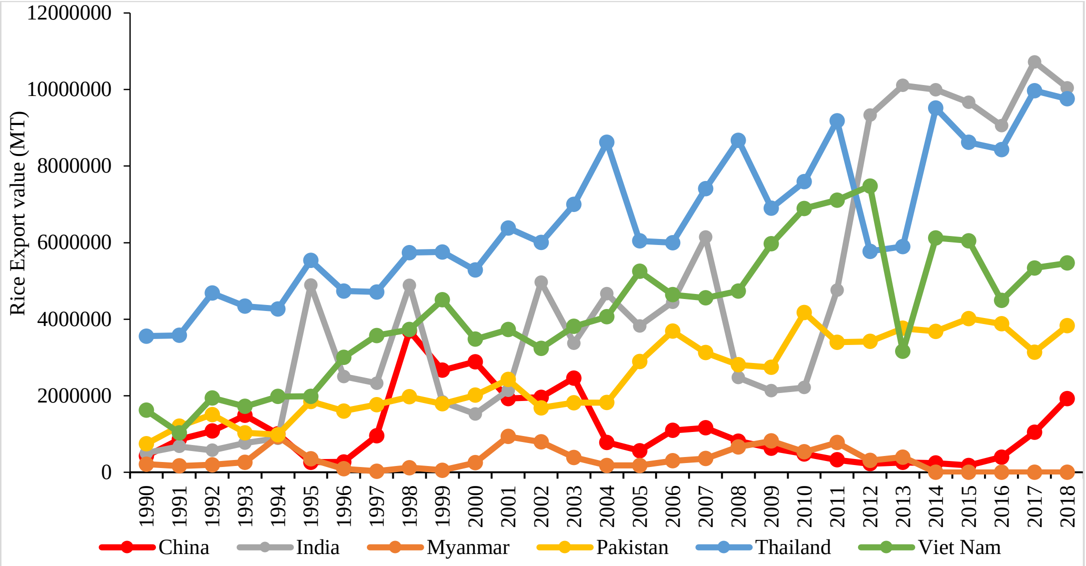

Figure 1. 2
Quantity of Export by Major Export Partners of Nigeria (1990 - 2018)
Source: FAOSTAT data.

The trend in Figure 1.2 shows the fluctuations in supply of rice to import dependent countries. The trend of export supply by major exporting countries such as Thailand, India, and Vietnam show a fluctuation in rice supply. As indicated in Figure 1.2, where in 2008 for example some major export countries indicated a declining supply of rice to export market. These includes India (6.4 million MT to 2.4 million MT), Pakistan (3.1 million MT to 2.8 million MT), China (1.3 million MT to 0.96 million MT). The case was worse for India, dropping from around 6.4 million MT to 2.5 million MT. Other exporting countries such as Thailand, Myanmar, Vietnam and China suffered another sharp decline in export in subsequent years. Thailand from 2008, Myanmar in 2010 and 2012, Vietnam in 2013, while China had a long-term continues decline since 2007. All these coincide with the increasing number of climate shocks in the form of floods, drought, serious cyclones and decline in availability of water, soil and land in these countries (Redfern et al., 2012).

According to the FAO report, in 2016, the Philippines experienced strong winds coupled with heavy rains and localized floods which resulted into losses to the agriculture sector, including its main staple rice paddy crop, as well as maize and other high value crops (FAO 2016). In another event, Thailand experienced a dry weather which reduced plantings and productivity of the 2015 food crops (FAO, 2015). In republic of Korea productivity of rice and maize dropped by 12% and 15% respectively, consequently resulting into a decline in the total output of rice.

These challenges compelled the exporting nations to regulate export in order to fulfil local consumption needs (Roy-Macaulay, 2019). Thus, resulting in policy responses in the form of total export ban, restricting quantity of export and in some cases involves the reduction in allocation of water and land resource to rice production in response to decreased water availability induced by climate change (FAO, 2017). These threatens import stability, higher prices volatility and further escalation of food related crises such as hunger and malnutrition. As a result, the challenges of food insecurity, hunger, malnutrition, crisis and poverty could manifest higher for food deficit countries that relies on food import. Considering these impending consequences, climate change has become a major concern of experts from different fields such as; environmental sciences, economics, agriculture and politics across the world.

1.2.2 Adaptation Technologies and Rice Productivity

Amidst the increasing concerns on the threat from perpetual climate change threat, various adaptation technologies are employed across several regions to control the threats. The development of strong adaptation technology and policies for strengthening resilience of the agriculture sector to climate change becomes a priority. Consequently, studies have indicated the need for new research paradigm shift on various aspects of climate change adaptation at national and sub national levels. Especially with focus on developing countries of the world whose economies are agriculture dominated. More importantly, since wider gap exist in the progress towards deployment of adaptation technologies to climate change between developed and developing economies (Ford & Berrang-Ford, 2011; Gagnon-Lebrun & Agrawala 2007; Solomon et al., 2007; Costello et al., 2009).

Although, the economies of most developing countries such as Africa are dominated by agriculture, the sector are largely characterized by weak ability to adapt, and higher vulnerability. Also, the production system is still characterised as highly rainfed, weak institutional supports and low technology usage thus, the high vulnerability. Particularly, the lack of strong and suitable technologies influences the high vulnerability level (Hatfield & Takle, 2014). The poor technological base of the agricultural systems in the regions of Africa and its poor economic status have limited the regions human and financial capacity to anticipate and respond to the direct and indirect effects of climate change. (IPCC, 2001; United Nation Framework Convention on Climate Change [UNFCCC], 2005); International Institute for Tropical Agriculture [IITA], 2017).

Besides, it is crucial fact that current adaptation technologies in African countries such as rainwater harvesting, irrigation schemes, seed technologies and technologies on early warning are adopted from other regions, thus are mostly not effective (Matewos, 2020; UNDP, 2018; Nairizi, 2017). Furthermore, according to the UNDP (2018), the earlier adaptation projects in Africa were characterized as small scaled and largely focused on investing and diversifying assets largely through agricultural technologies and practices with a mixed level of support for adaptive decision-making (UNDP, 2018). These issues have contributed to the region's weak adaptive capacity in addition to the issue of dynamism in the impact of climate change, implying that climate impact varies across space and time (de Graaff, Kessler, & Nibbering, 2011).

The dynamic nature of climate change implies the same adaptation technologies successfully deployed in a particular region might not be suitable for another region (World Bank, 2012; UNDP, 2007). This dynamism arises due to differences in the nature of climate, vegetation and soil types across geographic locations (FAO, 2010). On the basis of these variations, the FAO have developed the Agro Ecological Zone (AEZs) classification. The AEZ is a classification of regions, countries and sub-country levels base on variations in their climate type, vegetation and soil types (Anubhab & Kavi, 2020; FAO, 2010). Thus, the AEZ forms a relevant classification in the agricultural sector of most countries and regions.

There is need to develop location specific adaptation technologies across African regions (de Graaff, Kessler, & Nibbering, 2011). Since, differences exist across the AEZs, the impact is expected to differ across the different AEZs (Anubhab & Kavi, 2020). For example, an average global temperature increases of 4°C could result in an increase of as much as 10°C in some regions. Similarly, temperature and other climate parameters are different for all AEZs (World Bank, 2012; UNDP, 2007). Also, adapting to 4°C rise in temperature in one AEZ does not implies direct increase of the adaptation technique employed in the case of 2°C in another region or AEZs. Therefore, location specific impact assessment and development of appropriate technologies for adaptation (de Graaff, Kessler, & Nibbering, 2011). Although, the interventions on climate change adaptation strategies involve huge capital outlays and are mostly constrained in supply among developing nations.

1.2.3 Policies and Productivity

Further challenge to the rice productivity in Africa is the existing inconsistencies in policies. Existing issues of high import dependence, the eminent threat from climate change and low productivity can also be attributed to policy inconsistencies. Policies are required to drive the rice sector productivity growth and stronger adaptation to climate change (Seguin 2008; Costello et al. 2009; Karl et al. 2009). Adequate policies are considered as drivers for promoting the use of adaptation technologies and enhancing resilience of the rice sub-sector (Garnaut 2008; Lemmen et al. 2008; Costello et al. 2009; Karl et al. 2009). Several new policies can be integrated into existing policy priorities and programs such as input subsidy policies and trade policies in the regions. Especially, since studies have established the link between climate change and trade policies, and how the nature of trade policies could affect economies of developing countries of Africa (Kaushal & Pathak, 2015; Weibe et al., 2015).

There is exigent need for research response in consideration of the prevailing challenges of growth stagnation in Africa's rice sector and the imminent threat from declining global supply which can further compromise food access in many of Africa's regions (Easterling et al., 2007). It is imperative to conclude that there is an interplay between climate change, adaptation technologies, government policies and productivity of agricultural crops such as rice (Steffi, 2020). However, the issue of the nexus between factors such as climate change, adaptation technologies, policy dimensions and rice productivity and the implications on countries of Africa such as Nigeria have received little attention in literature. This is expected to support the fight against hunger, malnutrition, diseases, poverty and especially food security as they relate to agriculture across the world and especially in Africa (FAO 2009; Muller et al., 2011; Kochy et al., 2017; Enete & Amusa, 2010).

Thus, the current research interest in Nigeria is driven by the peculiar situation of the Nigeria's rice sector in the global continuum. Nigeria stands unique as it remains the largest rice importer in Africa and second largest in the world (FAO, 2017). Thus, as a top importer of rice in the world and a leading producer in Africa with its comparative advantage left untapped, Nigeria is considered a unique stakeholder in the rice industry. Hence, implying that in an effort to boost rice productivity in the Africa, it is pertinent to invest in countries with comparative advantage in rice production like the case of Nigeria. The Nigeria's rice sectors is characterised as highly vulnerable to climate change, weak adaptation capacities and overall sectoral policy inconsistency. Further insight on the unique situation of the rice sub-sector in Nigeria with focus on the imminent challenges impeding its growth is provided in the next subsection.

1.3 Rice Sector in Nigeria

Examining the consumption trend of rice in Nigeria confirms an upward growth in domestic consumption as revealed in Figure 1.3. The consumption of rice has continued to rise since the 1960s, consumption rose by 32% by 1964. A significant growth was experienced around 1977, when consumption grew by 50% and then declined again in 1980. Another notable year was in the early 1990s when Nigeria experienced a growth in consumption of about 80%. Ever since then rice consumption in Nigeria has continued to be on the rise at a consistent average of about 5% per annum. Although, Akande (2001) reported a higher value of about 10% per annum basing its argument on the changing preferences of consumer in favour of rice.

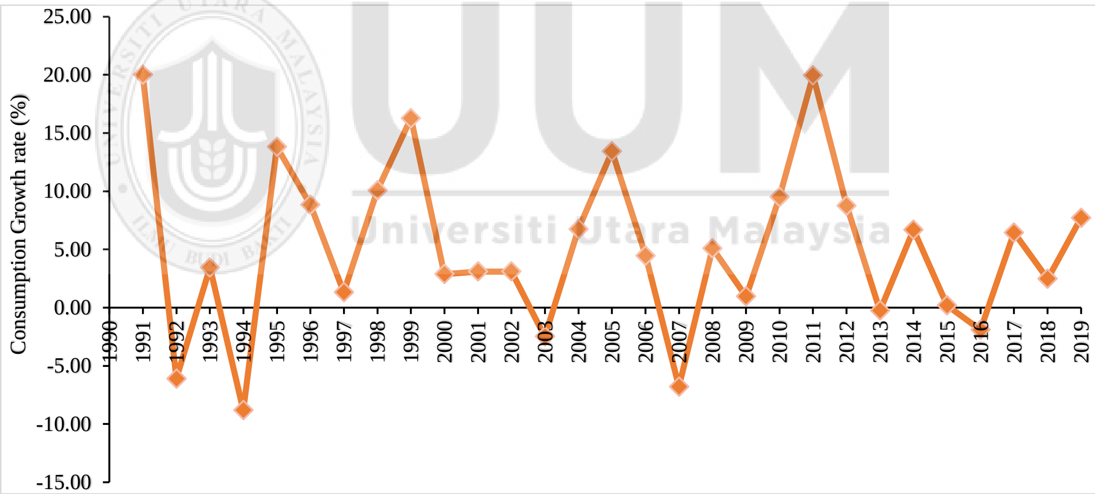

Figure 1. 3
Annual Growth Rate of Nigeria Rice Consumption, (1990 - 2019)
Source: OECD-FAO, 2020.

Since 1990, the growth rate of Nigeria's rice consumption has been positive except for few years where consumption declined. The years indicating declining growth are; 1992, 1994, 2007 and 2016. The consumption decline was mostly attributed to increase in price of foreign rice and policy reforms which also affects directly the prices of the locally produced variant (IFPRI, 2017; Steve et al., 2013; Stifel, & Randrianarisoa, 2004). Figure 1.3 shows an overall positive growth rate in rice consumption over the period of 1990 - 2019 in Nigeria.

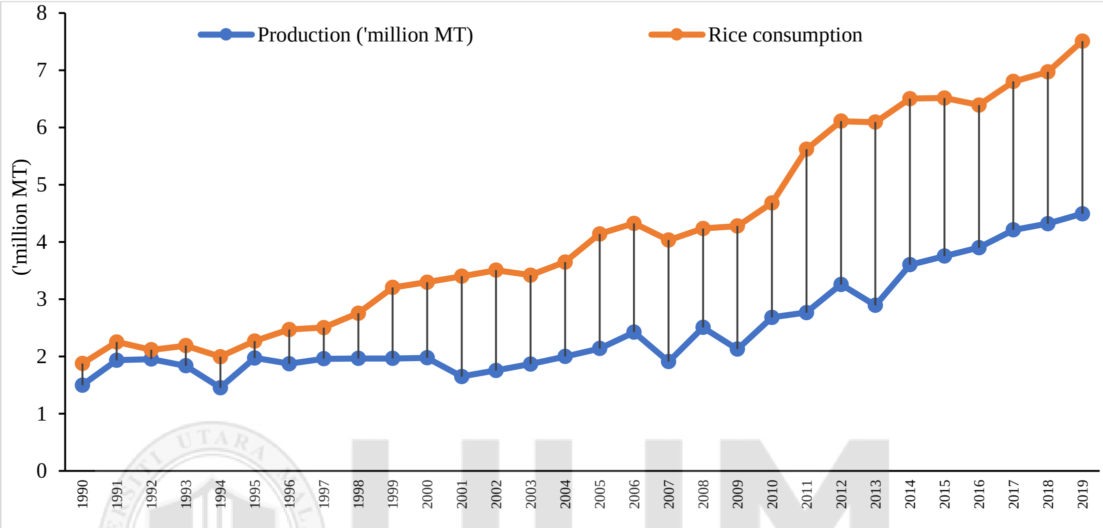

Figure 1. 4
Growth Rate of Rice Production and Consumption, (1990 - 2019)
Source: OECD-FAO, 2020.

According to Figure 1.4, the gap between the domestic rice production and total consumption have continued to widen up between the period of 1990 to 2019. Production have increased from 1.5 million MT in 1990 to a value of 4.49 million MT in 2019, thus indicating a gap of 3.1 million MT. The domestic production has failed to meet up current demands hence, the high dependence on import. As a result of the increasing consumption needs of rice in Nigeria, the Government resorted into import to supplement the shortage in local production of rice. This large gap between production and consumption have persisted despite Nigeria's land capacity and human capital for sufficient rice production.

The land characteristics across Nigeria's six AEZs provide suitable environment for rice production. These AEZs is described by FAO as boundaries or demarcation of sub national regions based on soil type, vegetations and climatic characteristics. Thus, AEZs offer a standardized support for the characterization of climate, soil, and terrain conditions relevant to agricultural production. The diversity in terms of temperature, rainfall and growing seasons among AEZs in Nigeria supports the production of numerous crop types as indicated in Table 1.1. The volume of rainfall decreases from 3000 mm in the humid forest to around 500 mm in the Sahel savanna. Also, there is a break in rainfall marking the period of dry season every year. This occurs within a range of three to eight months depending on the AEZs. Whereas the dry period or season varies from high rainfall areas in the south (humid forest) to the driest areas in the north such as the Sahel savanna. In terms of temperature, Nigeria generally experiences uniformly high temperature throughout the year.

Table 1. 1
Temperature range, Rainfall and Growing Periods by AEZs.

S/N	**AEZs**	**Rainfall (mm)**	**Temperature (^{0}C)**	**Growing season in days**
1	Sahel Savanna	250-500	21-32	≤ 90
2	Sudan Savanna	500-900	25-30	91-150
3	Northern Guinea Savanna	900-1200	27-29	150-180
4	Southern Guinea Savanna	1200-1500	26-29	181-210
5	Derived Savanna	1500-2000	26-28	211-270
6	Humid Forest	2000-3000	25-27	270-360

Source: Akpa et al. (2016)

The AEZs in Table 1.1 are formed based on the variations in climatic and soil characteristics across Nigeria. The differences in climatic characteristics of the AEZs in Nigeria have accounted for the variations in terms of volume of rainfall and temperature across Nigeria. This implies the severity of impact of climate change will also vary by the nature of AEZs. Consequently, the productivity of food crops such as rice that are produced across these AEZs will be differently impacted by climate change (Anubhab & Kavi, 2020). Especially, when the wide variation in farming technologies and practices in the AEZs are also considered. Overall, these observed differences across AEZs such as the climate types and farming techniques will in turn define the ability of each AEZ to adapt to climate change and improve productivity.

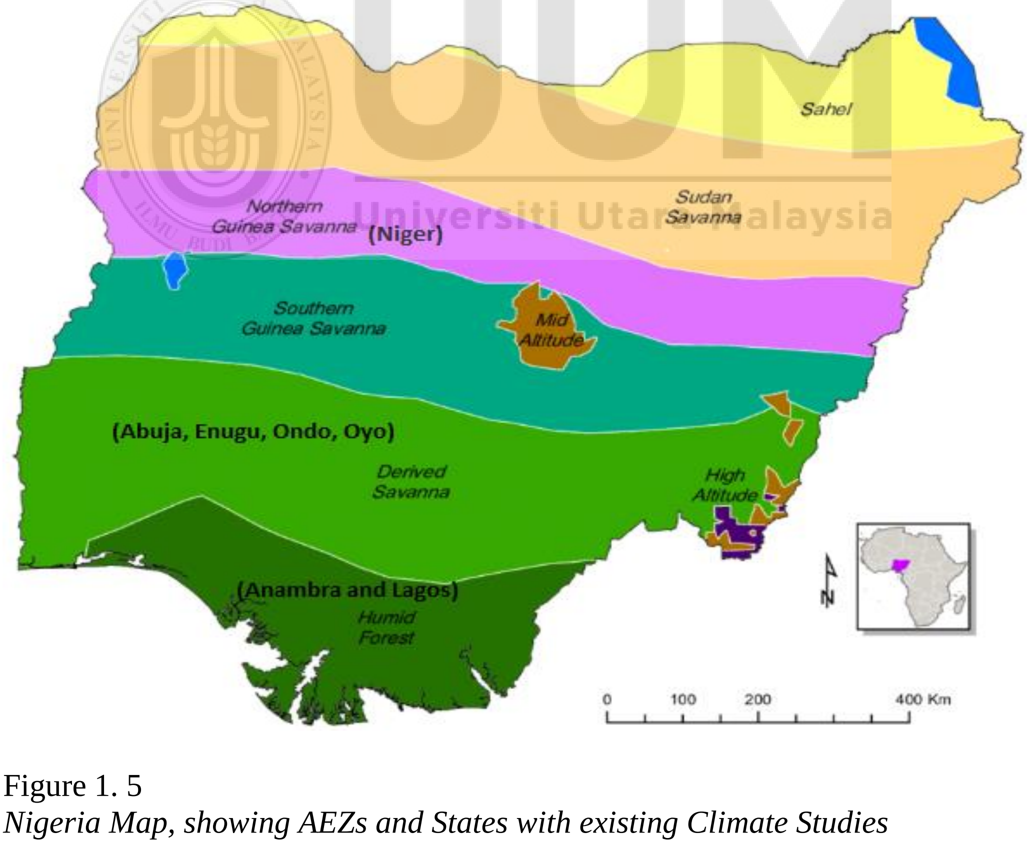

Figure 1. 5
Nigeria Map, showing AEZs and States with existing Climate Studies
Source: Edited from Dawi et al., 2017.

1.3.1 Rice Productivity in Nigeria

Nigeria's rice productivity has been widely acknowledged to be low compared to productivity across the world. The average national productivity of rice in Nigeria was around 1.2 MT/ha in early 1960s with an area of about 0.20 million ha and an estimated annual production of 0.24 million MT (FAOSTAT, 2019). The production reached one million MT by 1980, this increase was mainly attributed to increase in land area rather than productivity improvement (Chamberlin et al., 2014). After 1980, rice productivity in Nigeria was on a steady increase until it reached a peak of 2 MT/ha by the year 1987. While from the year 1987, rice productivity has continued to decline, with only a slight increase to about 2.1 MT/ha in recent times (FAOSTAT, 2019). Government neglect of the sector for the booming petroleum sector could have accounted for the decline (Garba, 2013). Although, studies (Sibiko & Qaim, 2019; Tadesse et al., 2019; IITA, 2017) have indicated that low input usage, failed national efforts and policy inconsistencies had led to the undesired outcome of low productivity growth (Garba, 2013; FAO, 2016).

The productivity increase in Nigeria has been insignificant and unable to meet up the average productivity rate in the world or even some countries within the Africa's region (FAO, 2016). Increase in total output has always resulted from expanding production area with only a meagre contribution from improved productivity. As a result, the total output of rice from domestic sources has failed to meet up the local consumption need in the country. In view of the stagnation in growth of rice productivity and the inability to meet the rising consumption demands that has consequently, subjugated the country into becoming heavy import dependent, the

Government of Nigeria have continually directed national resources and effort towards improving productivity and attaining food self-sufficiency through various policy formulations.

1.3.2 Nigeria's Agricultural Input Usage

The majority of farmers constitute smallholders with small farm sizes, usually between 0.01 and 2.0 ha. These farmers also surfers from limited resource inputs and produced mostly at a subsistence level. Among necessary farm inputs are fertilizer, improved seed varieties, agrochemicals (pesticides, herbicides, and fungicides), irrigation, animal power, and mechanized farm equipment (Sheahan & Barrret, 2017). The average inorganic fertilizer use rate is 26 kg/ha (equivalent to 57 kg/ha total fertilizer) (Sheahan & Barrret, 2017). While FAOSTAT reported an average fertilizer use of 2.6 kg/ha, based on the Living Standard Measurement Study-Integrated Surveys on Agriculture (LSMS-ISA), the average fertilizer use is 64.3 kg/ha.

In terms of irrigated agricultural area, the FAO reported a total land area of 218,800 ha representing just 0.61% of the land area. While the LSMS-ISA reported a value of 274,681 ha representing 2.5% of entire land, although the irrigated area increases to 4.1% of total land area when private irrigations are captured. The number of tractors is estimated at 24,800 by FAOSTAT, while the LSMS-ISA reported 449,688 tractors with only 1.6% of the farming household owning a tractor. The average number of labour use depends on the technique of plant adopted, but on average, the mean value for labour in broadcasting is nine persons/ha, that of drilling is 23 persons/ha and for transplanting and nursery management the mean value is 34 persons/ha (Erenstein, et al., 2003).

Much of the sustained agricultural growth necessary for economic transformation comes from expanded input use, especially modern inputs—like the improved seed, fertilizers, and other agrochemicals, machinery, and irrigation—that embody improved technologies (Sheahan & Barrret, 2017). Irrigation and mechanization technologies have received far less policy attention, potentially translating into stagnation or even reversing prior progress in expanding their use (Sheahan & Barrret, 2017). Nigerian governments have considered the level of fertilizer use across the country as low (Liverpool-Tasie, et al., 2017). Studies have observed that the average inorganic fertilizer use rates are generally above the wide perception (Sheahan & Barrret, 2017; Liverpool-Tasie, et al., 2017). Given the low usage level, the government has tried to stimulate fertilizer demand by growing the commercial fertilizer sector and lowering fertilizer prices (Rashid et al., 2013; Minot & Benson, 2009). The strategies include fertilizer subsidies, extension services to develop soil fertility management technologies, and programs to increase farmers' access to credit, such as the growth enhancement support scheme (GESS).

1.3.3 Nigeria's Agricultural Policies and Rice Productivity

Rice is considered a priority crop and often times considered to be synonymous to food security in Nigeria (FAO, 2014). Thus, Nigeria have continually directed national resources and effort towards improving rice productivity and attaining food self-sufficiency. Government policies on rice in Nigeria are characterized as inconsistent

(Seguin 2008; Costello et al. 2009; Karl et al. 2009). This is because, successive Government kept changing policies in search of a better policy framework to enhance self-sufficiency level (SSL) (Boansi, 2013).

Despite decades of policies directed towards the goal of self-sufficiency in rice production, the issue of low productivity of the Nigeria's rice sector still continue to override national efforts to enhance productivity (see Figure 1.6). Boansi (2013), reported in his study that rice policies for Nigeria is focused primarily on raising the level of domestic output and to attain self-sufficiency in rice (even though it remains a challenge today).

Generally, the Government policy tools towards the attainment of the objective of rice SSL are in three categories. The use of subsidies to producers, trade policies (in form of tariffs, quantitative restrictions (quota) and outright ban on imports) and more recently policies to enhance climate change adaptation. The adaptation technologies involve deployment of innovative technologies to strengthen national resilience to climate change. Similarly, the trend in the agricultural policies related to rice productivity in Nigeria can be categorized into three: trade policies, subsidy policies and policies on climate change (adaptation technologies or policies).

Rice trade policies in Nigeria are broadly grouped under three periods: the "Pre-ban" (1971-1985), "Ban" (1984-1995) and the "Post ban" (1995-date) periods (Akande, 2002). The ban period signifies the total ban on the importation of rice into Nigeria, while the other two (pre-ban and post ban) are the periods before the total ban and after the total ban on rice import respectively. While during each of the period, a number of policies are formulated, this will be explained in detail based on Table 2.2 in Chapter Two.

Aside from the trade policies another vital policy is the input subsidy policies in Nigeria. The subsidy policies are directed towards improving domestic productivity and recent examples includes: The Growth Enhancement Support Scheme (GESS) which is a policy initiative under the Agricultural Transformation Agenda (ATA) by the immediate pass administration in 2013. More recently is the Agricultural Promotion Policy (APP) covering (2016 - 2020), under this policy is the Anchor Borrowers Program for promoting dry season rice production through credit provision and improved input supply.

The third agricultural policy relates to climate change and it is covered under the "National Adaptation Strategy and Plan of Action for Climate Change Strategies, Policies, Programs and Measures" (NASPA). The NASPA constitute several strategies and technological innovations (such as development of portable irrigation schemes, early warning systems on climate change and climate tolerant crop varieties). In the NASPA three strategies are outlined towards developing a climate resilient agricultural sector.

The first strategy under NASPA involves the adoption of an improved system of agriculture for crops and livestock alike. Under this we have; the diversification of livestock and improving system of range management; provision of new crop varieties that are tolerant to drought, improved livestock feeds; adopting of better soil management practices; and providing early warning/meteorological forecasts and related information). Second strategy under NASPA involves the implementation of innovative strategies for natural resources management; increased use of irrigation potentials and efficient water use; rainwater harvesting and sustainable ground water use; promotion of re-greening efforts. Finally, the third strategy laid emphasis on water management in the savanna zones especially the Sahel savanna zone. This is justified by the high risk of impact on the agricultural sector in that zone.

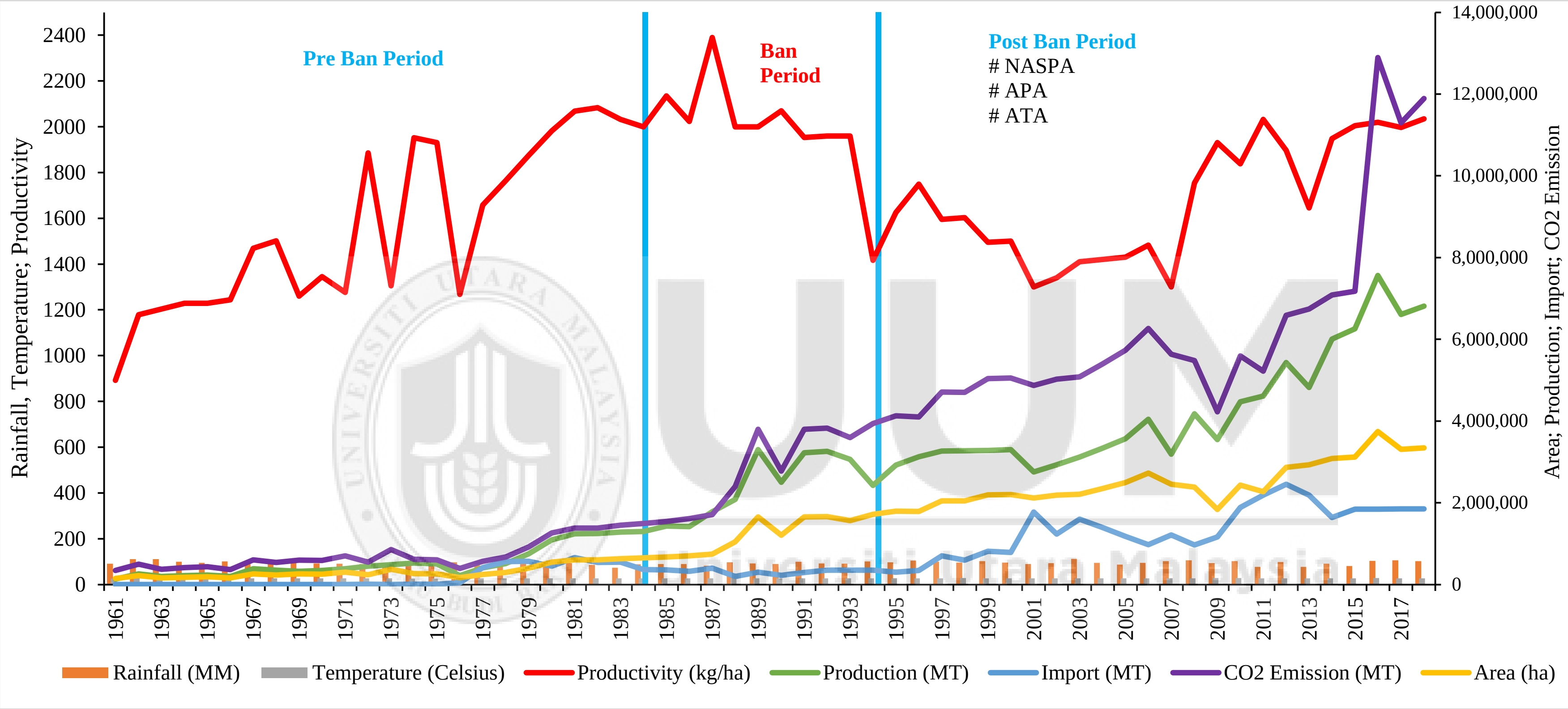

Figure 1. 6

Rice Productivity, Climate Factors, Production and Import from 1961-2016

Source: Constructed using data from FAOSTAT, 2019; World Bank Group 2018

Figure 1.6 presents the trend of rice productivity, production, import, policies and temperature, rainfall, and CO_2 emission as measures of climate change. Based on policy period, the graph is divided into three sections which are; the pre-ban, ban and post ban periods. The first section is known as the pre-ban period and span from 1961 – 1984. This is the period prior to the total ban of rice import into the country. During the pre-ban period, series of other policies in the form of tariffs, import quota and restriction of import license were used to control import, this is shown in Table 2.1, Chapter Two.

The second section of the graph is known as the ban period; this lasted from 1985 - 1994 and represents the total ban of rice import in Nigeria, while the structural adjustment program was also introduced during that period. The last section then covers from 1995 till date and marks the period after the total ban of rice import in the country. During this period there are series of other policies in the form of partial import restriction, producer-oriented policies (input subsidies such as Growth Enhancement Support Scheme (GESS), Anchor Borrowers Program (ABP), and different tariff values).

As a result of the low productivity and the inability of domestic production to meet up local demand, rice import has dominated the country's food import. Importation of rice became the dominant alternative employed by Government in meeting domestic needs. Whereas the enormous potential for domestic rice production considering availability of human capital and land resources have been underutilized. Thus, Nigeria gradually drifted from 100% SSL into a major import dependence. The historical trend of rice import arising thereof will be briefly discussed.

According to FAO statistics, in the early 1960s, Nigeria was at 100% SSL in its rice production. Nevertheless, as a result of higher demand for rice around 1970, the rate of import increased exceptionally. Import then declined from 1981 motivated by policy measures by the government to reduce the rising importation of rice, particularly higher import tariffs. Even though, the value of the then annual imported rice at an annual basis was over 0.3 million MT. Also, the imports quantity dropped considerably from 1985 as a result of the embargo placed on import of rice between 1985 and 1994. Shortly again import began to increase continuously, the continuous rise in import then gave rise to the adoption of many policy instruments aimed at improving local productivity and reduce import, with no significant improvement.

In the 2008 report of the Nigerian Export Promotion Council (NEPC; 2008), about 5 million MT of rice was the estimated domestic demand out of which 2.1 million MT is imported into the country. While FAO (2008) estimated the country's illegally imported rice at 0.8 million MT, adding this to the official import, raises the import figure to about 3 million MT, while Nigeria's domestic production remains approximately 2 million MT. In 2011, the total domestic demand was 5.2 million MT. Whereas more recently, according to FAO (2017), Nigeria's population of over 180 million was estimated to use nearly 6 million MT of rice per year and just over 50% (3.1 million MT) was imported. The heavy importation have positioned Nigeria as the third with Iraq (after the Philippines and China) in the group of major rice importing countries in the world (Ojo, Ogundeji & Babu, 2020).

The challenges of Nigeria's dependence on rice import are enormous. These challenges include but not limited to the high depreciation of Nigeria's foreign exchange. Nigeria spent only about USD 0.2 million (0.0045% of GDP) on rice importation in 1961, by 1972, the value of import rose to USD 1.68 million (0.014% of GDP). Since then, the value has grown to USD 1.2 billion (0.30% of GDP) by 2011 (Ayanwale & Amusan, 2011). Akande (2001) also estimated Nigeria's annual expense on rice import alone at over USD 300 million. According to FAO (2017), Nigeria spends close to USD 10 billion (0.014% of GDP) as shipment cost only for food importation annually, while about USD 1.8 billion (0.025% of GDP) is spent as cost of rice shipments annually, rice also accounted for 1.26% of the entire budget. If this amount has been invested in improving local agriculture, this could help improve the low productivity and as well generate employment as well as diversifying the economy (Ogbalubi & Wokocha, 2013). Hence, the issue of persistent low productivity of rice in the Nigeria continues to pose numerous problems to the Economy of Nigeria as captured in the problem statement of this study.

1.4 Problem Statement

Africa's food production system is the least productive in the world, and Nigeria's rice sector is particularly noteworthy. Nigeria is Africa's most populous country, with the highest rice consumption and a leading producer. Nigeria's productivity, on the other hand, remains below the global average. Nigeria's current average productivity of 2.1

million tonnes per hectare is about 50% lower in comparison to the global average of 4.2 million tonnes per hectare. Thus, food deficit has persisted indefinitely in the phase of increasing demands. As a result, Nigeria has maintained a strong global import profile, ranking third in 2019 behind China and the Philippines. Nigeria faces significant economic consequences as a result of this situation.

Economic consequences include the local industry's lack of competitiveness, resulting in low income generation for local rice farmers, and increased unemployment. This is in addition to the enormous financial burden on Nigeria’s economy. Nigeria imported food worth over USD 6.52 billion (1.6 percent of GDP) in 2018, with rice accounting for USD 8.8 million (FAO, 2019). This enormous financial burden may not be sustainable in light of Nigeria's declining oil revenues, rising population, unemployment, and increased demand. Additionally, import dependence subjects the food security of Nigeria to global shocks.

Evident from past global pandemic and recent COVID-19 pandemic import dependence is unsustainable especially for resource endowed country like Nigeria. Global events such as the recent border closure in response to the current COVID-19 pandemic and escalating food import costs, as witnessed during the previous 2007/2008 food crisis all jeopardised food security. Thus, demonstrating the critical importance of investing in domestic productivity in Nigeria. Especially given the potential for rice production across Nigeria's over 84 million hectares of arable land, which span the entirety of the AEZs. This ensures sustainable resource utilization, food sovereignty, more income and employment generation.

However, the Nigerian government's series of national efforts aimed at increasing domestic rice productivity have not yielded the desired results over time. This is mostly attributed to institutional factors that includes corruption, and policy instability. Existing theoretical and empirical literature have also highlighted productivity constraints such as low input utilization, the threat of climate change, government policies, and the weak state of adaptation. Importantly, as a global challenge, climate change poses a significant threat to rice productivity (Wiebe et al., 2015; IRRI, 2018; Castells-Quitana et al., 2015; FAO, 2016). By 2050, the IFPRI projects that climate change will reduce rice productivity by 14% in South Asia and 10% in East and Pacific Asia. African countries, more precisely Sub Saharan Africa (SSA), have also been projected to experience a 15% decline (IRRI, 2018).

While government policies such as input subsidy ensure access to production inputs, and trade policies also drive investment in the agriculture. Thus, policies are strong determinant of productivity in the sector. However, for Nigeria, corruption and government/policy instability modify these goals by diverting resources meant for public purposes to personal use. While extant literature has examined how these factors (corruption and government instability) influence various economic sectors (Krueger et al., 1991; Anik et al. 2017; Trabelsi & Trabelsi, 2019; Shittu et al., 2020). The literature is scanty in the case of agriculture or the rice sub-sector. Additionally, while government have committed to climate change adaptation technologies through national policies (such as NASPA) however, there is under investment in capital equipment or technology in relation to Nigeria’s climate change adaptation. This is mainly attributed to institutional factors such as policy instability, inconsistency, and corruption which interferes with the effectiveness of these policies over time. Consequently, the level of adoption and use of these technologies are considered low and inefficient in Nigeria (Igudia, 2017; Akinbamowo, 2013).

Despite the volume of studies on rice productivity constraints, several limitations exist among the extant literature. Compared to other economic sectors, there is a scarcity of studies relating the effect of institutional factors (corruption, government and policy instability) on productivity in the agricultural sector. Also, even though, several studies have examined how climate change threat impact agriculture, they mostly ignore how the impact and vulnerability differ by crop types (Islam, Tarique & Sohag, 2014). Additionally, an important factor neglected by foremost studies on the nexus of climate change with productivity is the consideration of existing differences across AEZs. However, it is biased to assume homogeneity between AEZs especially since the AEZs differ in climate, soil, and vegetation types. This implies the maximization of productivity requires the deepening of contextual knowledge of climate change impact at the AEZ levels (Steynor & Pasquini, 2019; Anubhab & Kavi, 2020).

Thus, it is concluded that a critical assessment of the important determinants of rice productivity in Nigeria at the sub-national level, such as the AEZs, is key to effective robust policy development. Furthermore, practically none or little has been done in interacting these important factors in a model as determinants of rice productivity in Nigeria. Therefore, the study contributes to the world food challenge that has currently left over 26.4% of the world population in moderate to severe food insecurity. Overcoming these challenges especially among the vulnerable populations of the world is critical for inclusive growth and sustainable development. Especially in Africa which is home to over 674.5 million of the world population suffering from moderate to severe hunger and over 250.3 million people suffering from undernourishment (FAOSTAT, 2020).

1.5 Research Questions

In view of the highlighted problems and the efforts by the Nigerian government to boost rice productivity and the impending complications from climate change impact in the sector with further consideration of the limitation of existing studies in covering the different AEZs, the current study is proposed to provide insight unto these research questions and objectives:

1. What are the types of climate changes, adaptation technologies and policies, influencing rice productivity?
2. What are the impacts of climate change, adaptation technologies and Government policies on rice productivity?
3. What are the impacts of climate change, government policies and adaptation technologies on rice productivity among the AEZs?

1.6 Objective of the Study

The main objective of the study is to assess the impact of climate change, policies and adaptation technologies on rice productivity across AEZs in Nigeria. While the specific objectives are to:

1. Describe the types of climate changes, adaptation technologies and policies, influencing rice productivity;
2. Assess the impacts of climate change, adaptation technologies and Government policies on rice productivity;
3. Measure the impact of climate change, government policies and adaptation technologies on rice productivity across the different AEZs of Nigeria.

1.7 Scope of the Study

The economic implications of climate change impact on rice production is considered in this study and rice is selected because of its strategic position and role in food security across several countries including Nigeria. The variables of interest in this study includes climate change (carbon emission, temperature, rainfall and flood intensity), government policies (trade policy, government stability and corruption) and adaptation technologies (irrigation capacity and NASPA). The study is at the level of the AEZs of Nigeria, the AEZs mark the boundary between climate and soil types within the same country (FAO, 2009).

The measure of rice productivity or yield as used in this study refers to the output of rice per unit of land area which is a partial factor productivity. Kazungu, (2009) asserted that productivity is a satisfactory measure of relative economic efficiency. Other reasons for focusing on land productivity are; first, data limitation (such as; data on labour force in rice production, input usage, and machineries). Second, the theoretical justification on which trade liberalization policies originate would tend to suggest that low income countries are efficient in land based activities. Hence, besides data considerations, the theoretical underpinning provides adequate rationale for carrying out this analysis. Third, since about 70% of Nigerians are predominantly small holder farmers whose livelihood hinges on land based activities, the question of climate change and trade policies versus land productivity becomes paramount.

The study employs panel data covering the periods from 1980 to 2018. The justification for using 1980 as the starting period is due to the availability of data. Although the study is able to obtain longer timer series data for the climate change variables such as temperature, CO_2 emission, rainfall and policies, however the availability of production data, adaptation technologies are made available from 1980 onwards.

1.8 Significance of the Study

The issue of how the global changes in climate affects agriculture is critical. The challenge posed by the current trend of climate change has the tendency of affecting the global supply of rice and consequently higher price response. Nigeria's agriculture is already under significant pressure to meet the demand of rising population using finite, water resources and often degraded soil, which are now further stressed by the challenges of climate change (Awotoye & Mathew, 2010). Research into issues of climate change as it relate to rice productivity, such as establishing the magnitude of and variation in productivity associated with climate change across the different AEZs is of priority. This will enhance management design of interventions aimed at boosting rice productivity, alongside the policy instrument towards enhancing the national interest of self-sufficiency in rice production.

Further again, there is a serious campaign by the government to transform agricultural sector of the country to the initial position of self-sufficiency in major cereal crops especially rice as it was in the early 1960s. Hence any policy target on rice will in addition to enhancing productivity, food security and income also help in minimizing hunger and poverty. Projections of the consequences of climate change, adaptation technologies by AEZS, and Government policies in enhancing farmer's productivity are valuable for policy making towards enhancing adaptation and rice productivity at AEZs level.

1.9 Organization of the Thesis

This thesis consists of six chapters. Chapter two focuses on providing more details with regards to the Nigeria agricultural production system and economy, the different AEZs in Nigeria, relevant Government policies and climate change adaptation technologies. Specifically, this chapter aims at providing a deeper understanding the rice productivity issue in Nigeria.

Chapter three entails comprehensive review of relevant literatures on the important variables of the study. These are rice productivity as the dependent variable, and other factors such as climate change, various government policies (such as trade policies and input subsidy policies) and different regional adaptation technologies. These are important factors identified to influence the productivity of rice. Also in this chapter are the reviews of related theories such as the production-function theory, Ricardian model, anthropogenic global warming theory and the environmental Kuznets curve theory.

Chapter four involves development of research framework based on the theoretical and empirical reviews. The chapter then explicates the methodology that will be employed in this study. The chapter starts with introduction, data collection procedure then the conceptual framework, followed by other sections such as specification of the theoretical model, empirical forms of the model and method of estimation and finally ends with a summary of the methods for each objective. While chapter five presents the findings and discussion of the research based on the methodological design of the study. Chapter five covers the results of the preliminary tests, cross-sectional dependence, unit root tests, and cointegration test. The result of the Hausman test followed, then the descriptive result, and finally both long and short-run estimates of the PMG. As the last, chapter six covers the conclusion and recommendations that are based on the findings reported in preceding chapter. This includes a summary of objectives, conclusions and recommendations at the level National level and also at the AEZs level.

CHAPTER TWO

OVERVIEW OF CLIMATE CHANGE AND NIGERIA'S AGRICULTURE

2.1 Introduction

The current chapter is focused on providing an insight into the Economy of Nigeria, its agricultural potential, the historical trend and role of rice sector in Nigeria's economy. The section thus includes section 2.2 which provided a glance on Nigeria economy; then section 2.3 which describes rice consumption and self-sufficiency level in Nigeria; the next section 2.4 covers the Nigeria rice production and import; this is followed by section 2.5 presenting Nigeria's policies and initiatives on rice production in Nigeria; section 2.6 Nigeria's agriculture and climate change and finally section 2.7 which entails Nigeria's climate change policy framework**.** Climate change issues will also be discussed with emphasis on the sensitivity of the country to climate change and how it has impacted on the production of Nigeria's food staple specifically rice. It will also analyse the implication of climate change to Nigeria's attainment of self-sufficiency and food security as related to rice productivity.

2.2 Nigeria at a Glance

The position of Nigeria is between coordinates 2°49' E - 14°37E and 4°16N 13° 52 N and is in climatic region is the humid tropics. It has a land zone of 923, 850 km. The largest nation in Africa with a population evaluated at 190 million individuals (FAO, 2017). The nation has the 27th greatest economy on the planet, with a total national output (GDP) of USD 486.7 billion starting at 2015 (World Bank, 2015). Nigeria is as well the biggest economy in Sub Saharan Africa (SSA). Nigeria is a lower middle-income developing nation, with the per capita GDP in current USD of about USD 2,950. The economy is expanding at an average of 6% every year.

In terms of agricultural land, Nigeria is comprised of 84 million hectares of arable land while, just 40% is cultivated of which rice production covers just 10%. Nigeria is a short fall in the food demand for sustenance. Over 70% of Nigeria's populace are engaged in agriculture as their essential occupation and means for livelihood. Nigerian food sector is essentially of rainfed nature and described by low productivity, low innovation and labour intensive work (IITA, 2017).

Table 2. 1
Average Rice Productivity and Production by AEZs in Nigeria (2004)

AEZs	**Productivity (MT/ha)**	**Total Production**	**% Contribution**
Sahel Savanna	1.09	264.30	6.18
Sudan Savanna	1.32	433.30	10.13
Northern Guinea Savanna	2.02	1344.10	31.43
Southern Guinea Savanna	2.11	380.90	8.91
Derived Savanna	1.97	1432.80	33.50
Humid Forest	2.38	421.00	9.84
Total	1.81	4276.40	100

Source: Adapted from Ajetumobi et al., 2015

2.3 Nigeria Rice Production and Import

The potential land size for rice cultivation in Nigeria is evaluated at 4.6 to 4.9 million hectares. Be that as it may, just about 1.7 million hectares of this land is being used to produce rice (WARDA, 2000). Although the contributions of each AEZs varies, rice is produced in all AEZs in Nigeria as shown in Table 2.1. With the Derived Savanna having the highest contribution and the lowest contribution from the Sahel savanna. Notwithstanding the rice production capacities of the AEZs, the area cropped to rice still remain inadequate. In 2000, out of around 25 million hectares of land cultivated to different arable crops, just about 6.37% was for rice. At the same period, the average national productivity was 1.47 MT/ha against the world normal of 3.5 (FAO, 2006).

The value of domestic rice production in Nigeria is evaluated to be around 3 million MT while the domestic demand for rice is around 5 million MT which has prompted a tremendous demand – supply gap of around 2 million MT of rice yearly, thereby motivating the reliance on importation to fill the current gap (Akande, 2002; Erenstein, et al., 2004; Amaza and Maurice, 2005; Daramola 2005, Awe, 2006). As indicated by the United Nations Food and Agriculture Organization (FAO), the nation imported 2.3 million MT in 2016, about 50% of the nation's evaluated needs.

Lately, rice production has been extending at the rate of 6 - 7% per annum in Nigeria, with 70% of the increment predominantly due to extension of land area, with just 30% being ascribed to an expansion in productivity (Fagade, 2000; Falusi, 1997; WARDA, 2007; Okoruwa et al., 2007; IFPRI 2017). The extension of land territory to expand rice production in Nigeria leads to the expansion in amount of the emitted GHGs to the environment leading to changes in our atmosphere. Despite the fact that the generated increment in rice production has not been sufficient enough to take care of the consumption demand of the constantly expanding population of Nigeria. The demand for rice has been expanding at a higher rate in Nigeria faster than in other West African nations since the mid-1970s. This has pushed the country from been self-sufficient in rice production to become import dependent.

2.4 Rice Consumption and Self-Sufficiency Trend in Nigeria

Compared to other parts of West Africa, rice demand has continually been rising at a faster pace in Nigeria as early as mid-1970s. This has pushed the country from been self-sufficient in rice production to become import dependent. The per capita consumption trails are below that of the sub region: in Nigeria per capita consumption are 3, 12, 18, 22, and 29 kg per capita for the range of years 1961 – 75, 1976 – 83, 1984 – 95, 1996 – 99 and 2000 – 2007 respectively. While, the regional consumption trends of 21, 27, 30, 34 and 35 kg per capita per annum for the same years. SSL were 99% (1961 – 75), 54% (1976 – 83), 77% (1984 – 95), 79% (1996 – 99) (Akande, 2002; Akande et al., 2007).

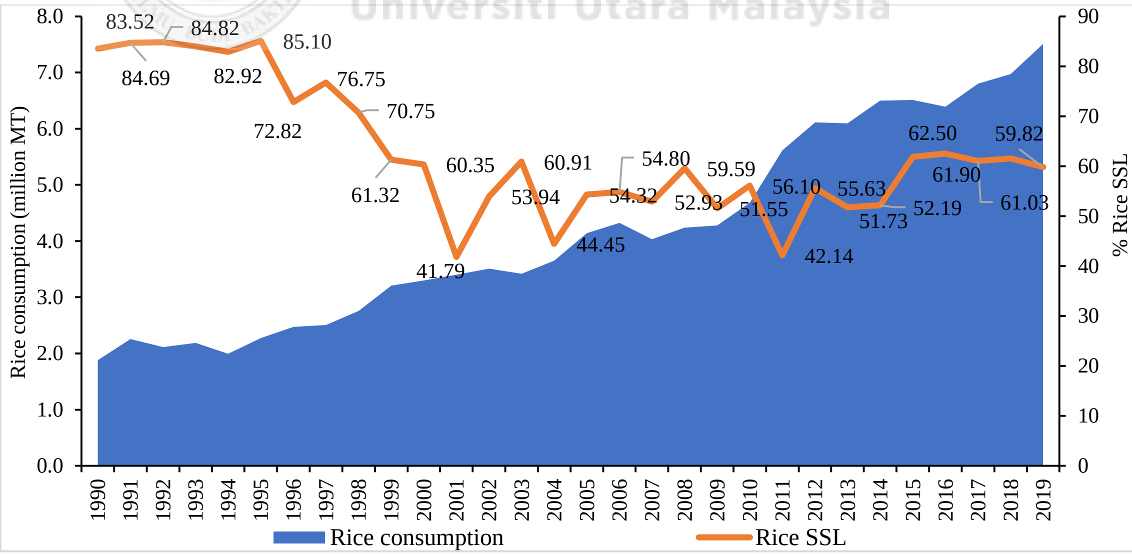

Figure 2. 1
Nigeria's rice self-sufficiency level in (%) (1990 - 2019)
Source: Constructed from FAOSTAT Data

2.5 Agricultural Policies and Rice Production in Nigeria

The Government of Nigeria has targeting the goal of revitalizing the agricultural sector in order to achieve self-sufficiency in its major food crops including rice. That is, to make Nigeria self-sufficient in its major food crops and less reliant on food imports. The general approaches adopted to achieve this agenda was to increase the production and productivity of the country's five key crops, including rice, sorghum and cassava. A number of food import substitution policies and measures were adopted to achieve this goal. Based on the targeted activities, Nigeria's rice policies can be broadly grouped into; producer-oriented and trade-oriented policies.

2.5.1 Producer-oriented Policy Decisions

Several policies have been directed towards supporting agricultural producers (Akpan, Emmanuel, & Patrick, 2015). These policies are basically concerned with boosting local production through credit provision and input supports to producers and research collaborations. More recently in 2012, the government launched the Agricultural Transformation Agenda (ATA) whereby input availability and access were supported in the framework of the ATA. The onset of a new policy termed Agricultural Transformation Agenda (ATA) transformed issues relating to input delivery challenges, build up famers' adaptation to different shocks and also improved credit availability so as to improve agricultural production. Through the ATA policy the usual procedure of direct procurement of fertilizer by government was reverted to private sector driven process. Contrary to the decades of practice in which high dependence on price subsidies has hindered market development in Nigeria.

To address the issue and consequently boost fertilizer usage in 2012, the Nigerian Government introduced a new policy under ATA known as Growth Enhancement Support (GES). Under the GES, farmers were offered 50% subsidy on fertilizer and hybrid seeds procured directly from designated Agro dealers. This was aimed at facilitating a shift to commercial farming against subsistence farming. Under the past framework, state governments' straight forwardly secured fertilizer from merchants and dispersed subsidized fertilizer to farmers. With the GES plot, the administration changed its job and started facilitating procurement, reviewing fertilizer quality, and assembling dynamic private-division support in the fertilizer esteem chain. Farmers currently get their sponsorships by means of a cell phone medium called the "e-Wallet" by vouchers.

Beneficiaries altogether; reached 1.2 million farmers in 2012 and around 5.2 million in 2013. The target was to cover 20 million agriculturists in the subsequent years. In 2012, the legislature likewise propelled (as a feature of the GES Scheme) the principal database of farmers to advance the proficient and compelling dissemination of subsidized seeds and fertilizers; create more extensive markets for farming sources of information and increment horticultural efficiency. The major challenge is that, these policies are highly inconsistent due to the fact that successive government kept revising existing policies even though the goals remain the same. Again, the usual inconsistency in policies was exhibited as the ban was partially lifted in October 2015.

After the change of Government in 2015, the ATA was replaced again in 2016, the new government introduced a Green Alternative: which was termed Agriculture

Promotion Policy (APP, 2016– 2020), which considers the horticultural part a key instrument to long-haul financial development. It means to organize explicit harvests; help horticultural development through private area drove business; fortify product esteem chains; enhance advertise introduction through foundation and ware trades; standard environmental change measures and ecological manageability into rural advancement; and execute nourishment intercessions for defenceless gatherings.

2.5.2 Trade-oriented and Macroeconomic Policy Decisions

Throughout the years, policies related to agricultural trade in Nigeria has continued to vary between liberal and protectionist regimes. The use of tariffs as well as import substitution tools such as (fertilizer and seed input subsidies) marks the primary trade policy instruments. Nigeria has been adjusting its tariffs to the Economic Community of West African States (ECOWAS) basic outside duty (CET). In 2017, Nigeria started arrangements to uphold the Continental Free Trade Area (CFTA), which tries to increase the intra-African trade, encourage free trade and accomplish more prominent territorial reconciliation.

The trade-oriented policies related to rice production in Nigeria can be broadly grouped into 3 different periods. According to Emodi & Madukwe (2008) in their report on the review of rice policies in Nigeria, the periods are classified as the pre ban period, ban period and the post ban period. The rice policies are marked by persistent inconsistencies ranging from high tariffs on rice import, import restrictions or complete ban, another issue highlighted in the study is the lack of involvement of stakeholders in the policy formulation process. The pre ban and post ban period of rice policies in Nigeria are similar. This period marks different tariff regimes. While the ban period involves use of policies that completely bans importation of rice into the country. The summary of these policies is presented in Table 2.2.

Table 2. 2
Summary of Rice Trade Policies in Nigeria (1974 - 2014)

S/N	PERIOD	POLICY MEASURES
	Pre-ban period	
1	Prior to April 1974	66.6% Tariff
2	April 1974-April 1975	20% Tariff
3	April 1977 - April 1978	10% Tariff
4	April 1978-June 1978	20% Tariff
5	June 1978-October 1978	19% Tariff
6	October 1978-April 1979	Imports in containers under 50kg were banned
7	Apr-1979	Imports placed on restricted license only for Govt. Agencies
8	Sep- 1979	6-month ban on all rice imports
9	Jan-1980	Import license issued for only 200,000 metric MT of rice only
10	Oct-1980	Rice under import restrictions with no quantitative restrictions
11	Dec-1980	Presidential Task Force (PTF) on rice was created and issued allocations to customers and traders through Nigeria National Supply Company (NNSC)
12	May-1982	PTF began the issue of allocations directly to customers and traders in addition to those issued by NNSC
13	Jan-1984	PTF Disbanded and rice importation placed under general license
	Ban Period	
1	October 1985 to 1994	Importation of rice banned as Structural Adjustment Program was introduced and all commodity boards were disbanded
2	1995	100% Tariff
3	1996-2000	50% Tariff
4	2001	85% Tariff
5	2002	100% Tariff
6	2003	150% Tariff
7	2004	75% Tariff
8	2005-2006	100% Tariff
9	2007	109% Tariff
10	2008	0-30% Tariff - This was 0% Jan - Sept, and 30% by October
11	2009	30% Tariff
12	2010	30% Tariff

13	2011-2012	50% Tariff
14	2013	110% Tariff
15	2014	110% Tariff

Source: Akande 2011; Ajetumobi, 2015.

2.5.3 Infrastructure and Technology Related Policies and Development

Nigeria's agricultural sector suffers from an infrastructure and technology deficit challenge. Infrastructures such as access roads, irrigation schemes, and machineries are grossly considered insufficient (FMARD, 2016). Since early 1970's, the Government have made effort towards developing the agricultural sector through infrastructural and technological support to enhance productivity growth and enhance the nation's food security. These efforts involves; support to rural infrastructural development; the development and maintenance of large dams and their auxiliary infrastructure; provision of support to state and local government in the development and maintenance of small and medium scale dams for maximum use of irrigation water.

Despite the interventions, the Nigeria's agriculture continues to surfer the challenge of low technology use as existing technology are mostly not adaptable to the local context or not affordable to the small-scale farmers making up the majority of the country's food producers. These issues hindered the ability of the sector to operate sufficiently or to drive the much needed productivity growth in sector. Several policies embarked on and implemented by government are either defunct or abandoned, and some restructured with more been introduced in recent time (Ugwu & Kanu, 2012). A review of these policies are presented in the following sub sections.

2.5.3.1 National Accelerated Food Production Programme (NAFPP)

National Accelerated Food Production Programme (NAFPP) was an agricultural extension programme initiated in 1972 by the Federal Department of Agriculture during General Yakubu Gowon's regime. The programme focused on bringing about a significant increase in the production of maize, cassava, rice and wheat in the northern states through subsistent production within a short period of time. As major staple foods of Nigerians, if produced in abundance, hunger and related food crisis will be put to check. This was achieved through the introduction of high yielding varieties, use of appropriate fertilizers, agrochemicals, good storage and processing facilities, provision of credit as well as marketing outlets.

2.5.3.2 Agricultural Development Projects (ADP)

ADP formerly known as Integrated Agricultural Development Projects (IADP) was earlier established in 1974. The ADP is the implementation organ of the state ministry of agriculture and natural resources. It is semi-autonomous and focuses on the small farmer. This approach to agricultural and rural development was based on collaborative efforts and tripartite arrangement of the federal government, state government and World Bank. The ADPs were established to provide extension services, technical input support and rural infrastructure to the farmers/rural dwellers. This concept involved the provision of Infrastructural facilities such as roads, schools, water supply in the rural areas at the right times in required quantity to farmers. The Activities of ADPs in Nigeria spread over three thematic areas; provision of infrastructural rural facilities, conducting worthwhile trainings on improved agricultural technologies and supply of farm inputs to enhance the technical and economic efficiency of small farmers in general.

2.5.3.3 River Basin Development Authorities (RBDAs) (1976)

There are eleven River Basins Development Authorities (RBDAs) which were created through decree No 87 0f 1979. Initially, their activities cut across most area of agriculture development but the mandate was later reduce to cover only water resource development and maintenance of irrigation, dams. The existing abundant water resources in the country and its potential for increasing agricultural production prompted the establishment of River Basin Development Authority (RBDA). The scheme became necessary because of persistent short rainy seasons in many parts of the country which has continued to restrict cultivation to only single cropping per year. However, with the establishment of various large-scale irrigation facilities the country witnessed unprecedented multiple cropping patterns.

2.5.3.4 Operation Feed the Nation (OFN)

This programme evolved on 21st May 1976 under the military regime of General Olusegun Obasanjo. The programme was launched in order to bring about increased food production in the entire nation. Some of these strategies included subsidized production inputs, increased bank credit to farmers, establishment of commodity boards and fixing of attractive prices for agricultural produce. Policy instruments include mass media, centralized input procurement, massive fertilizer subsidy and imports. Although successful in increasing the domestic food production, the programme lasted till another regime and was replaced the Green Revolution.

2.5.3.5 Green Revolution (GRP)

The programme was inaugurated by Shehu Shagari in April 1980 to increase production of food and raw materials in order to ensure food security and self-sufficiency in basic staples. The federal government ensured the success of the programme by providing agrochemicals, improved seeds/seedlings, irrigation system, machine (mechanization), credit facilities, improved marketing and favourable pricing policy for the agricultural products. Policy instrument include food production plan, in put supply and subsidy, special commodity development programme, review of Agricultural credit guarantee scheme, increased resource allocation to RBDAS etc. This ended by 1983 when military toppled the civilian government.

2.5.3.6 Agricultural and Rural Management Training Institute (ARMTI)

The Agricultural and Rural Management Training Institute (ARMTI) Ilorin, was established in 1980 by the Federal Government with a loan from the World Bank to build and strengthen human resources management capacity in the agricultural and rural sector of the Nigerian economy. The Institute became a parastatal of the Federal Ministry of Agriculture and Rural Development with the promulgation of Decree No. 37 of December 31, 1984, now Agricultural and Rural Management Training Institute (AMRTI) Act Cap 11 Vol. 1 Law of the Federation of Nigeria, 1990.

2.5.3.7 National FADAMA Development Project (NFDP)

The first National FADAMA Development Project (NFDP-1) was designed in the early 1990s to promote simple low cost improved irrigation technology under World Bank financing.

2.5.3.8 National Centre for Agricultural Mechanization (NCAM)

The National Centre for Agricultural Mechanization (NCAM) was established by Decree No. 35 of 1990. NCAM is mandated to mechanize Nigeria's agriculture by developing simple need-based and low cost technologies using locally sourced materials that reduces farmers' drudgery, increase their productivity, and income. The NCAM are in charge of testing and standardizing different farm machineries and equipment. The NCAM also engaged in equipment fabrication and distribution at subsidized rate. They promoted animal traction and development of appropriate hand tools for agricultural production.

2.5.3.9 National, Special Programme on Food Security (NSPFS)

This Programme was launched in January 2002 in all the thirty six states of the federation during the Olusegun Obasanjo's regime. The broad objective of the programme was to increase food production and eliminate rural poverty. Other specific objectives of the programme were: assisting farmers in increasing their output, productivity and income. Interestingly, the success of this programme was just a temporary increase of food production (Manyong et al., 2003).

2.5.3.10 Agricultural Transformation Agenda (ATA)

The Transformation Agenda of the former president Jonathan administration identified seven sectors including agriculture as the main growth drivers during the transformation period, 2011-2015. The decision was prompted by the fact that the performance in these sectors has been constrained by several challenges including low productivity, low level of private sector investment, non-competitiveness, inadequate funding, shortage of skilled manpower, low investment in research and development, poor development of value chain and low value addition, poor regulatory environment, poor quality of goods and services and poor state of physical infrastructure, policy instability and discontinuity, low level of technology, paucity and poor flow of information and high cost of doing business (FMARD, 2016; FGN, 2011).

The ATA focused on how to make Nigeria's agriculture more productive, efficient and effective. Among its key achievements was a restructuring of the federal fertilizer procurement system. This was expected to be achieved through the Growth Enhancement Support (GES) investment that was targeted at 20 million farmers (Patrick Igudia, 2017). The ATA however did not deliver on all the targets, Nigeria still imports about $3 to $5 billion worth of food annually, especially wheat, rice, fish and sundry items, including fresh fruits.

2.5.3.11 Agricultural Promotion Policy (APP) 2016 – 2020

The new policy regime tagged the Agriculture Promotion Policy (APP) Policy is founded on three main pillars; Promotion of agricultural investment; Financing agricultural development programmes and Research for agricultural innovation and productivity. Nigeria is facing two key gaps in agriculture today: an inability to meet domestic food requirements, and an inability to export at quality levels required for market success. The former problem is a productivity challenge driven by an input system and farming model that is largely inefficient. As a result, an aging population of farmers do not have enough seeds, fertilizers, irrigation, crop protection and related support to be successful. The latter challenge is driven by an equally inefficient system for setting and enforcing food quality standards, as well as poor knowledge of target markets. Under, APA, the FMARD will prioritize improving productivity into a number of domestically focused crops and activities. These are rice, wheat, maize, fish (aquaculture), dairy milk, soya beans, poultry, horticulture (fruits and vegetables), and sugar.

2.6 Challenges of Climate Change in Nigeria

Severity of climate impact is dependent on certain parameters of individual countries these includes their geographical, socio-cultural, and economic profiles. The location and the characteristics of reliefs found in Nigeria have given rise to different climate types and AEZs. The climate ranges from tropical rainforest towards the coasts then covers upto the Sahel region as Nigeria's northern parts (Abiodun, Salami, & Tadross, 2011). In terms of rainfall in Nigeria, the spans from very wet coastal region having rainfall higher than 3,500 mm to the Sahel AEZs with less than 600 mm of rainfall per annum. The inter-annual variance in rainfall especially for the northern region remains large and this often leads to high climate threat inform of natural hazards. The hazard includes floods and droughts which seriously impairs the food production process. Some regions in the north could experience rainfall decline of up to 75% thus posing a serious challenge (Ibrahim, Ayinde & Arowolo, 2015).

Nigeria is located within the lowland humid tropics; the country is generally characterized by a high temperature regime almost through the year. In the far south, mean maximum temperature is between 30 and 32^{o}C while in the north it is between 36 and 38^{o}C (Ibrahim, Ayinde & Arowolo, 2015). However, the mean minimum temperature is between 20 and 22°C in the south and under 13°C in the north which has a much higher annual range. The mean temperature for the country is between 27 and 29°C, in the absence of altitudinal modifications. The diverse nature of the country's climate consequently gives rise to a high degree of biological diversity resulting mainly in six vegetation zones: the mangrove swamps, the salt water and freshwater swamps, tropical lowland rainforests, Guinea savannah, Sudan savannah, and Sahel savannah. Salt and freshwater swamps are along the coast of Nigeria.

In fact, recent studies have shown that precipitation decrease in the humid regions of West Africa, including southern Nigeria, since the beginning of the century is about 10-25% or about 2-5% per decade. If this trend persists, rainfall in the humid regions of southern Nigeria may be about 50-80% of its current values by the year 2100 (Ibrahim, Ayinde & Arowolo, 2015). With increase in ocean temperatures, however, there could be increase in the frequency of storms in the coastal zone of the country. In contrast to the humid areas of southern Nigeria, the savanna areas of northern Nigeria would probably have less rainfall, which, coupled with the temperature increases, would reduce soil moisture availability.

Recent studies have indicated that the Sudan-Sahel zone of Nigeria has suffered decrease in rainfall in the range of about 30-40% or about 3-4% per decade since the beginning of the 19th century. Already, these savanna and semi-arid areas suffer from seasonal and inter-annual climatic variability, and there have been droughts and effective desertification processes, particularly, since the 1960s. This situation may be worsened by the expected decrease in rainfall with greater drought probabilities and more rainfall variability and unreliability (IPCC, 2001).

2.6.1 Climate Change Policies in Nigeria

To reflect the growing significance of climate change threat in Nigeria the Government adopted Nigeria Climate Change Policy Response and Strategy (NCCPRS) in 2012. To guarantee a compelling response to the dynamic effects of climate change, Nigeria has received an extensive strategy, and also various explicit policies. The National Policy on climate change is a vital policy response to climate change that specifically aims at decreased carbon emission, increased economic growth and development path and building a climate-proof society through the fulfilment of set objectives. The arrangement unequivocally distinguishes climate change as one of the real dangers to financial development objectives and sustainable security.

Accomplishing these challenges, Nigeria proposed a plan targeted at adapting its economic sectors to climate change, this includes afforestation practices and also the area of energy supply. The NCCPRS is a climate change-versatile Nigeria prepared for quick and sustainable financial improvement. Its mission is to reinforce national activities to adapt to and mitigate climate change and include all sectors of society, including poor people and other vulnerable gatherings, for example, ladies and young people, inside the general setting of progressing sustainable financial advancement. While much stays to be done, the course of movement is clear.

Nigeria has many climate change and environment policies. A top-down strategy was primarily adopted by the mechanism of developing earlier policies, where the Government was predominantly responsible for developing the policies (Onyeneke, et al., 2020; FME, 2011). Moreover, adaptation to climate change has not been mainstreamed into these policies. This necessitated the development of the National Adaptation Strategy and Climate Change Action Plan for Nigeria through an evidence-based bottom-up approach.

The National Adaptation Strategy and Plan of Action for Climate Change Nigeria (NASPA), describes the Nigeria's adaptation priorities, bringing together existing initiatives and priorities for future action. Under this plan, some 13 strategic programs, policies, and measures were prepared according to sectors. The strategies presented below are those targeted on agriculture in the NASPA. The first strategy involves adoption of better and modern systems of agricultural production for both crops and livestock, this includes diversification of livestock and improvement of range management systems; increased availability of drought tolerant crops as well as livestock feeds; adoption of better ways of managing soil; and lastly providing early warning).

The second strategy is concerned with implementing techniques for enhanced management of resources such as; increased usage of irrigation techniques with lower water demand; enhanced rainwater as well as sustainable harvest of ground water and uses; increase planting of indigenous vegetative cover trees and also the encouragement of green technology; Lastly the strategy focuses on the most vulnerable AEZs, the savanna AEZ especially the Sahel savanna. This is as a result of the high vulnerability of the Zones to climate change impact.

2.6.2 Climate Change and Nigeria's Agriculture

Variation in climate variables such as temperature and rainfall has proven to be a challenge that threatens Nigeria's agriculture. Especially with extreme cases of temperatures, rise in sea level, variation in precipitation, as well as other extreme events (EPA, 2015). Traditionally, production of rice in Nigeria is majorly dependent on rain, hence, its natural vulnerability to rainfall variations (Tiamiyu et al., 2015). The extent of severity and intensity of climate reflects the variation in impacts across Nigeria. Generally, agriculture remains the sector with highest vulnerability in Nigeria. Under the current scenario of the agricultural sector, its productivity may decrease by 10 to 25% by 2080. Decline in the northern parts may be as 50%, resulting into decline of GDP by 4.5% by 2050. The historical trend of climate variations in Nigeria was assessed by the Nigerian Meteorological Agency (NIMET; 2008), the outcome showed a significant variation from in climate variables.

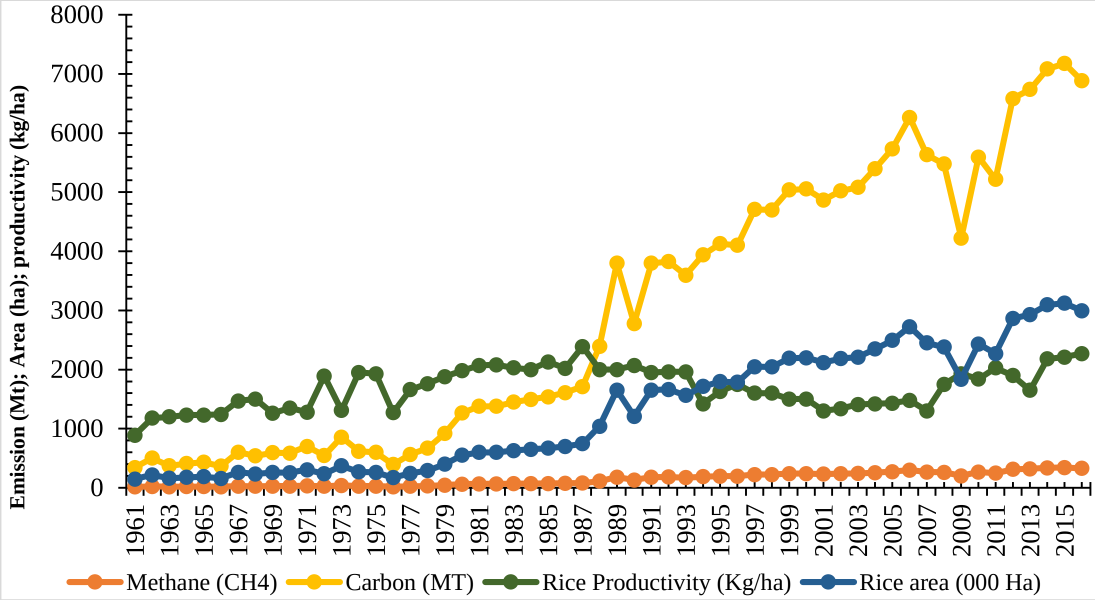

Figure 2. 2
GHGs Emission, Rice Area and Productivity (1961-2015)
Source: Constructed using data from FAOSTAT

The area under rice cultivation, rice productivity and emission of GHG's in Nigeria. Expanding the area under rice cultivation corresponds to an increasing trend in the emission of GHG (CO_2) increases, while on the contrary the trend in rice productivity is inverse to that of emission of GHG. Hence, compared to productivity increase other agricultural activities such as expanding land area and chemical usage contributes more to GHGs emission. Productivity per unit area is encouraged compared to expansion of cultivated area. According to Miranda, Fonseca and Lima (2015) out of the agricultural GHG emissions, rice cultivation accounts for about 35.6% of methane generation.

Between 1941 and 2000 there was proof of long-haul temperature increment in many parts of the nation. The fundamental special case was in the Jos zone, where a slight cooling was recorded. The most noteworthy increments were recorded in the extraordinary upper east, core northwest and southwest, where normal temperatures ascended by 1.4 - 1.9^{o}C. Higher temperatures result in; first diminished agricultural productivity and production across Nigeria. Secondly, it leads to high evaporation rate and diminished soil wetness. Thirdly, it bring decreases productivity and poor livestock production because of increased heat in the Sahel and savanna. Fourthly is that temperature affects human work efficiency and decreases labour productivity.

For precipitation, the past trends between 1971 to 2000 indicates a instability in the early unset of precipitation and early cessation which implies a shortened length of the growing season in many parts of the nation. The yearly precipitation diminished by 2-8 mm across most parts of the nation, however expanded by 2-4 mm in few regions like Port Harcourt. The fluctuations in precipitation have implications on agricultural production of Nigeria, particularly, it leads to productivity decline. The decline in precipitation in Sahel and Sudan savanna leads to inadequacy of water for livestock, less feed for livestock, and drought issue. Thirdly, rise in the intensity of rain along Nigeria's coastal line could result to flood, erosion, decreased fertility of soil and decline in productivity of its agriculture.

In accordance with DFID report of 2009, in the absence any adaptation action, Nigeria could loss around 2-11% of it is GDP by 2020. The Post Disaster Need Assessment (PDNA) report after the massive flood of 2012 revealed the total damage from the disaster to be valued at USD 16.9 billion, which is about 1.4% of the real GDP growth for the year. This implies climate change is a significant threat that could affect the Nigeria's developmental goal. Adaptation therefore becomes a major issue for most developing countries, Africa countries in particular such as Nigeria given its high vulnerability status and weak capacity to adapt resulting from its existing weak institutional capacity, rain dependent agriculture, and low input usage (Sibiko & Qaim, 2019; IITA, 2017).

2.7 Summary of Chapter

The role of rice sector in the economy of Nigeria is vital, in addition to being a source of income, it serve as a major source of food across the rural and urban population. The rice consumption rate has been on the increase over time while, the SSL is still below the total demand thus, the sector is highly dependent on import. As a substitute to import dependence the Nigeria government have directed several policy measures to boast the domestic rice sector. These efforts include trade restrictions via import quotas, tariffs, and total/partial ban, in addition input subsidies such as seeds and fertilizers are provided to support farmers. These efforts have not yielded the desired result and the rice sector continues to experience low productivity relative to other countries within Africa and across the world.

Despite several research efforts towards productivity improvement, the outcome remained unsatisfactory. Thus further research is necessary to unravel the challenges to the sector especially considering the further implication that climate change poses to import reliance. Thus this study proceeded to review of relevant literature to establish current state of knowledge on the rice productivity issue.

CHAPTER THREE

LITERATURE REVIEW

3.1 Introduction

In the present chapter reviews of the relevant literature related to the variables of the study are presented. The literature covers several studies on rice productivity; climate variables; adaptation technologies and associated government policies. In order to provide a sound theoretical basis to guide this study, the chapter begins with a theoretical review of relevant theories such as; the production theory; anthropogenic global warming theory; and environmental Kuznet curve theory. Following the theoretical review is the review of empirical literature relating various issues of agricultural productivity, climate change, policies and adaptation technologies.

3.2 Theoretical Review

A number of relevant theories were reviewed as both underpinning and supporting theorems for this study. The production theory is considered suitable in designing the framework for this study. The theory has served as theoretical underpinning for several studies on issues relating to agricultural productivity and climate change. It is proven to provide sound framework for most empirical researches on productivity (Lambert, 2016). Thus, the deployment of the theory in the current study as underpinning theory. Production theory uses a production-function that specifies the technical relationship existing between inputs and corresponding output in any form of production activity or process (Olayide & Heady, 1982). Additionally, the Anthropogenic Global Warming (AGW) theory and Environmental Kuznet Curve (EKC) are deployed as supporting theories. The AGW theory is included because it relates climate change to human activities such as agriculture. Further the AGW theory covers the implication of climate changes in form of temperature, rainfall, flood and drought on agriculture and other economic sectors. While the EKC theory relates environmental pollution to the level of economic growth. The next sub section present reviews on each of these theories as the basis for the framework of this study.

3.2.1 The Production Theory

The concepts of productivity is extensively grounded in the theory of production in economics (Pieri, 2010). The production theory explains the principles in which businesses such as agriculture make decisions on the quantity or amount of each commodity to supply and the amount it produces as well as the quantity of input material to be used. It guides input usage such as the fixed capital and labour it employs and the quantity to be used (Schmidt, 1986). Also, it describes the relationships between the price of a commodity and the factors used to produce it, or alternatively it defines the quantities of a commodity produced and its productive factors.

In the neoclassical approach, important contributions to the theory of production have been provided by Walras (1874). The neoclassical approach studies the production process with analytical tools, and the process is basically viewed as a vector of elements, in which the positive elements are the outputs of the process, while the negative ones are the inputs. Among the many theories of production and economic growth is the Cobb and Douglas (1928) production-function. That is, early contributions to production theory is presented by the Cobb and Douglas (1928) model. This theory upholds that an increase in factor input (labour and capital) raises the level of output in the long-run with assumption that the level of technology remains constant. Hence, variations in patterns of specialisation among economies is captured as a function of differences in factor endowments (Heckscher & Ohlin, 1991).

In further work, Solow (1956) ascertained through the production model, that a large amount of the growth that was ongoing at that period resulted from technology improvements rather than just increment in factor inputs. Thus, Solow's model takes the rates of saving, population growth, and technological progress as exogenous factor influencing growth. The work of Mankiw, Romer and Weil (1992) examined further the Solow growth (1956) model to ascertain its consistency with differences in living standard observed across nations. That is, whether poor countries tend to grow faster than rich countries. They revealed additional factors that augmented the Solow model which are accumulation of both human and physical capital.

Alternative contribution to the production theory by Dawson’s (1998) found support from Solow (1956) growth model to contend the model by Mankiw et al. (1992). Dawson’s (1998) emphasised that the productivity model of Mankiw et al. (1992) reflected the level of technology and inflows among nations. In addition, the production model further constitutes more factors such as institutions and governance, which have different explicit impacts on productivity across nations or economies. Therefore, choice of political governance/institution factor in the model is informed by the assertion that political institutions may be among the deep causes of economic performance (Shittu, Yusuf, El-Houssein & Hassan, 2020). Similar development was acclaimed by Griliches (1994) where they argued that earlier production framework did not take into account several important sources of aggregate productivity growth which could be the result into fruitful improvements in the current framework: these include: externalities, heterogeneous expectations, the rise of new products, x-inefficiency, changes in political (political stability) and regulatory environment (corruption).

Therefore, it is concluded base on the reviewed production theories that production is achieved through the combination of resources including land, labour, capital, organization, technology, enterprise and government contribution (Shittu *et al*, 2020). While productivity represents production efficiency achieved with the help of least cost combinations of inputs or factors. The relationship between factors of production is known as the production-function. Production-function is the creation of utility and units of values; it is the relationship between inputs and outputs (Shittu *et al*, 2020; Lambert, 2016). It is as well considered as technological relation showing for a given state of technological knowledge, how much can be produced with given amounts of inputs. The production-function is a mathematical equation representing the link between inputs and output in a production system. Furthermore, production growth processes are dependent on the form of production-function that is adopted. An overview of the different types of the production functions is thus highlighted next.

3.2.1.1 Cobb-Douglas Production-Function

Cobb-Douglas production-function is a result of the study by Charles Cobb and Paul Douglas in 1928, which was a cross-sectional study of manufacturing industries in America. The Cobb-Douglas form of production-function still remains one of the most applied theoretical as well as empirical foundations for the analysing growth along with productivity (Felipe & Adams, 2005). It is further highlighted that the evaluation of the parameters of a production functions is crucial for most studies on growth, changes in technology, productivity and also labour. Empirically estimating the aggregate production relation remains a veritable tool for most analysis in macroeconomics. The Cobb-Douglas function only considers just two input factors which are labour and also capital, for the whole production of the manufacturing sector. The standard Cobb-Douglas function is represented as:

$$Q = BK^{a}L^{b} \qquad (3.1)$$

Where: *Q* is real Output Quantity; B = positive constant, K is the flow of capital input, L is the flow of labour input, while parameters a and b signify the elasticity' coefficients of output for inputs, capital and labour, respectively. Output elasticity coefficient refers to the change produced in output due to change in capital while keeping labour at constant.

$$\text{Where, } b = 1 - a$$

Therefore, Cobb-Douglas production-function can also be expressed as follows:

$$Q = BK^{a}L^{1-a} \qquad (3.2)$$

If the resultant value of a + b is 1, it implies that the degree of homogeneity is 1 and indicates the constant returns to scale.

The Cobb-Douglas function presumes a relationship that stipulates the logarithm of the sum of output of an economy as the linear function of the logarithm of the labour and capital. The log-linear function is therefore written as:

$$InQ = InB + a\ InK + b\ InL \quad (3.3)$$

Motivated by literature on growth accounting developed base on Solow's (1957) study, Griliches (1963) re-established the application of aggregate Cobb-Douglas function back to the field of agricultural economics employed to measure and explore the pattern of growth in productivity and also changes in technology in agriculture, which later grew to become general approach (Antle & McGuckin, 1993). Furthermore, Bidle, (2011) expressed that evolution process of the Cobb-Douglas literature had led to emergence of new techniques emerged for estimating production relationships. This technique uses cost data in place of data on quantities of inputs and outputs. The new approach was established on the basis of the assumption that every input factor or output of a production system obtain payment equivalent to the marginal productivity value of the inputs or output respectively.

Furthermore, Bidle, (2011) had noted that during development of the Cobb and Douglas literature on estimation of production-function, new techniques emerged for estimating production relationships. The emerged technique employs the use of cost data instead of data on quantities of inputs and outputs. This new approach was established based on the assumption that every input factor in production obtain payment that is valued to be the same as the marginal productivity of the inputs. This can be used in circumstances where the data on input usage are scarce.

3.2.1.2 Leontief Production-Function

Leontief production-function uses fixed proportion of inputs having no substitutability between them (Campbell and Lindner, 1990). It is regarded as the limiting case for constant elasticity of substitution. The production-function can be expressed as follows:

$$Q = \min (Z_1/a, Z_2/b) \qquad (3.4)$$

Where, Q = quantity of output produced, Z_1 = utilized quantity of input 1, Z_2 = utilized quantity of input 2, a and b = constants

3.2.2 Anthropogenic Global Warming Theory of Climate Change

The AGW is a theory that offers crucial insight on the long-term increase in the earth's average atmospheric temperature due to human industrial and agricultural activities. The earliest of these theory on global warming and climate change argues in support of the emission of GHGs by human such as; CO_2, methane, and nitrous oxide. These has been further posited as the major inducers of the fatal increment of average temperature of the global (IPCC 2000). Release of these gases leads to a higher concentration of atmospheric GHGs above normal, a process known as "the enhanced greenhouse effect". These GHGs are detrimental to the earth surface as they function by assimilating the active reflected or internal thermal radiation from the sun. Thus, resulting into earth's atmosphere getting more hot than normal.

The two cornerstones supporting the AGW theory are undoubtably the twin observations of a global temperature increase since the early 20th century, and the gradual rise in atmospheric CO_2 concentration since the beginning of the industrial age, as indicated by proxies (Ouellette, 2008). However, that theory is founded on the assumption that: CO_2 emissions by human accounts for the build up the atmospheric CO_2 (Sabine et al. 2004).

According to Powell, (2017) the beginning of consensus-building on AGW is founded back in time in the study of Manabe and Wetherald (1967). Through the pioneered computer modelling, they asserted that global temperature will extend to 2°C as a result of the doubling atmospheric CO_2 although, the projection is considered to be a little lower than the current best estimate (Broecker, 1975; Weart, 2011). These global concern about the damaging potential of AGW was captured in the objective of the "first United Nations Framework Convention on Climate Change" held in Rio in June 1992. More recently, the consensus among scientific researchers studying the anthropogenic global warming is reported as 100% (Powell, 2017). How the induced climate change and effects on the environment impacts different economic sectors such as agriculture are emerging issues in the field of research.

3.2.3 Environmental Kuznets Curve Theory

Kuznets, an economist in 1995 invented the inverted U-shaped graph as the relationship between income level and economic development. He postulated that, at the stage of lower level of development, the growth in economies will at first result to wider inequality in terms of income, until it gets a peak, from where any additional rise in the economic development will lead to decline in the inequality level. The Kuznets curve when used to analyse environment, income and pollution relationship is referred to as EKC (Usenata, 2018). The EKC theory states that increase in the level of environmental pressure rises at the initial stages in the development process, then afterward it begins to decrease (Dinda, 2004). The EKC have been employed to establish the nexus between growth in agricultural productivity and environmental degradation through GHGs emission. It posits that at early stages of growth, environmental degradation rises at an increasing rate. Nonetheless, after some threshold, there is reversal at higher levels of agricultural progress through the use of more efficient energy and higher productivity.

According to EKC, environmental pollution grows at a faster rate since priority and attention are given to increasing output. These shows the lack of concern of farmers on the environment. The interest lies with attaining rapid sectoral growth, thus, leads to higher depletion of natural resources inform of deforestation, soil loss and wetland conversion. Consequently, leading to higher emissions of GHGs to the atmosphere and reduction in environmental quality. Then as farmers attain higher income, they adopt better technologies to increase productivity and protect the environment.

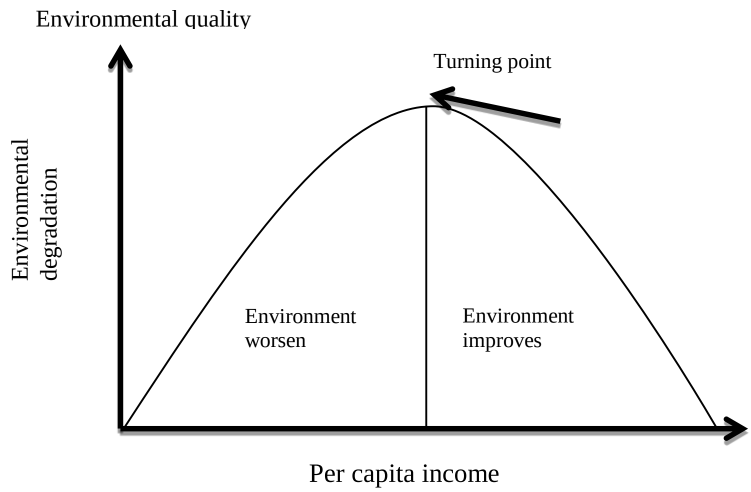

Figure 3. 1
Environmental Kuznet Curve

3.3 Empirical Review

This section presents a review of empirical literature on the important variables of interest in the current study. Related research specifically relevant empirical studies are reviewed in this section. These include rice productivity, climate change factors (that includes temperature, rainfall, flood and carbon emission), government policies (trade policies, subsidy policy, Gov. stability and corruption perception index) and adaptation technologies (Irrigation capacity and NASPA). The review provides the dimensional definitions for each factor and further offer insight on the existing evidences and highlight the gap in empirical literature. The empirical literature is thus extensively presented in sub sections based on variables, methodologies and regional distribution. Literature from the developed world was first considered as they form the basis for the emerging studies on climate change among most developing countries. Then specific cases in the context of Africa also followed alongside issues related to Nigeria. The review consequently begins with the conceptualisation of productivity then climate change phenomena.

3.4 Agricultural Productivity

Productivity is concerned with the economic performance of any production entity such as firm, farm, organizations, industries or an entire country (Greene, 2008). According to a generic definition, productivity is the ability of production factors to produce a given output (Latruffe, 2010). In the recent survey by Fried, Lovell, and Schmidt (2008), productivity is defined as the ratio of the outputs of a production process to its inputs. Productivity in agriculture can be estimated as partial productivity referring to a single factor or as total productivity (multi-factor). Total factor productivity (TFP) index is the relation of total production to total inputs on such production (Kijek et al., 2019; Coelli et al. 2005). Agricultural productivity as an economic concepts is frequently employed in scientific studies of the agricultural sector of an economy.

The factors that influence agricultural productivity have been a subject of many empirical literature. Several of the determinant factors have been examined by extant literature whereas, the list of these determinants are not exhaustively evaluated in existing empirical literature. A major concern of the 21st century is the issue of climate change and how it impacts economic sectors around the world. Thus, this study extends a brief overview of climate change issues and agricultural productivity in the next sub section then followed by other determinants of productivity in the agricultural sector.

3.5 Concept of Climate Change

The global warming phenomena continues to pose challenges to the natural condition and leading to global climate change (Roy, Pal, Chakrabortty, Chowdhuri, Malik, & Das, 2020). Natural forces and human activities results in global warming which is further linked to increasing rate of climate change (IPCC 2010; Roy et al., 2020). It is further emphasized that the recent changes in climate are mostly as a result of human activities (Anthropogenic causes) (IPCC, 2014). This is evident by the GHGs emission from activities such as; electricity and heat production, this represents 25% of the total emission. Also, agriculture and its related activities contributes 24% of the emissions. Other contributors are industries, transportation and building sectors. Through these processes, GHGs such as carbon, ammonia and water vapor are emitted to the atmosphere.

The continues increase in GHGs in the atmosphere leads to enhanced greenhouse effect (IPCC, 2014). The enhanced greenhouse effect leads to the trapping of more heat and depletion of the ozone layer protecting the earth surface. This then result to the issue of global warming which leads to erratic changes in the global climate. The effect of the changing climate is indicated by temperature variation, shorter period of rainfall and variations in the intensity of rainfall due to the El-Nino effect (Ruttan 2002; Roy et al., 2020). As a consequence of the increased intensity of rain and the shorter period, there is rise in the frequency of flood events experienced across regions in the world (Aggrawal 2010; Nikas et al., 2019; Mishra & Sahu, 2014). Flood is a temporary condition on the earth surface where dry land is suddenly overflowed. It is a much-known severe natural hazard. Then continues to threaten human survival due to its devastating implications.

Evidences from the International Strategy for Disaster Reduction [ISDR], (2008) have proven over some decades now that the threats from climate change have accounted for about 45% of deaths and 79% of economic losses. Similarly, the US Environmental Protection Agency (EPA; 2017) reported an increased frequency of natural disasters such as hurricanes, floods and long drought spells across the world. Implications of these disasters includes destruction of agricultural lands, rise in the prices of food commodities, deaths and destruction of infrastructural properties. Thus, several studies (Aggrawal 2010; Reilly et al., 2007; Nikas et al., 2019 and Mishra & Sahu, 2014) make use of these proxies (CO_2 emission, temperature, rainfall, flood and drought) as measures of climate change. The future values of the GHG emissions and these climate change proxies have also been the focus of several studies (Reilly et al., 2001; IPCC, 2001; Flamos, 2016; Nikal et al., 2019). These studies make use of trends to project future scenarios of climate change.

3.5.1 Projections of Future Climate Change

Several modelling frameworks are developed towards providing comprehensive understanding on determinants of climate change which can serve as guide to policy formation (Flamos, 2016). These models were developed due to limitation in the availability of theoretical tool that is capable of providing detailed and integrated explanations on climate change phenomena (Nikal et al., 2019). These models work by using simulation of the impacts of climate change based on different emission projections. These projections are developed based on the present and future emissions scenarios of GHGs.

Scientists have continuously made effort to establish the trend of climate change through studies of the emission pattern and concentration of GHGs. This knowledge is used to forecast the future changes under different GHGs emission scenarios. Depending on the emission scenario considered and the scale of coverage (Global, Regional or Local scale), a number of models have emerged. These models have yielded different results in terms of future climate change. One of such models is the Global Climate Model (GCM) or the Atmospheric- ocean general circulation models (AO-GCMs), this model projects at global level the future climate. These projections are used as inputs in evaluating the impact of climate variations on various sectors such as agriculture. Global Climate Models (GCMs) forecast future climate under the present and future projected emissions of GHGs (IPCC, 2001). Their utilization in impact evaluation studies on climate change cut across different geographic areas (Reilly et al., 2001).

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A major challenge with GCMs is that it is not adequate in measuring impact at regional or local level as it will hide spatial information specific to regions due to the large-scale nature. Hence the results of GCMs are downscaled to regional climate models (RCMs).

Downscaling of Global Climate Models (GCMs) is as a result of the fact that the exact values from simulations of GCM are grossly not sufficient for assessing impacts at regional and also local scales. Therefore, to adapt the GCMs to regional climate models (RCMs) then GCMs are scaled down to RCMs for regional and local use. The GCM projections and downscaled results are used as input in impact studies on agriculture. In general, approaches to climate change impact on agriculture and food security can be grouped into three. These are the agricultural oriented approach, the economic oriented approach and the third approach which is the integrated assessment approach that combines the two approaches (Figure 3.2).

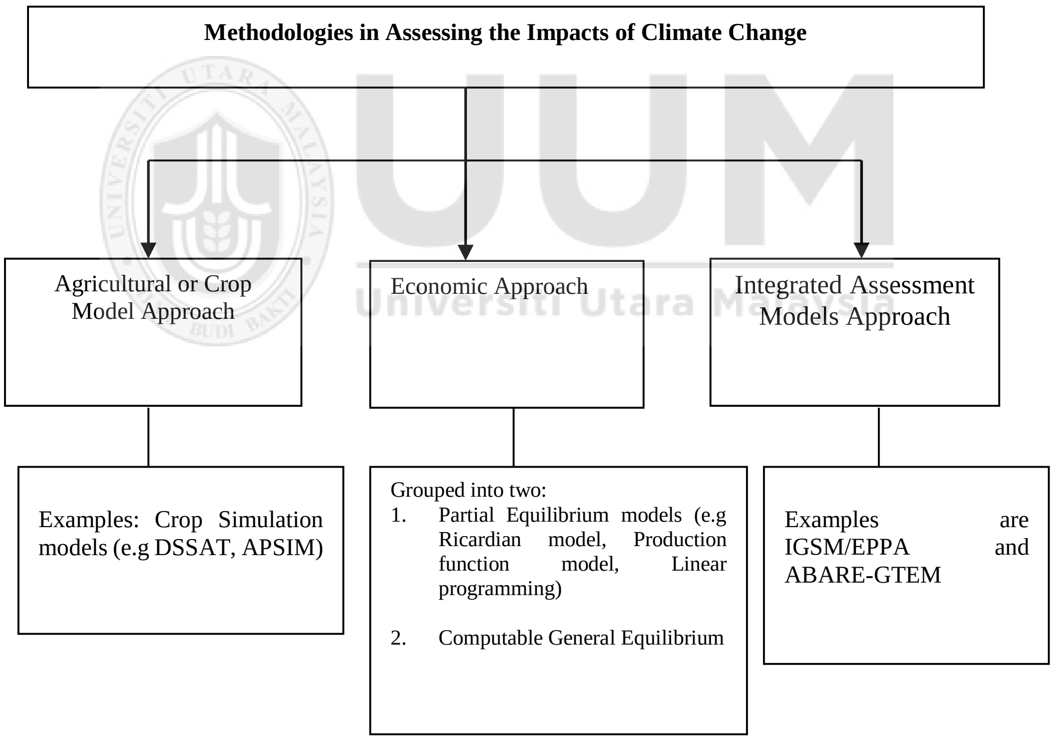

Figure 3. 2
Methodology in Assessing the Impact of Climate Change

3.5.2 Climate Change and Agricultural Productivity

In literature, the observed changes in the climatic variables (such as rainfall, temperature, carbon emission and attributed natural disasters) are used either in combination or individually to evaluate climate change impact on agriculture in most existing studies. That is, variables such temperature, rainfall, carbon emissions, light intensity, flood and drought are employed as proxies to assess how the deviation from their normal values influences agricultural productivity. Similarly, in terms of the methodology the literature has employed a number of methodologies to assess their impact.

The methodological literature is in varying dimensions based on the targeted scope (agriculture or economic scope) and the characteristics of the region covered by the study. In terms of complexity, the methodologies used in examining climate change impact on agriculture have varying degree of complexity and only covers specific targeted aspect or scope of agriculture. Example, the agriculture or the economic models can be considered as biased towards crop and economic aspects respectively. That is, each approach or model focuses on a particular area hence, producing outcomes that are limited only to the scope and strength of the method or approach chosen. Among the common methodological approaches in the previous literature include; the crop simulation methods, Ricardian model, and the production-function method. The production-function method can further be classified as; cross-sectional study, time-series or panel or longitudinal approach. This review begins with studies based on the crop simulation approach, then the trend and application of the Ricardian model for climate change impact on agriculture and the various production-function approaches.

3.5.2.1 Climate Change on Rice Productivity: Crop Model Approach

This approach analyses response of crops to changes in climate. Crop model-based studies deal with issues on how variations in weather factors such as temperature, precipitation including other related factors influence crops. Crop modelling approach forecast the changes that will be observed in terms of productivity under different conditions of climate, using either historical data set or future climate projections. A weakness of the crop models is that they restrict analysis to crop physiology, by simulating and comparing the productivity for crops under diverse climatic conditions (Eitzinger et al., 2003). Therefore, these models are regarded as agricultural based approach, as a result of their focus on the biological as well as the ecological impacts. Another limitation to this model also is that farmers' behaviour explicitly captured as well as the assumption of fixed management practice. Furthermore, they are specific on a particular crop; site (Mendelsohn & Dinar, 2009). Two distinct types of crop-oriented approaches are recognized from literature these are; the simulation or process-based model and the statistical analysis of historical data approach.

Crop simulation models (CSM) makes use of quantitative analysis of bio-physiological activities in order to predict growth in plants and its development given the influence of its environment and management practices already specified in the model as an input. Example of CSM includes; Models such as Process-based example include: Decision Support System for Agro-technology Transfer (DSSAT) model (Hoogenboom et al., 2012; Jones et al., 2003), Agricultural Production Systems Simulator Model (APSIM) (Keating et al., 2003), and the Global Agro Ecological Zone (AEZ) modelling framework (Fischer et al., 2002, 2005). Alternatively, others applied the empirical models to estimate the sensitivity level of agricultural productivity towards climate variations. This is usually based on production-function relationship (Kotani, 2013; Eitzinger et al., 2001 and Terjung et al., 1984). The logic behind this method is that agricultural production is basically dependent on soil and climatic factors which are applied into the model as explanatory variables.

A major study on climate impact on agriculture in Africa that applied the crop simulation method was the van Oort and Zwart (2017). Their study was the first of its kind in Africa which employed the crop simulation model to carry out some series of simulation experiment to estimate the likely effects that climate change has on rice production. The study applied simulation to estimate impacts on rice for both irrigated and rainfed systems. In the study, variety of rice used for simulation was high temperature tolerant variety which was measured as an adaptation decision. The study revealed that when no adaptation was considered, decrease of the growing period as a result of higher temperatures led to productivity decline by -24%. When adaptation was considered, the productivity will increase by +8% depending on the availability water. With Irrigation productivity in East Africa will increase by +25% resulting from the effect of optimal temperatures and influence of CO_2 fertilization.

While in West Africa productivity was projected to change by -21% when there is no adaptation while with adaptation it increases by +7%. For West Africa irrigated rice production, when adaptation was not considered, rice productivity during dry season would decrease by - 45%, with adaptation the decline was found to be less -15%. The major factor that brought about the decreased productivity was reduced photosynthesis as a result of high temperatures. When heat sterility was simulated, it barely increased and hence it was not related to the observed decline in productivity. The study concluded that these findings imply East Africa could gain from the changes in climate by employing the practices that will improve the management of water and plant nutrient. This is required in order to maximize the advantage offered by the favourable temperatures as well as the increased fertilization of CO_2. In the case of West Africa, the study suggested that more studies are required to assess the effects of extreme temperatures on photosynthesis and adaptation practices.

Similarly, Basak *et al*, 2010 in Bangladesh employed the CERES-Rice and DSSAT models to assess climate change influence on agriculture. These models simulated the effects of rising temperature and CO_2 concentration on rice. Basak *et al* concluded that climate change was likely to have predominately adverse impacts on the yield of Boro rice. They found that if climate change was to result in increased temperatures, that this would cause grain sterility during the growing season and hence a reduced yield. They also found that while changes to the level of atmospheric carbon dioxide and solar radiation might offset the impact of increased temperatures to some degree, that it would not be sufficient to mitigate it altogether. While Li et al. (2017) used the model CORDEX-East Asia model to examine climate impact on rice productivity in

Indochina regions. The findings also shows the positive effect of carbon, while temperature is negative. The study also affirms the positive role of irrigation in offsetting the negative effect of temperature.

According to the results computed by Aggrawal (2010), there can be a 3 to 7% decrease in the productivity of wheat, soybean, mustard, groundnut and potato due to a 1 degree Celsius rise in the temperature. Consequently, a predicted rise in the temperature between 2.5 degree and 4.9 degree Celsius by the year 2099 would lead to 10% to 40% destruction of these crops. South worth et al., (2000) addressed for 10 representative agricultural areas across the midwestern Great Lakes region, a five-state area including Indiana, Illinois, Ohio, Michigan, and Wisconsin. He emphasized that individual crop growth processes are affected differently by climate change. With existing hybrid varieties, an overall pattern of decreasing crop production under scenarios of climate change was found, due primarily to intense heat during the main growth period.

However, the results changed with the hybrid of maize (*Zea mays* L). Productivity from long-season maize increased significantly in the northern part of the study region under future climate change. Across the study region, long-season maize performed most successfully under future climate scenarios compared to current productivity, followed by medium-season and then short-season varieties. The study also highlighted the spatial variability of crop responses to changed environmental conditions. Furthermore, they found that potential future adaptations to climate change for maize productivity would require either increased tolerance of maximum summer temperatures in existing maize varieties or a change in the maize varieties grown.

Introducing the ozone changes as a factor, Reilly et al., (2007), altered the MIT Integrated Global Systems Model (IGSM), and employed the Terrestrial Ecosystem Model (TEM) and Emissions Prediction and Policy Analysis (EPPA) components of the models to examine the combined effects of changes in climate, increases in carbon dioxide (CO_2), and changes in tropospheric ozone on crop, pasture, and forest lands and the consequences for the global and regional economies. Scenarios of limited or little effort to control these substances were examined alongside policy scenarios that limit emissions of CO_2 and ozone precursors. The study found that the effects of climate and CO_2 are generally positive, while that of ozone is detrimental. Unless ozone is strongly controlled, damage could offset CO_2 and climate benefits. They found that resource allocation among sectors in the economy, and trade among countries, can strongly affect the estimate of economic effect in a country.

3.5.2.2 Climate Change on Rice Productivity the Economic Oriented Approach

The economic approaches in assessing impact of climate change have been classified into two main groups; the general (GEM) and the partial equilibrium models (Nikas et al., 2019 and Mishra & Sahu, 2014). The GEM also referred as computable general equilibrium (CGE) have a wider interpretation of global economy with multiple sectors. The GEM considers impacts of particular policies on social, economic and environmental units instead of optimum policies. The GEM views the global economy as a multiple combination of interrelated economic sectors (ranging from labour market, capital and energy etc.). It gives a comprehensive view at the economy, by considering the economy to be network of interrelated components. In solving the GEM, an equilibrium price is set for all the markets concurrently (implying a price that equates demand with supply across the sectors). Some examples of the general equilibrium models are; JAM (Gerlagh, 2008), IGEM (Jorgenson et al., 2004), SMG (Edmonds et al., 2004), (Crassous et al., 2006) and WIAGEM (Kemfert, 2001).

The GEM is a complex model because it represents the entire economy in a single model thus, making the structure complex while also it is difficult to model the growth of an economy using the GEM (Nikas et al., 2019). Due to the complexity in the use of GEM, it is marked as inappropriate for most developing nations. The partial equilibrium models are instead more widely employed in the cases of developing countries. The partial equilibrium models (PEM) present comprehensive analysis on interaction of environmental impacts with single or specific sector of the economy. The PEM are normally employed in assessing potential climate impact on a particular economic sector. The PEM as an economic model is used in examining how productivity adjust to market interactions and its implications on production, income, consumptions, prices and trade. Over time, some studies (Nikas et al., 2019; Füssel, 2010; Ortiz & Markandya 2009) were carried out in order to examine the economic aspect of the impact of changes in climate on agriculture.

A number of literature that assessed the macroeconomic implications of agricultural and climate change effects. Notably, Reilly et al., (1994) analysed the economic impacts of reduction in agriculture production using a partial equilibrium model and estimated which regions of the world would be winners or losers under climate change. Kan, Kimhi & Kaminski, (2014) employed the Partial equilibrium model to study food market with the incorporation of production responses by various micro units. Findings shows that climate change affects food prices, farm profits and consumer's surplus. Another study by Stevanovic et al. (2016) used a partial equilibrium model and estimate changes in agricultural welfare due to climate change. Findings shows that the proportion of changes in welfare on trade liberalization scenarios was reported to be 0 to −0.5%.

Alternatively, based on a global scale Ren et al. (2016) recently conducted a similar analysis using a computable general equilibrium (CGE) model, and concluded that the macroeconomic impact would be small in absolute terms (less than 1% of GDP). Whereas, Ciscar, et al., (2011) investigated the economic effects of climate change in Europe, and found that a macroeconomic loss of about 0.3% would occur in most global warming scenarios when using a CGE model. As seen, the order of magnitude of the projected global agricultural economic losses due to climate change is small (about 0–1% of GDP). Therefore, it is reasonable to use food prices and population at risk of hunger as indicators rather than GDP change when assessing climate change impacts on the agricultural sector.

Furthermore, Fujimori et al., (2018) also employed the CGE model to assess the macroeconomic effects of CC resulting from alteration in crop yield. The study asserted that changes in agricultural yield resulting from climate change will affect agricultural output, food prices, and economic variables including GDP. The finding shows that global impact on GDP includes 0.02–0.06% change in GDP by 2100. Both CGE and PEM are focused on global economies, while they are also complex to handle. Again, as an alternative approach, several studies have similarly deployed the use of econometric techniques to assess the implications of climate change on agricultural sector as presented in the subsequent sections of this review.

3.5.2.3 Impact of Climate Change on Rice Productivity the Ricardian Approach

The Ricardian model named after the 19th century classical economist David Ricardo (1772-1823). The model is based on the premise that land values would reflect land profitability within a perfectly competitive market. That is the land values would normally depict their net productivity. This concept was then applied in several climate change studies such as the earlier study of Mendelsohn, Nordhaus, and Shaw (1994). Therefore introducing a new approach in literature aimed at analysing the effect of climatic, economic, and environmental factors on the cost of agricultural lands. This approach focuses on the net income of farming systems instead of focusing on crop yields and, unlike most impact studies, takes adaptation strategies (cropping system management) into account.

The principal characteristic of the Ricardian model is that it treats adaptation to climate change as a 'black box'. In fact, it estimates the relationship between the outcomes of farms and climate normal using cross-sectional data and including, among regressors, appropriate control variables. As such, it implicitly considers farmer adaptation, by including in the regressors the adaptation techniques of farmers. The Ricardian model optimistically assumes that farmers will adjust to climate change (adaptation) and it will be relatively inexpensive, however, research has shown that farmers are slow to adjust to climate change because farmers slowly update to their estimate of the true climate. Another limitation of Ricardian models is the assumption that farmers can observe all changes in climate.

Among the earliest researches applying this technique is the study by Mendelssohn et al. (1994), their study was phenomenal as it set a pace for many other studies that followed. They introduced a cross-sectional method which involves regressing land value per acre such as annual cropland or pasture on climate and some other variables as control. The result revealed an existence of a quadratic form of relationship between land value and climate factors (mean temperature and precipitation). Based on the result of the study, impacts of climate change is estimated to vary from a decline of about USD5.8 billion to rise in revenue of USD36.6 billion.

As a deviation from the earlier work where they used a cross-sectional data, Mendelsohn *et al*, (1996) carried out another study using aggregate value per acre of land. This time the outcome shoed that aside the impact on current farm value, climate variations will as well affect the possibility of cultivating a land. Mendelsohn *et al*, (1999) followed up the previous studies by adding more climate readings; inter annual precipitation and temperature, also included is the diurnal temperature. From the results of the Ricardian model the effects of inter annual variations of precipitation was found to be less significant as compared to temperature. Mendelsohn and Dinar (2003) then later re-examined the previous study of U.S. county study by Mendelsohn et al., 1994 to examine the effect of adding withdrawal of surface water into the

Ricardian model on the differences in the value of farms across US. The result showed that the use of irrigation could enhance adaptation of agriculture to variations of climate.

The use of the Ricardian Model framework continued among other authors studying climate change and agriculture. These earlier studies were mostly concentrated in the developed countries. Maddison (2000) applied the Ricardian model in England and Wales. The choice of variables included in his model differs from those of Mendelsohn in US. The model result showed the determinants of prices for farmland were climate, the quality of soil, and elevation.

Reinsborough (2003) applied the same approach in Canada also. Using the Ricardian model, Reinsborough assessed the possible response of the Canadian agriculture to global warming. Findings showed that there is a marginal benefit from climate change for agricultural sector in Canada. This benefit was estimated at USD 1.5 million annually as farm revenue. Weber and Hauer (2003) also supported that Canadian agriculture could benefit significantly from climate change. Though, the estimated benefit was higher compared to that of Reinsborough (2003). Hauer estimated the benefits of USD5.24 billion in annual GDP. Hauer also projected an average of 50% increase in value of Canadian Agricultural land by 2040, which will rise further to 75% or greater by 2060.

This study used a finer grid at national as well as regional scale with regards to agricultural operations as compared to Reinsborough (2003). Though the two studies

Reinsborough (2003) and Weber and Hauer (2003) showed that Canada could gain from changes in climate condition. The two studies have been criticized based of a number of weaknesses like, the fact that it employed a national level data which is non-homogeneous, model misspecification such as the omission of relevant variables. Considering the fact that adaptation and impact will vary across arid Prairies and crop types such as soybean regions of Southern Ontario.

Considering the challenges and weaknesses in the earlier Ricardian model, the study by Polsky (2004) recognized the need to consider spatial effects as well as temporal variations. Polsky's Ricardian model therefore captured the time-specific eventualities, and also space differences. Also, Polsky asserted that land value does not only depend on local environment but also on the situation of its geographical neighbour. Polsky therefore formulated 6 spatial models to examine the interaction between human and environment and how this relationships and climate sensitivities continued to vary over time and space during 1969 to 1992 period in U.S.

Considering adaptation practices related to climate change, Schlenker et al., (2005) applied the Ricardian approach also. In the model irrigation was added to the model due to, theoretical issues and possible bias that is associated with treatment of irrigation in the earlier studies using the Ricardian approach. They indicated that the use of the proper measure of climatic factors will lead to a robust estimation. The study also agrees with earlier studies that US counties will suffer a profit loss ranging between USD 5billion to USD 5.3 billion annually.

Another improvement in the Ricardian approach was done by Kelly et al. (2005). Where, they extended the approach by differentiating between expected and the actual climate or weather condition. The study postulated that expected weather by the farmers determines their choices in terms of type of crop to plant. On the other hand the actual realized weather affects profits. The study therefore introduced the measure of how climate and shocks from weather affects farm profit. Their finding was in agreement with earlier studies in United States reported above. A challenge in the study of Kelly et al. (2005) is in the scope; only Midwest was covered and secondly their approach in treating the unobserved farm features which could play a crucial role in profit determination. To address the issues above, Deschênes and Greenstone (2007) considered in their profit function technique the aggregate data for United States, and also the individual states. Additionally, they included climate as a county level fixed effect, hence enabling them to concentrate on the influence of weather on profits of farms.

With the aim of investigating whether a Ricardian study in one particular country can also represent the effects in another country or part of the world, Mendelsohn and Reinsborough (2007) compared two countries USA and Canada. The results confirmed that sensitivity to climate vary across the two countries. Consequently, the US which is in the temperate climate differs in sensitivity and the outcome of study in US cannot correctly predict the sensitivity of polar zone region such as Canada and vice versa. Also, they suggested further studies to establish a cross sections study for individual region in order to have reliable climate sensitivity information.

So far, the studies reviewed were from the developed parts of the world, this further signifies the concentration of research in the developed countries. Whereas; the developing countries have limited concentration of research especially in the areas of climate change and even where they exist, they are not detailed, or approaches are usually weak. Although a few studies exist in that have applied the Ricardian model to the study of impact of climate variation on agriculture in different parts of developing countries, these are reviewed below.

3.5.2.3.1 Ricardian Model and Developing Countries Literature

In India, among the earliest study with a model specification comparable to the Ricardian approach is McKinsey and Evenson (1999). In particular, they utilized a net revenue specification of the model, and using two-stage least squares, examine the processes of technological and infrastructure change that characterized India's green revolution. In contrast to earlier studies, McKinsey and Evenson examined the primary technological variables of the green revolution, specifically concerned with adoption of varieties with high yield, multi-cropping and irrigation. Other data includes soils and climate data, public as well as private investment also as variables. Their study pointed out that technology development and diffusion are affected by climate. Further, technology development was found to influence the effect changes in climate have on productivity. Also, technology significantly impact on net revenue of agriculture in India.

A similarly study was carried out in India by Kumar and Parikh (2001), this time they employed the use cross-sectional and farm-level set of data to assess how climate variability affects India's farm net revenue. It was found that even where adaptation is practiced, losses resulting of unstable climate tend to be considerably large. Given a temperature increase between 2°C to 3.5°C, loses will range from 9% to 25%. Kumar and Parikh also projected a decline in rice productivity of about 30% to 35% for India. Similarly, there is a revenue loss of about USD 3 to 4 billion for same temperature variation. These authors asserted that policies of government and prices have significant influence on the changes in revenues. Similar to Kumar and Parikh, using county level and not farm-level cross-sectional data on agriculture, Liu et al., (2004) found that increase in seasonal temperature as well as rainfall has a positive effect on agriculture in China, this is contrary to India's case. Although, some few parts of china was also projected to experience loses as well.

Employing both Ricardian and farm experimental models (5 AOGCM), Seo et al. (2005) studied how agriculture in Sri Lankan will be affected by climate variability. They assessed the net revenue for rice crops, rubber, coconut and tea per hectare of land. Both models confirmed that increases in the rate of precipitation will have a net positive effect on the 4 crops, the gain in net revenue ranges between 11% and 122% compared to the present value. While for temperature increases, there is a loss in productivity ranging between negative 20% to gain of 72%. Seo *et al* concluded that with warming, the already dry regions (the Northern and Eastern provinces), are expected to lose large portions of their current agriculture, but the cooler regions (the central highlands), are predicted to remain the same or increase their output.

As a slight deviation, the findings of Kurukulasuriya and Ajwad (2007) using a farm-level data in Sri Lanka showed that only 14% variations in revenues across farms are accounted for by climate factors in the model. At the national level, a change in net revenues of between−23% and+22% is likely depending on the climate change scenario simulated. These impacts will vary considerably across geographic areas from losses of 67% to gains that more than double current net revenues. In general, the study concluded that in Sri Lanka, higher temperature has just a slight effect on farm revenue, contrary to 20% to 72% reported in Seo et al., (2005).

Most of these studies in the developing countries are concentrated outside Africa, therefore pointing out the fact that Africa lags behind when it comes to the issue of research especially climate related researches. Regardless of the lopsided distribution of climate impact research, the earlier studies in the developed countries laid the foundation for the increasing number of researches in developing countries (Edame, et al., 2011), and subsequently in Africa.

3.5.2.3.2 Ricardian Model and Literature in Africa

Among the earlier empirical research on climate change and its impact on Africa's agricultural sector is a cross country assessment of 11 countries of Africa which includes: South Africa, Ghana, Egypt, Burkina Faso, Ethiopia, Cameroon, Kenya, Niger, Senegal, Zimbabwe and Zambia). The study was carried out by Kurukulasuriya and Mendelssohn, (2006), it involves partnership among representative agencies in the various countries and the "*Center of Environmental Economics and Policy in Africa*" in Pretoria university.

In a cross-sectional study of 11 African countries, Kurukulasuriya and Mendelssohn, (2006) assessed climate impact on farmlands for 9000 farmers. They regressed net farm revenue against water, soil, climate and economics variables; according to the findings a decline in precipitation and an increase in temperatures will also have negative effects on net income. The study concluded that the impact cannot be generalized within the African continent, since different geopolitical zones have different climate features and climate scenarios. Though these studied countries were assumed to encompass the major agro-climatic regions as well as the various farming systems within Africa. However, in spite of the population size and role of Nigeria in agriculture and its diverse climate and land size, it was not included in this major study of Africa's climate sensitivity.

Basing their argument on the lack of attention on the livestock sub sector in Africa proposes a study two different variations of the Ricardian approach was employed by Seo and Mendelssohn, (2006). Data from 10 countries out of the 11 cross country survey was used, Zimbabwe was excluded due to unstable situation of the country. Large and small farms were then studied across Africa. The results indicated that net revenues for livestock in Africa decreases with increased temperature. Whereas small farms were not found to be sensitive to temperature base on the first model. The second model suggests that increased temperature reduces leads to decline in net revenue.

Using the cross country data also, individual country level assessments were also report as presented below:

Using the Ricardian approach, Mano and Nhemachena (2006) found that revenue from farms across Zimbabwe was significantly affected by climates, soil, and hydrological factors used in the model. Furthermore, a sensitivity analysis result using scenarios of 2.5 ^{0}C and 5 ^{0}C temperature increases will lead to decline in the farm revenues close to USD 300 million for both scenarios. In Kenya Mariara and Karanja (2006) used both winter and summer temperature in their model. The study found that increment in temperature for winter results in increase in crop revenue, while summer increase in temperature result in decline of revenue. For the case of precipitation, there is a positive correlation between increases in precipitation and crop productivity.

For Cameroon, Molua and Lambi, (2006) finds that a 3.5% increase in temperature associated with a 4.5% increase in precipitation in the absence of irrigation facilities would be detrimental to Cameroon‘s agriculture, leading to a loss of almost 46.7% in output value. This would negatively affect the economy as a whole, since close to 30% of Cameroon‘s national GDP comes from agriculture.

In Egypt, empirical results from four variants of the standard Ricardian model showed that a rise in temperature would have negative effects on farm net revenue in Egypt according to Model 1. While the second, third, and fourth models, included the linear term of hydrology, the linear and quadratic terms of hydrology, and the hydrology term and heavy machinery to the analysis improved the adaptability of farm net revenue to high temperature. Marginal analysis indicated that the harmful effect of temperature was reduced by adding the hydrology term and heavy machinery to the analysis. Also, estimates from two climate change scenarios showed that high temperatures will constrain agricultural production in Egypt (Eid et al., 2006).

A similar study In Burkina Faso carried out by Ouedraogo et al. (2006) found that if temperature increases by 1°C, farm revenue will fall by 19.9 USD/ha, while if precipitation increases by 1 mm/month, net revenue increases by 2.7 USD/ha using a standard Ricardian model. The elasticity shows that agriculture is very sensitive to precipitation in Burkina Faso. Other studies in this series include (Sene et al. 2006), who assessed the impacts of climate change on the revenues and adaptation of farmers in Senegal and finds that farmers have several ways of adapting to climatic constraints in Senegal. These include amongst others diversifying crops, choosing crops with a short growing cycle, weeding early in the north and late in the south, and praying etc.

Also in Zambia, Jain (2006), finds that an increase in the November–December mean temperature and a decrease in the January–February mean rainfall have negative impacts on net farm revenue in Zambia, whereas an increase in the January–February mean temperature and mean annual runoff has a positive impact. In Ethiopia, the results were not much different, Deressa (2006), also finds that net farm revenue would fall in summer and winter if temperature increases whereas increase in precipitation during spring will increase net farm revenue. Simulation of uniform scenarios that is increasing temperature by 2.5 ^{0}C and 5 ^{0}C; and decreasing precipitation by 7% and 14% suggest that increasing temperature and decreasing precipitation are both damaging to Ethiopian agriculture. However, the author concludes that decreasing precipitation appeared to be more damaging than increasing temperature.

The case of Ethiopia was revisited by Deressa and Hassan (2009) using the Ricardian approach, where they used a county level data to regress climate factors on such as rainfall and temperature, household, and soil related variables on net revenue. The result of analysis point to the fact marginal rise in temperature at summer and also winter influences crop revenue negatively. On the other hand, a marginal increment in precipitation for spring period result into gains in crop revenue per hectare.

Gbetibouo and Hassan, (2005): in their report additionally utilized a Ricardian model to quantify the effect of environmental changes on South Africa's farmlands. A regression of farm net income on atmosphere, soil and other financial elements was done to capture adaptation practices. They utilized climate, agricultural, and soil data to analyze their effects on 7 field crops (maize, wheat, sugarcane, guinea corn, groundnut, soybean and sunflower), in 300 regions of South Africa. They found that field crops were sensitive to marginal temperature changes than they are to variations in precipitation. Temperature rise was found to positively affect net revenue while rainfall had negative effect. They also highlighted the importance of season and location to the effect of climate change by revealing the spatial differences in climate change effect therefore the need for uniform adaptation strategies across the different AEZs of South Africa. Results from scenarios simulations also indicated that impacts would influence changes in farming system and technique in the diverse regions.

However, in Nigeria some individual research efforts have been conducted in spatial scale or different sub sectors of agriculture that is crop based studies, livestock sub-sector or agricultural system entirely in order to determine the effects of climate change on productivity of agriculture in Nigeria. Results varies across studies and characterised as inconsistent, which might be as a result of variation in models, scenarios and differences in the characteristics of the studied area and adaptation levels, a review of the few studies across Nigeria are highlighted below;

Ajetomobi, Joshua, Abiodun, Ajiboye and Hassan, (2011) used the Ricardian model to evaluate climate variations effects on revenue of rice farms in Nigeria. They considered two scenarios; the first is farms under irrigation and secondly dry land conditions. They therefore examined some important climate variables including average precipitation and temperature. Data collection was done by a cross-sectional survey of 1200 rice farmers in 20 rice producing states in Nigeria, selected base on 6 geopolitical zones available in Nigeria. The results of their study revealed that when temperature and precipitation increase, there is decline of net revenue in the case of dry land rice farms, while contrary result was reported in some studies from earlier study (Mariara and Karanja 2006; Seo *et al* 2005; Liu et al., 2004).

Also, when irrigation farms were considered, the revenue from rice farm will increase as a result of increment in both values of temperature and precipitation. This result also contradicts some earlier studies such as (Mariara and Karanja 2006; Seo *et al* 2005; Liu et al., 2004). The results evidently demonstrated the importance of irrigation as a means of adapting to climate variations. Similarly, Ater and Aye, (2012) applied the Ricardian approach on maize production in Nigeria. Among variables in the Ricardian model for this study are; temperature, rainfall, and maize revenue. Results showed that maize revenue is sensitive to variations in climate. Furthermore, scenarios from CGM2, PCM and HADCM3 models were used for predicting future impact; the result showed that; reduction net revenue will continue for the period forecasted.

Deviating from cereals to other tree crops, Lawal and Emaku, (2007) carried out their research on cocoa crop production. Their study found a weak and negative correlation in the case of both rainfall and humidity against cocoa productivity across the years. For temperature there correlation was positive on cocoa productivity. The study went further to examine the black pod disease incidence and its correlation with climate variables. This disease had a strong and positive correlation against both temperature and humidity and vice- versa for rainfall. While Ojo and Sadiq (2010) suggested that improved productivity could be achieved with reduced occurrence of blackpod diseases on cocoa. To reduce the incidence of the disease, the temperature should be maintained at optimal level of 29°C, rainfall at 1,125 millimeter and relative humidity at 74%.

There are two types of static panel data approach found in the literature. These are fixed effect method and random effect method (Gumel et. al., 2016; Guiteras, 2008). This fixed-effects approach has the advantage of controlling for time-invariant district-level unobservable such as farmer quality or unobservable aspects of soil quality at sub national level. The random effect model on the other hand assumes that there is no correlation between unobserved and timely independent variables and independent variables. If this assumption is neglected, the fixed effect model will provide a more unbiased assessment. For this reason, the fixed effect model gives a better estimate (Gumel et. al., 2016). Some of the outcomes of the earlier studies using this approach are reviewed below:

Guiteras (2008) applied the panel data approach to agriculture in India, employing a panel data of over 200 districts covering 1960-1999. Following the estimation strategy by Deschênes and Greenstone (2007), the study regressed yearly district-level agricultural yields on yearly climate variables (temperature and precipitation) and district fixed-effects. The resulting weather parameter estimates are identified from district-specific deviations in yearly weather from the district mean climate. The paper found a significant negative impact with medium-term (2010-2039) climate change predicted to reduce yields by 4.5 to 9%, depending on the magnitude and distribution of warming. While long-run climate change (2070-2099) was found to be more detrimental, with predicted yields decline of 25% or more. Guiteras concludes that climate change could significantly slow the pace of poverty reduction in India.

Lobell, Schlenker and Costa-Roberts (2011) carried out a global assessment of climate change impact on crop production. The study found that with the exception of the US, all other regions engaged in crop production had between 1980 to 2008 temperature trends that exceed the standard deviation of historic variations across years. The models measure the yields response of four major crops to changes in weather showed that globally, the production of maize and wheat will decline by 3.8 and 5.5% respectively compared to a situation where there is no change in the trends of climate.

While the case of soybeans and rice, indicated a balance between losses and gains resulting from climate change. Implying that, the gains from some countries arising from technology, carbon dioxide fertilization, and other factors will be able to offset the losses in other countries.

Advancing on the use of other values rather than only the mean of productivity, Isik and Stephen Devadoss (2006) focused on the impacts of climate variables (temperature and precipitation) on the mean, variance, and covariance of wheat, barley, potato, and sugar beet yields in Idaho. They employed an unbalanced panel data for four crop district levels in Idaho (North, Southwest, South Central, and East). The data for wheat and barley yield span from 1939 to 2001, that of potato span from 1949 to 2001 and sugar beet yields covered the period of 1975 to 2001. They developed an econometric model of stochastic production functions to quantify the impacts of climatic variables on the mean, variance, and covariance of productivity of the four crops. Then the estimates of the production-function parameters and their elasticity are utilized to analyze the impacts of the projected climate change on agriculture. Their findings reveal that climate change will have little effect on the mean crop yields, although the variance and covariance for the crops considered will be significantly reduced.

3.6 Concept of Adaptation Technologies

According to the IPCC (2000), adaptation refers to the act of evolving new social and ecological methods as a means of reacting to existing and expected changes or shocks such as climate change. The capacity of a region to adapt to climate changes such as erratic changes in temperature and rainfall patterns could vary by regions with the poorer ones lacking the incentives and the necessary technological drive to respond. Thus, adaptation policies should be based on science and incorporate knowledge of indigenous peoples and traditional practices (FAO, 2017). That is, for successful implementation, the adaptation technologies or strategies have to consider peculiarities of a region, the social, economic and cultural setting of the targeted users.

Those nations having weak economic resources, limited technology, information and skills deficiency, inadequate infrastructure, institutional challenges, tends towards weak adaptation capacity, hence they are highly vulnerable. The developing countries specifically have found it difficult to adjust to climate change mostly due to weak adaptation capacity (Lal, 2003). Climate change adaptation is of paramount importance to agriculture, thus, various studies in extant literature have examined the link amidst various adaptation technologies and the agricultural productivity. These approaches could either achieve the successful moderation of the harm or the exploitation of impending benefits or opportunities (Moser & Ekstrom 2010).

The literature on adaptation technology and agriculture have been separated into different dimensions; those focusing on the effectiveness and impact of specific adaptation technologies (such as irrigation, improved varieties, early warning and early planting). Another category focuses on the factors that determines the adoption of the various adaptation technologies. Furthermore, studies have examined adaptation policies across several regions example is the National Adaptation Strategy and Plan of Action on Climate Change (NASPA). In general, literature on adaptation technologies mostly focused on the different forms of adaptation technologies, adaptation policies and the determinants of farmer's adoption of these technologies. Adapting to agriculture to climate change requires the deployment of innovative technologies generally referred to as adaptation technologies. Importantly the literature on the issue of water management in agriculture and climate particularly, the link between productivity threats and adoption of modern irrigation have wide coverage. The adoption of traditional irrigation methods has shown to be beneficial to reduce farmers' vulnerability to weather conditions, making production and incomes more stable (Salazar & Rand, 2016). In the context of climate shocks, existing literature have examined a variety of technologies employed as adaptation technologies to curb the effect of climate change on agriculture. These technologies or strategies include; irrigation schemes, agro forestry, practices of conservative agriculture, early detection and warning systems.

Among the earlier extant studies include Elizabeth, et al. (2012) where they studied adaptation technologies to climate change by covering different AEZs in Kenya. Farmer's perceptions were examined base on existing adaptation techniques and factors affecting their choice to adapt. Base on the outcome of the study there are eminent challenges to climate change adaptation. It was also found that households have adjusted their practices as a means of responding to climate variation such as adjusting planting choices. Studies by Salazar and Rand (2016) concludes that in Chile controlling for pre-conditions that determine irrigation choices clearly improves understanding of farmer irrigation adoption decisions. Further the study asserted that weaker knowledge about and lower automatic diffusion of modern irrigation is a main obstacle for improving productivity of small farmer.

While, only few of the households afforded better means of adapting such as agro-forestry and irrigation. Similar to the study by Elizabeth et al. (2012), the study by Thamo, et al., (2016) also examined adaptation at farm-level: The study assessed the relationship among changes in production, adaptation options and profits in Western Australia. Using bioeconomic optimization farm model the study showed that, the profit margins was found to be more sensitive to variations in climate as compared to productivity. Further under extreme scenarios of climate, adjustment by farmers includes; decreased use of inputs, size and changes in land use. These adjustment or adaptations increased farm income by USD 176,000 annually. Most of the existing studies (He, Wang, & Cui, 2020; Busari, Senzanje, Odindo, & Buckley, 2019; Jin et al., 2014; Ringler, Bhaduri, & Lawford, 2013; Rosegrant & Perez, 1997; Lipton et al. 2005; Munir et al. 2002; Hussain & Hanjra 2004) concluded that productivity is consistently better across irrigated regions as compared to non-irrigated regions.

Another category of study are those that examined the determinants of farmers adoption of various adaptation technologies; In Malawi, Mulwa, et al., (2017) examined the determinants of adaptation in the events of climate shocks and the influence of factors like information, education and credit on choice of adaptation to variations of climate. Through a multivariate probit approach, it was found that characteristics of a plot, constraints to credit and availability early climate information are the factors found to be significant in explaining adoption option. The simulated effects from a multivariate probit demonstrate demonstrated that while issues, for example, credit stay urgent, in relative terms, the accessibility of atmosphere data had an extensive effect; as much as 45% on the likelihood of farmers actualizing crop diversification as an adaptive measure. These outcomes demonstrate that adjustment and adapting to weather and atmosphere changes among farmers is probably going to be motivated by information availability.

In East Africa, Shikuku, et al., (2017) examined the adaptation behavior and their determinants in East Africa. The study used a survey data of 500 households selected countries in east Africa (Ethiopia, Kenya, Uganda, and Tanzania). Adaptation was examined using the livelihood index. The index involves assigning weight to each approach on the basis the marginal contribution of the approach to the livelihood of a household. From the results, farmers' approaches in the four regions mainly involve the adoption of new varieties of crops and adjusting planting times. While practices involving management of soil, water and land were disliked by household in the regions. The determinants of choices of adaptation includes; household size, farmers' groups, household sex, and credit access. While food insecurity, have a negative correlation with the choice of adaptation strategy.

Furthermore, studies have examined adaptation usage base on national adaptation policies meant to support the adaptation capacities of farmers such as the National Adaptation Strategy and Plan of Action on Climate Change (NASPA). Adapting to agriculture to climate change requires the deployment of innovative technologies generally referred to as adaptation technologies (Garcia et al., 2020). As indicated by

Lipsey (1999), government intercessions are ordinarily in form of policy formulation towards changes. These strategies can be in form monetary, fiscal, and agricultural or through starting programs aimed at enhancing welfare amongst the urban and rural populace. For agricultural part, the policy arrangements comprise of choices that impact the dimensions and relative costs of inputs and yields, selection of investment choices and asset allocation (Adesiyan et al., 2016).

Also, policies on climate change borders on assessing vulnerability, mitigation plans and most importantly, adaptation at regional or country level. Adaptation in Africa is at present being tended to through conventional development aid (FAO, 2017). Associations like the World Bank and USAID are attempting to "climate-proof" their assets. In addition, most customary development aid (frequently target sectors like health and farming), this will enable nations to end up stronger in fighting climate change. However, the enduring setbacks in development aid both in meeting the financial prerequisites and in having the ideal results implies, that adaptation aids are not sufficient.

3.7 Government Policies

Reforms of agricultural policies and regulations, both at national and regional levels are necessary to safeguard enabling environments for agricultural sector growth (Tadesse et al., 2019). Countries were successful in enforcing policy reforms that support productivity growth (Steve et al., 2013; World Bank, 2001). Some governments are providing incentives, credit and input subsidies, assuring minimum price for farmers, and providing support for marketing. The impact of these policies drives on productivity have been the focus of several studies in literature.

In general, Adedeji et al., (2016) studied the growth trend of rice productivity in Nigeria and also analyzed the impact of economic reforms on productivity of rice. The study analyzed rice productivity in Nigeria across AEZs. Data used was from 1996 to 2010 and analyses were done using the "Malmquist Index". The outcome of the study showed that during the period of reform, the productivity growth of the country was found to decline, while base on the AEZs and post 2000 period, the productivity increased. Specifically, Adesiyan et al. (2016) focused his study on a particular crop (Yam) not the entire sector. They assessed how changes in policy influence the production of yam and its consumption in Nigeria. Data was collected through a survey of a cross section of 700 participants. For the analysis a "Multi-Market Model" was employed. According to the results, distortion in policies related to yam and its substitute crops like rice has negative consequences on the production of yam, its prices, and share of cultivated land as well as income of farming households across Nigeria.

Various policy choices are argued, deliberated and assessed in various studies particularly climate change related literature, one of the solid contentions is to create climate change policy on the basis or foundation of international trade arrangements (Ahmed & Long, 2013). Going by these conflicting arguments on the connection among trade policies and changes in climate, the ability of developing countries to meet their food demand is further complicated. Given their food deficit nature and the unstable policy in most parts of the region such as Nigeria, it is pertinent to analyse the policy inconsistency effect on the productivity of its major food commodity such as rice. Based on this background, the stated objective which aims at investigating the influence of the past paradigm changes in agricultural policy on Productivity of rice in the advent of climate variation in Nigeria is categorized into three (3). The policies of concern in this study are categorized as follows:

1. Trade policies (degree of rice trade liberalization or restriction in Nigeria);
2. Agricultural Subsidy policies (as the percentage of input subsidy available to rice producers);
3. Institutional factors (corruption and political stability)

3.7.1 Trade Policies and Rice Productivity

Trade reforms or policies have been an instrument employed by government to ensure economic growth of any sector in a country. Overall the trade system could either operate on an open liberalised trade or trade restriction policies that hinges on the use of tariffs, import restrictions or ban, and import quota systems. The effectiveness and impact of these policies have been a subject of interest in the literature, especially with the severity or complexity of threat posed by climate change. As indicated by Ahmed and Long, (2013), the significant threat and challenge to be faced by the economies of the world in coming years will include; conflict between climate change and world trade community over policy issues. They further stressed that it is presently a generally acknowledged rule that climate change and world trade share some degree of association, which can be harnessed for the purpose of achieving the social objective of development.

Also, over the past, stakeholders in the study of climate change have called attention to the fact that trade liberalization is a major contributor to environmental pollution. The climate change network in general believe that world trade arrangements challenge domestic and national efforts towards mitigating climate change (Ahmed and Long, 2013). This implies the ability to balance the gap between increasing demand for food and its production will greatly depends on how policies are developed to enhance trade, and also developing the required infrastructures and institutions (Te Velde & Warner, 2007). Steve et al., (2013) suggested that it is noteworthy to consider the experience from policy reforms across many developing countries, which suggests that agricultural trade liberalization rarely occur in isolation.

Furthermore, for ensuring nations have a plan of national development pertaining to food security strategies, the trade policies are instruments utilized for compelling and diverting assets to appropriate sector such as agriculture to meet the planned goals (Analogbei 2000). Wiebe et al., (2015) compared how variation in climate will affect productivity, cultivated area, import, exports, as well as prices for the selected 5 crops, under different trade practices that is with trade restriction and no restrictions. 3 different scenarios were used that is the SSP 1, SSP 3 and RCP 8.5. The study also evaluated the scenario of no climate change and using the existing trade policy. The results revealed that with a more liberalized trade in SSP 1 climate change scenario; there is sudden increase in volume of trade resulting in lower prices.

On the contrary under a serious trade restriction and SSP 3 scenario, there is resultant decline in trade while prices also go up averagely by 25.2%, unlike the case under with usual trade policies with only about 15.5% increase. Conclusively, there is a wide margin of variation among crops and models used. This clearly reveals the role of trade policy in alleviation of the negative impacts of changes in the world climate. In the contest of Nigeria, the policies related to rice trade focuses on import and is largely inconsistent, mainly as a result of persistent changes in government. As regime changes, the previous policies are usually discontinued regardless of its effectiveness and new governments develop different policies at the inception of the new regime (Abbas et al., 2018).

The study by Edwards, (1997) employs data from 93 countries to evaluate the productivity of factors and growth in open economies, using 9 alternative measurements of trade policy. Edwards study was robust in the choice of openness indicators, choice of estimation technique, period covered, and the functional form of the model. The result argues that more open economies have evidence of rapid productivity growth. Similar to Edward, (1997), Harrison (1994), employed a micro level sectoral data of firms in Cote d'Ivoire to evaluate the relationship among productivity of firms, market power along with trade reforms.

A time-series analysis of activities of different sectors prior to and post trade liberalization in 1985, revealed productivity growth have tripled following the reform. Also using the percentage of tariffs as measure for trade policy confirms that growth in productivity increased 4 times for least protected firms or sectors. The third measure of trade policy used by the study is import penetration, using this revealed that the association between productivity rise and trade policies was larger. This study concluded that the assessment of productivity changes resulting from reforms of trade policies using time-series is more robust, contrary to depending on a cross section assessment. It is principally helpful for the cases where protections are applied to sectors that are not efficient.

Same principle was used by Krishna and Mitra (1998), where panel data of firms was used for evaluating how trade liberalization of 1991 in India affects productivity growth and market discipline. In terms of methodology, the study was different from the earlier ones by allowing change in the "return to scale" post trade liberalization. This relaxation of the restriction on estimation, considerably leads to improvement in the regression estimates. The study results confirm the rise in competitiveness and drop in the prices. Additionally, there is proof from the study that suggests decline in the "returns to scale" and also increased rate of growth in firm productivity in preceding years after the reforms, although the evidence was weak.

In the context of agriculture, the World Bank (2001) asserts that the declining productivity in agriculture was already reversed by global reforms that were started in 1990s. On the contrary Skarstein (2005) disagrees with the World Bank assertion he strongly argues that economic liberalization was not able to bring about the targeted growth of productivity in agriculture. Skarstein argument was as well supported by outcomes from other independent studies such as; "Baffes (2005), Sen (2005), Danielson (2002), and Mitchell and Baffes (2002)". These studies also provided evidence contrary to the positive effect of the "structural adjustment policies" on the agriculture sector by World Bank.

Later studies like Stifel and Randrianarisoa, (2004) also examined the effects of policy changes in agriculture sector. These policies concerns include trade tariffs, fertilizer subsidies, and those related to transaction cost). They evaluated these policy changes in Madagascar and found that they considerably affect the intake of calorie across households for urban as well as rural communities. In the case of Rakotoarisoa, (2011) his study centers on how production respond to distortions in trade policies across developed and developing countries. Specifically, Rakotoarisoa examined the effects of distortions of policies on trade on rice productivity in 33 countries involved in rice production; He compared the high subsidies enjoyed by developed nations and nature of taxation among poor developing nations, and then analysed how these policies influence the productivity of developing countries farmers. The outcome of his study presented that given the nature of the developing countries inability to control or dictate prices, policies (foreign and domestic) that results into price fall, production will decline. Especially as farmers realizes small or even loses from increasing production by adopting technologies or expanding their acreage.

3.7.2 Input Subsidies Policy and Agricultural Productivity

Agricultural subsidies could have two forms of effects on productivity that is either positive or negative effects. Negative effect is usually an outcome of subsidies which are directed towards entities that are less productive, which then leads to poor allocative as well as technical efficiencies. While the effects are positive when such subsidies induces investment into technology that enhances productivity gains and improved management techniques, access to credit supports, and consequently mitigating climate change effects (Minviel & Latruffe, 2014).

The positive effect of subsidy and productivity have been affirmed by numerous studies; Seck (2017) examined the productivity among farmers at Senegal River Valley that benefited from subsidy programme. The study found a positive correlation between subsidy and productivity. According to Rakotoarisoa, (2011) the absence of input subsidy policies and lack of infrastructure and low level of income discourages investment technologies to enhance adaptation and consequently productivity. Contrarily, several studies that includes; Kumbhakar and Lien (2010); Guan and Oude Lansink (2006) and Bezlepkina and Oude Lansink (2006) employed an unbalanced panel data from Norway and found that subsidy payment has a negative effect on productivity although it positively influenced technical efficiency.

3.7.3 Institutional Factors and Agricultural Productivity

Government involvement in the agricultural sector is pervasive and significant (Ahearn, Yee, & Huffman, 2002). While, in recent years it has also been realised that good governance significantly affects a country's agricultural productivity (Bayyurta & Yilmaz, 2012). These qualities of governance are measured through group of indicators from the World Bank's Worldwide Governance Indicators (WGI), which includes: Voice and Accountability, Government or Political Stability and Absence of Violence, Government Effectiveness, Regulatory Quality, Rule of Law, and Control of Corruption (World Bank, 2011). The six WGI are recognized by many researchers as the most effective tools for assessing the status of governance in different countries. Weak governance indicators tend to negatively affect agricultural projects are considered less likely to attain targeted objectives for nations having weak governance

(World Bank, 2011). The study further asserted that, the governance factor are weakest in conditions that require public sector support to develop its agricultural sector.

The 2007 World Development Report (WDR) by World Bank focused on agriculture and found that governance problems are particularly pronounced in agriculture-based countries. The report further highlighted that governance problems constituted a major factor that affected the implementation of the recommendations concerning agriculture in the WDR of 1982 (World Bank 2007). A weak governance environment inhibits dialogue with the government and makes it difficult to design interventions. About half the countries in Sub-Saharan Africa are fragile states or post-conflict countries (World Bank, 2011). An example is the case of Nigeria which is consistently ranked close to the bottom in international comparisons of corruption., Independent Evaluation Group (IEG) IEG's recent country assistance evaluation (CAE) noted that although the Bank's strategic objective was to support agricultural intensification and diversification, this support depended on the resolution of fiduciary issues related to earlier Bank investments in Nigerian agriculture to address the issues of agricultural productivity.

Staatz and Dembélé (2008) identified the opportunity for increased productivity and efficiency of investment in African agriculture. The opportunity will consequently lead to significant increment in productivity and output among smallholders. The study suggested an approach for SSA region which involves the development of series of differentiated agricultural revolutions particularly suited to their ecological environment and market. Factors such as weathered soils; weaker infrastructure, highly heterogeneous social systems; poor governance makes it difficult to achieve economies of scale in some of the determinants of agricultural development. Also, For instance, Messer, Cohen and D'Acosta (1998) estimate that during periods of conflict, agricultural production drops an average of 12.3% each year.

According to Camposs et al. (1999), corruption can compromise the efficiency of production by imposing unpredictable taxes. The study asserted that several countries with weak regulations and protectionist policies put high indirect taxes on agriculture. While base on Krueger et al. (1991) study of 18 countries with a data span of 24 years (between 1960-1983), the market unfriendly macroeconomic policies caused indirect taxes in agriculture by more than three times that of direct taxes. They also viewed that these policies have a deter growth of agricultural production. Further, the study indicated that governance infrastructure could influence performance of agricultural sector in various dimensions.

Lio and Liu (2008) analysed 118 countries, whether a relationship exist between agricultural productivity and governance indicators for the years 1996, 1998, 2000 and 2002 in their study. They found that when independent variables included in the model separately, the rule of law, control of corruption and government effectiveness increase agricultural productivity. When all of the variables were included in the model at the same time while rule of law significantly increases the agricultural efficiency, political stability and voice and accountability have emerged a significant decrease in agricultural efficiency. In that study it is concluded that countries of which citizens respect to regulatory quality have higher efficiency in agriculture. Low agricultural efficiency has been seen in more democratic countries is one the other important finding.

Bayyurta and Yilmaz, (2012) combined the DEA and regression approach to analyse global agricultural sector. The DEA technique in the first stage to assess the agricultural efficiencies. While, second stage involved panel data using GLS regression to examine effects of Worldwide Governance Indicators (WGI), education index, among developed and developing country productivity. Study found that regulatory quality is positively related to agricultural efficiency. Additionally, the findings shows developed countries have better agricultural efficiency. Thus, it is affirmed that agricultural productivity in developing countries lingers behind developed country's productivity.

There is limitation regarding the assessment of corruption factors in the agriculture sector which is the dominant economic sector in most developing countries including Nigeria. Further, the findings on these factors in other economic sectors have been mixed, the literature have reported both positive impact (Musibau et al., 2017; Krueger et al. (1991); Shittu et al., 2020; Friedrich, 1972) and negative impact (Li et al., 2000; Ahmad, Ullah, & Arfeen, 2012; Hall & Jones, 1999)

In conclusion on the issues of policies, the current chapter, has presented a very wide view of implications in terms of productivity growth and development discourse especially for the agricultural sector. Literature have mostly asserted that, trade liberalization policies are counterproductive for most developing countries. Except if, the issue of “diminishing returns to land” is properly checked (Kazungu, 2009). Through interventions in the form of farm inputs, availability of credit, improved production technology. A key constraint of the previous literature concerning trade policy alongside productivity is the fact that the firms are assumed as same. However, the research trend now considers firm heterogeneity, examples are; studies by Melitz, (2003); Gustafsson & Segestrom (2006).

3.8 Literature Gap

Again, from the review of related literature, research gaps include: First, aside from few limited studies, no other critical effort has been made towards examining the effect of multiple dimensions of climate factors on rice productivity in Africa and Nigeria in particular prior to Mendelson *et al* 2006. However, few efforts in this direction saw the introduction of various proxies for climate change and agriculture nexus model. Specifically, the extant literature had failed to consider the variations in nature of climate and soil types across AEZs in Nigeria and the dynamism in the impact of climate change across these AEZs Provide. Similarly, majority of studies assessed impact on the entire agriculture sector, therefore neglecting a critical issue concerning how crops differ in their soil and climatic requirement hence exhibit different vulnerability to climate change.

Secondly, the methodological literature is in varying dimensions based on the targeted scope (agriculture or economic scope) and the characteristics of the region covered by the study. In terms of complexity, the methodologies used in examining climate change impact on agriculture have varying degree of complexity and only covers specific targeted aspect or scope of agriculture. Example, the agriculture or the economic models can be considered as biased towards crop and economic aspects respectively. That is, each approach or model focuses on a particular area hence, producing outcomes that are limited only to the scope and strength of the method or approach chosen.

In terms of methodology, most existing studies in Nigeria have employed methods such as the Crop Simulation Model, the cross-sectional techniques or the Ricardian Model. These approaches suffer from the inability to distinguish between changes resulting from economies of scale or technological innovations. While, panel data technique (ARDL PMG) could account for such differences but, the literature on Panel Data Approach is scanty, especially in the context of Nigeria.

The PMG estimator has some advantages over others. First, it provides an asymptotic distribution of estimators, and yields the most consistent and efficient estimates, unlike Instrumental Variables (IV), Generalized Methods of Moments (GMM) techniques or simple static methods, which assume homogeneity of all the long-run and short-run parameters. Unlike the case of all other dynamic estimators, which require the same order of integration for all the variables in the model, the PMG permits the co-integration relationship to exist irrespective of whether the variables are I(0) or I(1) or combination of them (Wu et al., 2010). The PMG estimator is consistent and efficient not only in the presence of stationary and non-stationary variables, but also in the case of endogenous variables, since endogeneity of explanatory variables can be overcome by adding a sufficient number of lags of these variables (Binder and Offermanns, 2007). Furthermore, selecting lag order in the ARDL model using the appropriate selection information criteria such as AIC, SC and HQC takes into account the results of the diagnostic tests, ensuring that there is no residual serial correlation, non-normality, heteroscedasticity, and functional form misspecification (Feridun, 2009).

Thirdly, given the established relationship amongst trade policies, climate change adaptation policies and agricultural productivity, these non-climatic variables will also be included to extend the current model in the study of climate change impact on rice productivity in Nigeria. Given these identified gaps, the current study is proposed. Thus, 10 important variables and four control variables are included in the model of the study and the details are presented next.

3.9 Factor Included in the Rice Productivity Model of this Study

Base on the established practical, theoretical and methodological limitations amidst literature from the developing country's region and most especially Nigeria, the study develops a rice productivity model that integrate important factors affecting the rice productivity across regions in Nigeria. This framework of the model comprises of 10 important variables made up of one dependent and nine independent or explanatory variables that explains rice productivity in Nigeria. In addition, to control for specification or omitted variable bias four control variables were also introduced in the model. These four control variables includes land area, labour, mechanization and fertilizers usage. While, the explanatory variables added in this study are: divided into three major categories: Climate change factors (temperature, rainfall, flood and CO_2); Policies (Trade policies or import tariffs) and institutional factors (corruption and government instability) and adaptation technologies (irrigation capacities and NASPA).

3.9.1 Climate Change Factors

Existing climate change studies employed the observed changes in the climatic variables (such as rainfall, temperature, carbon emission and attributed natural disasters) either in combination or individually to evaluate climate change impact on agriculture in most existing studies (Eitzinger et al., 2003). That is, variables such temperature (Liu et al., 2004; Aggrawal, 2010;), rainfall, carbon emissions (Basak *et al*, 2010; Reilly et al., (2007), light intensity, flood (Aggrawal 2010; Nikas et al., 2019; Mishra & Sahu, 2014) and drought (Shiferaw et al., 2014) are employed as proxies to assess how the deviation from their normal values influences agricultural productivity. Thus, to assess climate change impact, four measures are used in the present study: carbon emission, temperature, rainfall and flood).

3.9.2 Adaptation Technology Factors

Adapting to agriculture to climate change requires the deployment of innovative technologies generally referred to as adaptation technologies (Garcia et al., 2020). The adoption of traditional irrigation methods has shown to be beneficial to reduce farmers' vulnerability to weather conditions, making production and incomes more stable (Salazar & Rand, 2016). Owing to the peculiar issues with the irrigation system in Nigeria such as the low coverage and weak management. Irrigation capacity is considered as a measure of adaptation technology in this study. Furthermore, studies have examined adaptation usage base on national adaptation policies (Adesiyan et al., 2016). As indicated by Lipsey (1999), government intercessions are ordinarily in form of policy formulation towards changes. Thus, the second measure of adaptation technology in this study concern National Adaptation Strategy and Plan of Action on Climate Change (NASPA). The NASPA is Nigeria's effort towards adapting its various sector to climate change and encompasses a number, all technologies used by Nigeria in adapting agriculture to climate change. Thus, this policy is introduced as a dummy.

3.9.3 Policy Factors

Trade policies: Trade reforms or policies have been an instrument employed by government to ensure economic growth of any sector in a country. As indicated by Ahmed and Long, (2013), the significant threat and challenge to be faced by the economies of the world. Overall the trade system could either operate on an open liberalised trade or trade restriction policies that hinges on the use of tariffs, import restrictions or ban, and import quota systems. The ability to balance the gap between increasing demand for food and its production will greatly depends on how policies are developed to enhance trade, and also developing the required infrastructures and institutions (Te Velde & Warner, 2007). Thus, this study measures trade policy base on the value of import tariffs in Nigeria. Although input subsidy was considered in the current study, it was dropped from the study owing to issues of auto correlation between factors in the model.

Government involvement in the agricultural sector is pervasive and significant (Ahearn, Yee, & Huffman, 2002). While, in recent years it has also been realised that good governance significantly affects a country's agricultural productivity (Bayyurta & Yilmaz, 2012; World Bank 2007). Policies and economic growth are directly associated with institutional factors such as control of corruption and government stability (Bayyurta & Yilmaz, 2012; Lio & Liu, 2008; Camposs et al., 1999). Thus, current study employs the government tariffs and corruption perception index as policy related factors in addition to tariff policies.

Government stability: This refers to the propensity of occurrence of any change in governance thus promotes uncertainty in government policies, economic support (subsidies and incentives), conflict and even overall dis-stable economy (Cullen, Turner & Washington, 2018; Shittu, 2020). This discourages investment and thus hampers productivity growth across economic sectors of the country.

Corruption perception index: Corruption represents a complex, economic, social and political challenges faced by most nations of the world (Campbell, 2013). (Ahmad, Ullah, & Arfeen, 2012). There is limitation regarding the assessment of these factors in the agriculture sector which is the dominant economic sector in most developing countries including Nigeria. Further, the findings have shown these factor to be significant in affecting economic productivity in several economic sectors (Shittu et al., 2020; Friedrich, 1972; Li et al., 2000; Ahmad, Ullah, & Arfeen, 2012; Hall & Jones, 1999). Thus, current study employs the corruption perception index as a measure of country's corruption to assess impact on rice productivity.

3.10 Chapter Summary

In literature, climate change has been assessed through the use of variables such as temperature, rainfall pattern, flood, carbon emission, drought intensities. The relationship between these climate variables and agricultural productivity has been commonly estimated using various models. “Ricardian model, agronomic model, crop simulation model (CSMs) and the production-function model”. These models represent methods commonly adopted in climate impact research (Kaur, 2017; Lee et al. 2013; Ekbom, 1998). The Ricardian model assesses impact of climatic variables and other factors on land values and agricultural revenues relying on cross-sectional data (Mendelsohn et al., 1994). Whereas, the Crop Simulation Models limits the estimation to physiological properties of crops and they examine crop productivity by employing various climate scenarios (Salvo et al., 2013).

The production-function approach uses production-function and accommodates various environmental inputs to examine the impact of these inputs on the production (Callway et al., (1982); Decker et al., (1986); Adams et al., (1988), (1990); Rind et al., (1990); Rosenzweig and Parry, (1993). Given the enormous advantage of the Production-function method in assessing productivity of crops, it is favoured in literature for the assessment of a specific crop and not just the sector at large. This is important as climate change impact varies both by region (AEZs) and also by the type of crop. Therefore, this study will employ the production-function method to achieve the objectives of the study.

CHAPTER FOUR

METHODOLOGY

4.1 Introduction

This chapter describes the methodological procedures used in this study which comprises of a number of sections as follows: The chapter begins by presenting the theoretical framework for the study, followed by the conceptual framework, then types of data and their sources, population and study sample, model specifications, preliminary assessment of data and method employed in the estimation of the rice productivity model. These procedures are in line with the specified objectives of the study that mainly involve the assessment of the impact of climate change, policies and adaptation technologies on the rice productivity across AEZs in Nigeria.

The methodology chapter is also detailed based on the specific objectives of the study which are to: (i) to describe the types of climate changes, adaptation technologies and policies, influencing rice productivity; (ii) assess the impacts of climate change on rice productivity; (iii) examine the impacts of climate change adaptation technologies used in response to climate change shocks on rice productivity; (iv) determine impact of Government policies on rice productivity; and (v) measure the impact of climate change, government policies and adaptation technologies on rice productivity across the different AEZs of Nigeria.

The Pool Mean Group (PMG) ARDL econometric approach was used to analyse the research objectives. Objective (i) was achieved through descriptive analysis of the data.

While, objectives (ii) to (iv) were achieved from the result of the long-run estimates of the PMG ARDL model. Then objective (v) was achieved from the short-run output of the PMG ARDL model. That is, the short-run estimate of the PMG was used to assess dynamism in the relationship between rice productivity and determinant factors for each state. The short-run coefficients of PMG estimates are allowed to vary across groups as indicated in the methodological section. This property of the PMG is employed to achieve objective five of this study. Prior to the model evaluation, various relevant tests were carried out on the data collected to ensure robustness of the outcome.

4.2 Theoretical Framework

The study framework is developed based on three fundamental theories that is the production theory, the Anthropogenic Global Warming (AGW) theory and the Environmental Kuznets Curve Theory (EKC). The framework is developed as indicated in Figure 4.1:

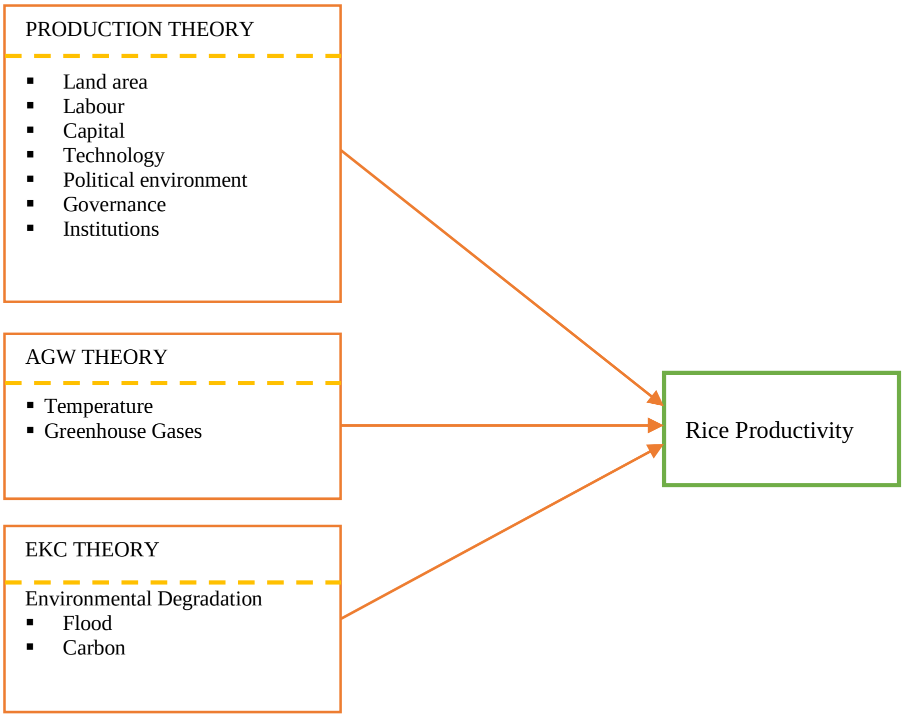

Figure 4. 1
Theoretical Framework

The production theory serves as the major or underpinning theory while, the AGW theory and the EKC theory are used as supporting theories in this study. These theories link the independent variables and dependent variable used in this study. The production theory began with the simplest form involving two fundamental factors which are labour and capital to produce a given output (Cobb & Douglas, 1928). Over time and on the basis of different schools of thought, the production theory has been developed to encompass several important factors that affects productivity such as; rates of saving, population growth, and technological progress (Solow, 1956); human and physical capital (Mankiw, Romer & Weil, 1992); Government investment in R&D (Griliches, 1994); institutions and governance (Dawson, 1998).

The AGW theory argues that human activities contribute mainly to emission of GHGs such as, Carbon, methane and nitrous oxide. The two postulations of the AGW theory are related to global temperature increase and the gradual rise in atmospheric CO_2 (Ouellette, 2008). These factors are considered to influence several economic sectors like agriculture and other human activities. Whereas the EKC theory considers environmental pollution like the issue of climate change. According to the theory, economic sectors such as agriculture prioritise attention towards increasing productivity or output. Accordingly, there is initial lack of concern on environmental degradation such as deforestation, soil loss and wetland conversion resulting from higher utilization of natural resources to improve productivity. Subsequently, these lead to higher emissions of GHGs to the atmosphere leading to degradation and reduction in environmental quality. Then, as producers attain higher income levels, they adopt innovative technologies to ensure both increase of productivity and environmental sustainability.

4.3 Conceptual Framework

On the basis of the underpinning and supporting theories alongside reviewed literature in the current study, important factors are conceptualised as the determinants of rice productivity in Nigeria. These factors include; climate change, trade policies, and adaptation technologies. That is, these factors form the conceptual framework that is employed to study the rice productivity across AEZs in Nigeria. The conceptual framework is presented in Figure 4.2.

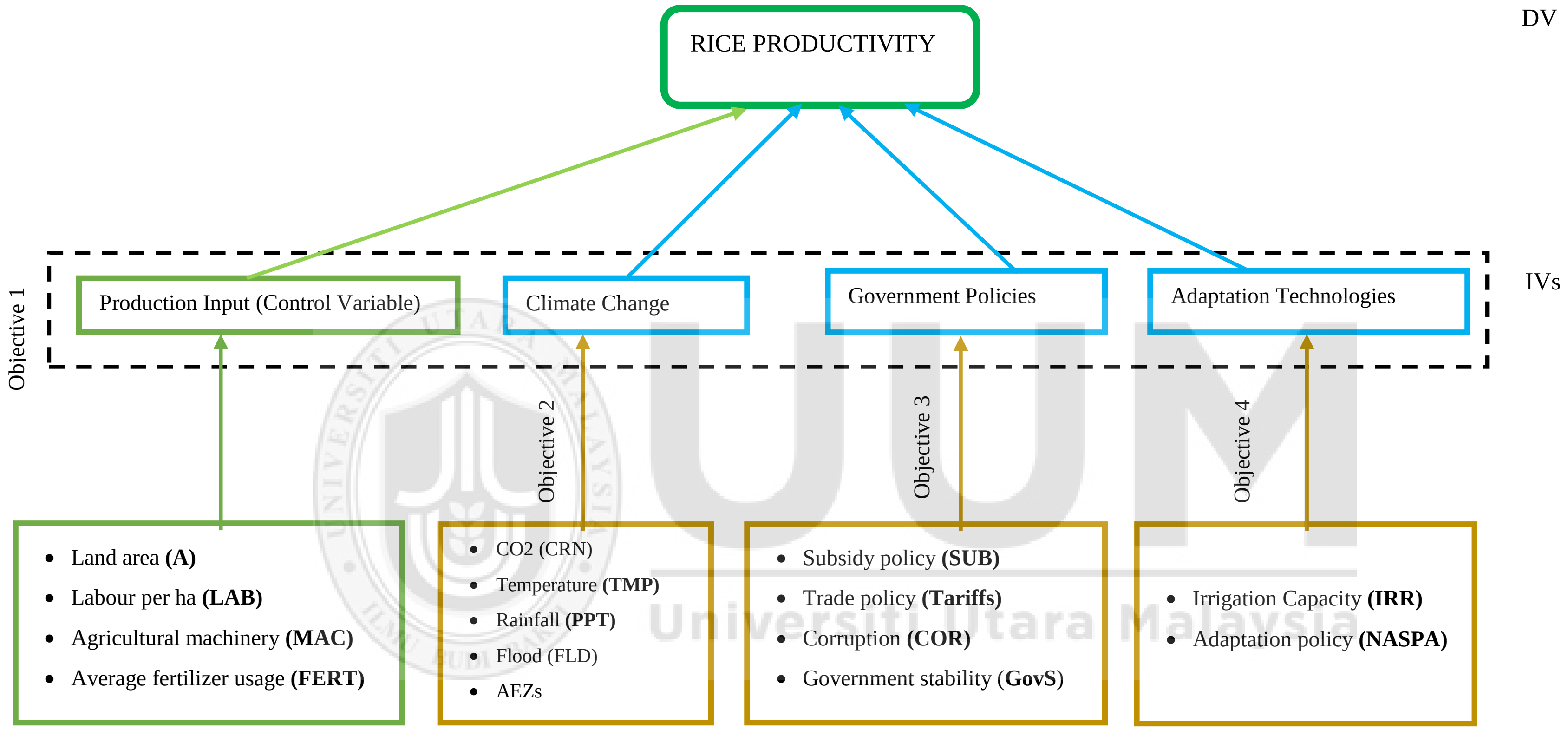

Figure 4. 2
Conceptual Framework

Figure 4.2 presents the conceptual framework of the research. At the middle level are all the major factors conceptualised as determinant of rice productivity. These factors include; climate change, trade policies, and adaptation technologies. These factors alongside the production inputs (control variables) are directly linked to rice productivity. All the variables highlighted in red are the new variables. These variables has been added into the framework and can be considered as new variables and filling up the gap of the study. At the bottom level of the conceptual framework are the measurements for each of the factors specified above and are linked to its respective factor. The measurements for climate change include; temperature, rainfall, flood and CO_2. Policies are measured using trade policies (percentage of tariffs), subsidy policies, and institutional factors (corruption and government stability). While, adaptation technologies are measured based on irrigation capacities and the national adaptation strategies and policy action (NASPA).

Among these factors, institutional factors like corruption and government instability were introduced as new variables to extend the current model of rice productivity in Nigeria. This is considered amidst the growing concerns that corruption and government stability persistently remained an issue affecting social and economic growth efforts such as productivity especially among developing economies (Ahmad, Ullah, & Arfeen, 2012). There is limitation regarding the assessment of these factors in the agriculture sector which is the dominant economic sector in most developing countries including Nigeria. Further, the findings on these factors in other economic sectors have been mixed, the literature have reported both positive impact (Shittu et al., 2020; Friedrich, 1972) and negative impact (Li et al., 2000; Ahmad, Ullah, &

Arfeen, 2012; Hall & Jones, 1999) on investment and economic growth. Thus, these new factors are considered owing to their role in influencing agricultural investments that can enhance rice productivity. Further considering the existing gap in literature that covers the AEZ classification, this study detailed its findings by assessing variables across the level of AEZs.

4.4 Types of Data and Sources

The study involves analysis of determinants of rice productivity across Six AEZs of Nigeria. Each of this AEZ were proxied by the major rice producing states in the Zone. Then for each AEZ, annual data spanning from 1980 to 2018 was retrieved. Thus making up six (6) panels or cross sections with data series for 38 years. Given the nature of data required for this research, substantial data was drawn from secondary sources. The climate data, rice productions data, government policies with institutional factors and the data on adaptation policy variables were retrieved from secondary sources such as repositories of Nigerian Meteorological Agency (NIMET), Food and Agricultural Organization (FAO), World Bank (WB), Ministries of Agriculture, Agricultural Development Programs (ADP), Lower River Basin Development Authorities and other relevant agencies and parastatals. Also, data was sourced from credible data bases. Specifically, the data for production, and input usage are retrieved from the Ministries of Agriculture with the exception of labour which was obtained from the National Bureau of Statistics (NBS), climate data temperature, rainfall, flood and drought data was obtained at Nigeria Meteorological Organisation (NiMet).

Table 4. 1
Definition of Variables

Variables	Symbol	Units	Description
Agriculture machinery	MAC	Number/100 Ha	Agricultural tractors, refer to total wheel, crawler or track-laying type tractors and pedestrian tractors used in Agriculture (FAOSTAT, 2019)
Fertilizer consumption	FERT	Kg/ha	Average consumption of chemical fertilizers in kg/ha
Labour	LAB	Number/Ha	The average size of labour employed per hectare of agricultural land per season or per production cycle
Land area	A	Hectares	Total area of cultivated land under rice
Temperature	TMP	Celsius (0C)	Annual mean temperature
Rainfall	PPT	Millimetres (mm)	Annual mean precipitation
CO_2 Emission	CRN	Kilo tonnes	Annual Carbon emission by rice sector
Flood intensity	FLD	Severity index	Nature of the impact (weak = 0.5, moderate =1 and severe = 1.5)
Trade policies	TRAD	Percentage of tariff	The percentage of tariff charged on the importation of rice annually as a tool to discourage or encourage import
Government stability	INS	Index rating from 0 to 12 (0 = very low risk of instability and 12 = very high risk of instability)	Government Stability is an assessment both of the government's ability to carry out its declared program(s), and its ability to stay in office. Maximum score of 12 points and a minimum score of 0 points. A score of 0 points equates to very low risk and a score of 12 points to very high risk
Corruption	COR	Corruption perception index (0 to 6)	An assessment of corruption in the political system. Such corruption threatens foreign investment by distorting the economic and financial environment. Thus, reduces the efficiency of government and business. (0 implies very high corruption, 6 very low corruption)
Irrigation capacity	IRR	Hectares	Proportion of Agricultural land area under irrigation
NASPA	NASPA	Dummy (1 = NASPA, 0 = periods prior to NASPA)	National Adaptation Strategy and Plan of Action for Climate Change

4.5 Population and Sampling

Nigeria consists of 36 states with the inclusion of federal capital makes 37 territories. These are spread across 6 AEZs and each have the potential for rice production (see Table 4.2). The AEZs is a classification of states based on their differences in climate and soil types (FAO, 2009). The data for this study was collected across 6 AEZs in Nigeria with each AEZ represented by the major rice producing state in each AEZ. Thus the unit of analysis for this study is the AEZs represented by states. Although rice is produced across the different states, the production capacities varies (see Table 4.2). This study was focused on the main rice producing states for each AEZs. This is as a result of factors such as the low rice production among other states and consequently the limitation on data availability from the rice sectors in the other states. Also, the production of such states have no significant contribution to the gross national output of rice. Thus, a representative state was selected on the basis of rice production capacity for each AEZ. The data also span from the period of 38 years from 1980 to 2018.

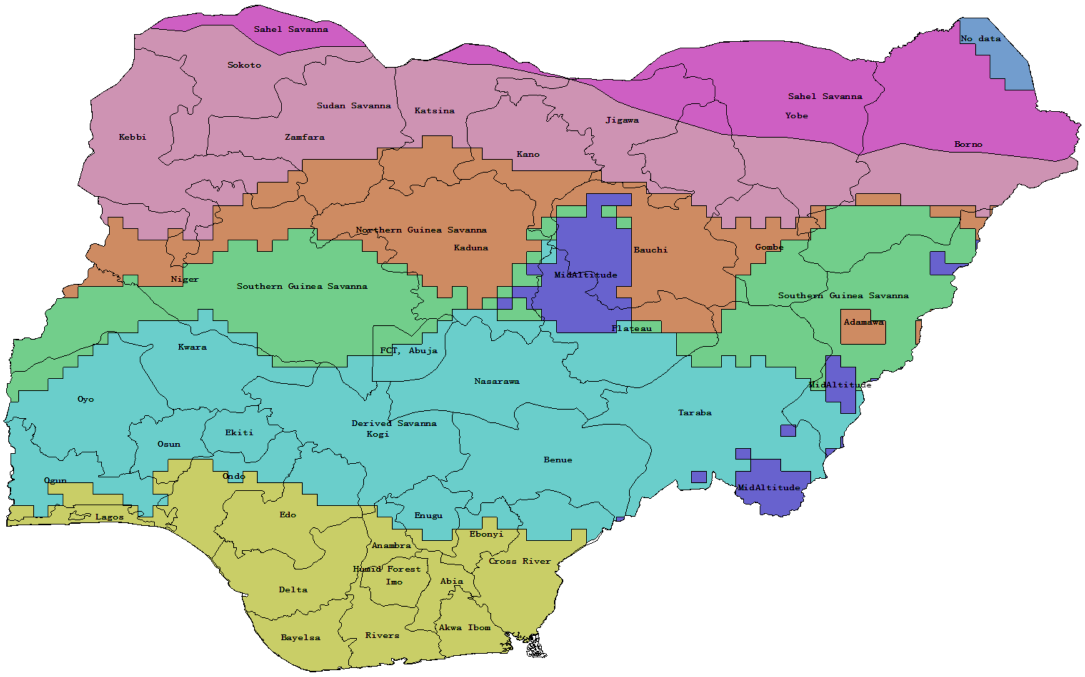

Figure 4. 3
Nigeria Map, showing AEZs and the Corresponding States
Source: GIS

Table 4. 2
Rice Production, Productivity by AEZs and States (2014)

AEZs	**State**	**Production of Rice (000MT)**	**Productivity (MT/ha)**	**Selected States**	**Other Crops Produced**
1. Sahel Savanna	1. Borno	204.8	1.08	Borno	Peanuts, Beans, Maize
	2. Yobe	59.5	1.09		
2. Sudan Savanna	1. Sokoto	22.5	0.95	Kano	Millet, Sorghum, Peanuts, Beans
	2. Kebbi	109.9	1.71		
	3. Zamfara	30.9	1.09		
	4. Katsina	46.6	1.39		
	5. Kano	192.9	1.61		
	6. Jigawa	30.5	1.16		
3. Northern Guinea Savanna	1. Adamawa	206.6	1.58	Kaduna	Cotton, Sorghum, Maize, Shea nut
	2. Bauchi	65.6	1.6		
	3. Gombe	110.9	2.22		
	4. Kaduna	961	2.68		
4. Southern Guinea Savanna	1. Niger	760.9	1.67	Niger	Rubber, Maize, Sugarcane, Sorghum
	2. Jos	0.9	2.55		
5. Derived Savanna	1. Abuja	22.8	1.07	Benue	Cotton, Maize, Cassava,
	2. Benue	466.1	2.06		

	3. Ekiti	66.5	2.28		
	4. Enugu	48.2	3.13		
	5. Kogi	164.8	2.02		
	6. Kwara	57.2	2.45		
	7. Ogun	19.9	1.4		
	8. Ondo	72.5	2.33		
	9. Osun	20.9	1.37		
	10. Oyo	1.4	1.37		
	11. Taraba	322.7	2.07		
	12. Nassarawa	169.8	2.03		
6. Humid Forest	1. Abia	24.7	1.89	Ebonyi	Rubber, oil palm, yam, Cassava, Maize
	2.Akwa Ibom	0.3	3.3		
	3. Anambra	43.4	2.28		
	4. Bayelsa	140.6	1.5		
	5.Cross river	0.2	1.41		
	6. Delta	3.4	4.98		
	7. Ebonyi	187.6	2.47		
	8. Edo	13.3	2.69		
	9. Lagos	6.3	1.73		
	10. Imo	1.1	0.62		
	11. Rivers	0.1	3.3		

Source: Ajetumobi et al., 2015

4.6 Model Specifications

This section describes the theoretical and empirical models that is used to address the specific research objectives in this study. Thus, the next subsection presents the theoretical, functional and empirical specification of the models used in the study.

4.6.1 The Theoretical Model

The Cobb Douglass production model is still the most universal form in theoretical and empirical analyses of growth and productivity, the estimation of the parameters of aggregate production functions is central in much of today's work on growth, technological change, productivity, and labour (Felipe & Adams, 2005). For the theoretical specification, this study therefore employs the Cobb-Douglas production-function. The specification starts from the standard Cobb-Douglas production-function as highlighted in theoretical review and is specified thus:

$$Q = B_{it}\, L_{it}^{\alpha} K_{it}^{1-\alpha} \qquad (4.1)$$

where: Q is production, B is a constant or level of technology; L is a measure of the flow of labour input, K is a measure of the flow of capital input, α is output elasticity of all the inputs. The subscripts *i* is cross-sectional groups of AEZs for rice crop and *t* is the time period.

4.6.2 Functional Form of the Model

The standard theoretical form of the Cobb-Douglas production-function specified earlier can be written in its functional form as follows:

$$lnQ = B_{it}, fln(\, L_{it}, K_{it}) \; (4.2)$$

The logarithm Cobb-Douglas functional model has subsequently been modified and extended by several authors to include several exogenous and endogenous variables. Nastis et al., (2012) expanded both technological and capital inputs in the Cobb-Douglas model, to express the production (Q), at any time period as a function of: agricultural labour input (L), materials (M), physical capital investment (P), human capital (H) and physical resource endowment (R). Hence the functional form of the model is expressed as:

$$lnQ = fln(L_{it}, M_{it}, P_{it}, H_{it}, R_{it}) \quad (4.3)$$

Kumar et al., (2014) further expressed the Cobb-Douglas model as a function of several variable inputs like labour, cultivated area, fertilizers, while irrigated area, tractors and pump set are measures for materials and physical capital investment. Also, included in their functional model are many exogenous factors like forest area, and literacy rate (human capital) thus, functional form is expressed in the logarithm form as:

$$lnQ = fln(L_{it}, A_{it}, N_{it}, T_{it}, P_{it}, F_{it}, E_{it}) \quad (4.4)$$

Where Q is total production; L labour used in rice production; *A* is the total land area for rice production; N is the total fertilizer nutrient consumption; *T* is the number of machineries like tractors, P is the physical capital investment; F is forest area, and E is literacy rate

Therefore, the current study follows the model by Kumar et al., (2014) to specify our functional form of Cobb-Douglas production-function as follows:

$$lnQ = fln(\ A_{it}, T_{it}, N_{it}, L_{it}) \quad (4.5)$$

Furthermore, considering that the production-function links output produced as a function of the inputs employed in the production process. The productivity of each of these inputs can be measured as partial factor productivity. This is regarded as the quantity of the input required to produce one unit of the output in the production-function and measured as the ratio of the output to the inputs (Felipe & Adams, 2005). While the combined effect of the entire inputs used in the production of a given quantity of output is known as the total factor productivity. Among the production inputs, land is considered as a vital production input especially in the agriculture sector. Also, the majority of developing countries such as Nigeria have their economic activities dominantly or primarily land based (Kazungu, 2009). Therefore, the model of choice in this study is concerned with the productivity of rice per unit of land area.

Thus, equation (4.5) is transformed to measure output per unit of land by dividing through with the total land area for each representative AEZs and for the respective time period. The result obtained represent the productivity of rice per unit of agricultural land, thus we have:

Dividing through equation (4.5) by the total land area we have;

$$In Y_{it} = f\ In(MAC_{it}, NUT_{it}, LAB_{it},) \quad (4.6)$$

Where:

$Y_{it} = (Q/A)_{it}$

$MAC_{it} = (T/A)_{it}$,

$NUT_{it} = (N/A)_{it}$

$LAB_{it} = (L/A)_{it}$

That is, Y becomes the total rice productivity per ha, *MAC* = the number of machineries per ha, *NUT* = the total fertilizer nutrient consumption per ha, *LAB* = is the average number of persons employed per ha.

4.6.3 Relationship between Climate Change and Rice Productivity

Assessing climate change impact, Rosenzweig and Iglesias (1994) developed the production-function approach that evaluates the impact of climate change on US agricultural sector. Their approach is built on the basis of existence of a production-function for a particular crop that connects its productivity to the physical factors (such as climate condition) and biological environments. Also, in addition to the conventional variables in production functions such as cultivated area, irrigated area, fertilizers, labours, tractors, forest area, and literacy rate, Kumar et al., (2014) employed the following climate variables; annual average rainfall, annual average maximum and annual average minimum temperature. Thus, the study relied on the aforementioned productivity model in equation (4.6) and further extended based on Rosenzweig and Iglesias (1994); Kumar et al., (2014) to include climate variables such as temperature, rainfall, carbon emission and flood into equation (4.6) as follows:

$$InY_{it} = f(In(MAC)_{it}, In(NUT)_{it}, In(LAB)_{it}, In(TMP)_{it}, In(PPT)_{it}, In(CRN)_{it}, In(FLD)_{it}) \quad (4.7)$$

Where, TMP, PPT, CRN and FLD represent the annual temperature, annual rainfall, Carbon emission and flood respectively.

4.6.4 Relationship between Policies and Rice Productivity

Ahmed and Long, (2013) stressed that, it is a widely accepted principle that climate change and world trade are related. As climate change impact, the study therefore linked world trade policies to domestic and national efforts to climate change. Also, Wiebe et al. (2015) compared the impacts of climate change with or without trade restriction on the productivity, cultivated area, consumption, exports, imports and prices of five commodities. Similarly, Minviel and Latruffe (2014) analysed results on the effect of subsidies on technical efficiency. Following the above studies both trade policy and input subsidy variables are then introduced to extend equation (4.7) thus, we have:

$$InY_{it} = f(In\,(MAC)_{it},\ In\,(NUT)_{it,}\ In\,(LAB)_{it},\ In\,(TMP)_{it,}\ In\,(PPT)_{it},\ In\,(CRN)_{it,}\ In(\,FLD)_{it}\ TRAD_{it},\ In\,(INS)_{it}\, In(Cor)_{it}) \qquad (4.8)$$

Where, TRAD is trade policy, INS and Cor represents Government stability and Corruption perception index respectively. The ln of all variables were used with the exception of Trad which is in percentage.

4.6.5 Relationship between Adaptation Technology and Rice Productivity

Furthermore, adaptation technologies or coping strategies depends on experience, knowledge, economic resources, available technology and infrastructure (Bryan et al., 2012 and Abdul-Razak & Kruse, 2017). Also, Nigeria the adaptation technologies were implemented through the NASPA. Hence, following the above studies two measures are employed to assess adaptation technology which are; NASPA (as a dummy) and irrigation capacity. These variables are also introduced into equation (4.8) thus we have:

$$\ln Y_{it} = f(\ln(MAC)_{it}, \ln(NUT)_{it}, \ln(LAB)_{it}, \ln(TMP)_{it}, \ln(PPT)_{it}, \ln(CRN)_{it}) \ln(FLD)_{it} TRAD_{it}, \ln(INS)_{it} \ln(Cor)_{it} NASPA_{it} \ln(IRR)_{it}) \quad (4.9)$$

Where NASPA and IRR are national strategic plan for climate change adaptation and irrigation capacity which were used as proxies for adaptation technology in Nigeria.

4.7 Empirical Model Specification

The empirical model of this study is founded based on the aforementioned functional form of productivity model which is developed based on production theory and related studies by Kumar et al. (2014); Rosenzweig and Iglesias (1994); Ahmed and Long, (2013) and Abdul-Razak and Kruse, 2017). Thus, the empirical model for the current study is therefore specified in order to test the relationship between climate change, policies and adaptation technologies on Nigeria's rice productivity. In order to achieve the objectives of the current study the following model is specified base on the equation (4.9):

$$\ln Y_{it} = \beta_0 + \beta_1 \ln(MAC)_{it} + \beta_2 \ln(NUT)_{it} + \beta_3 \ln(LAB)_{it} + \beta_5 \ln(TMP)_{it} + \beta_6 \ln(PPT)_{it} + \beta_7 \ln(CRN)_{it} + \beta_8 \ln(FLD)_{it} + \beta_9 TRAD_{it}, + \beta_{10} \ln(INS)_{it} + \beta_{11} \ln(Cor)_{it} + \beta_{12} NASPA_{it} + \beta_{13} \ln(IRR)_{it}) + \varepsilon_{it} \quad (4.10)$$

TRAD = Tariff charged on import of rice in percentage; *INS* = Government stability Index; Cor = Corruption perception Index; *NASPA* = National Adaptation Strategy and Plan of Action (0 for years before NASPA and 1 for years after NASPA). It represents a proxy for climate change adaptation policies/technologies; *IRR* = Irrigation capacity as a proxy for climate change adaptation technologies.

The error term ε consists of AEZ and time-specific effects and is given by:

$$\varepsilon_{it} = \nu it + \gamma it + \varepsilon it$$

Where, β_0 is constant coefficient; β_1 - β_{13}, are the regression coefficients for respective variables and ε_i is the intercept term in the model.

The model in equation (4.10) above will be used to achieve the second, third and fourth objectives of this study. The model will be able to explicate the impact of the climate change (Temperature, rainfall pattern, carbon emission and flood intensity), Policies (Trade policies, Government instability and Corruption perception index) and Adaptation technologies (Irrigation capacity and NASPA) on rice productivity as the dependent variable. The current study in analyzing the effect of AEZs, collected data at the level of AEZs.

4.8 Interaction Term

An interaction effect occurs when the relationship between one independent factor and the dependent factor is weakened or strengthened by the presence of another variable also called "moderator variable" (Andersson, Cuervo-Cazurra, & Nielsen, 2014.; Aiken & West, 1991). The impact of corruption on agricultural productivity is particularly relevant for a country such as Nigeria, which is ranked 146 out of 180 country level data on Corruption Perceptions Index (Transparency International, 2020).

The roles of corruption are theoretically derived among extant literature (Shittu et al., 2020; Musibau et al., 2017; Krueger et al., 1991). Also, based on the argument on systemic corruption in collective action theory, acting corruptly is more beneficial than acting fairly in the presence of systemic corruption (Tacconi & Williams, 2020). Corruption greases the wheels where bureaucracy is sluggish and ineffective (Huntington, 1968). To dishonest bureaucrats and government officials, bribe is an incentive for faster work. Furthermore, Nigeria's agriculture is largely dominated by the marginal, and small farmers having fragmented land and generally resource poor with weak access to capital and voiceless (Anik & Bauer, 2017).

In view of the emphasis on the interaction effect of corruption on the factors influencing economic growth or productivity across most developing countries, the study interacts the use of fertilizer and corruption to examine the effect on rice productivity. Also, given the strong correlation between mechanisation and labour (cor = -0.64), the interaction effect of these variables were examined. Thus considering these interaction effect and its likelihood to influence the result of this study, we extends the model in equation 4.10 to include interaction effects as follows:

$$In\,Y_{it} = \beta_0 + \beta_1\, In(MAC)_{it} + \beta_2\, In(NUT)_{it} + \beta_3\, In(LAB)_{it} + \beta_5\, In(TMP)_{it} + \beta_6\, In(PPT)_{it} + \beta_7\, In(CRN)_{it} + \beta_8 In(FLD)_{it} + \beta_9\, In(Cor)_{it} + \beta_{10}\, In(COR{*}FERT)_{it} + \beta_{11}\, In(LAB{*}MECH)_{it} + \varepsilon_{it} \qquad (4.11)$$

Where $In\,Y_{it}$ = the natural log of rice productivity, $\beta_0 - \beta_{10}$ are coefficients to be estimated. $(COR{*}NUT)_{it}$ is the interaction between corruption and fertilizer,

$(LAB*MECH)_{it}$ is the interaction between labour and mechanisation. Other parameters remain as defined in equation 4.10.

4.9 Method of Data Analysis

The core objective of this study is to assess the impact of climate change, policies and adaptation technologies on rice productivity in AEZs of Nigeria. Based on the empirical model specification in equation (4.10). The data analysis follows series of pre-estimation procedures that is, cross-sectional dependence (CSD) procedure to detect the presence of individual and time effects then followed by stationarity or unit root test, serial correlation, multicollinearity, heterogeneity and cointegration test.. This is followed by the selection of appropriate ARDL model for estimation of the model. The outcome of these tests determined the choice of the proper estimator used in the analysis. Furthermore, according to Westerlund (2007), the ARDL estimation approach is suitable in panels containing time-series dimension (T) that are larger than the cross- sectional dimension (N). Hence, considering the current study have a time-series dimension that is larger than number of cross section (that is T=39 and N= 6), the use of ARDL model is further justified. The procedural steps are discussed in the following sections.

4.9.1 Cross Sectional Dependence Test

The pre-estimation procedure started with cross-sectional dependence (CSD) as a diagnostic test which is performed to detect the presence of individual and time effects between various states representing the AEZs. Based on literature, CSD can occur in panel data due to unobserved common factors or macroeconomic shocks (Guillaumin, 2009; Shittu & Abdullah, 2019). For example, shocks can occur in the form of changes in technological, political, environmental or climatic factors (Andrews, 2005). These shocks may then affect all cross-sectional units in the same magnitude and therefore result into CSD. While, alternatively the magnitude of the shock could be different for each cross section or AEZ. Thus, this test is important since the presence of CSD may lead to violation of an important assumption of the first-generation panel unit root tests. That is, the first-generation unit root test may not be sufficient to determine the order of integration of the variable when there is CSD or homogeneity (Guillaumin, 2009; Shittu & Abdullah, 2019).

To test for CSD in this study, two tests or approach used are the CD test proposed by Pesaran (2004) which recognizes the shortcoming of the earlier Breusch and Pagan's LM test in treating panel data with Large N. The general form of these tests are specified as follows:

Consider the standard panel data model

$$Y_{it} = \beta_0 + \beta_i X_{it} + U_{it} \qquad (4.12)$$

Where i=1,...,6 (number of cross sections or states) and t=1,...39 (time period).

Also, X_{it} represents K × 1 vector of regressors in this study which are: temperature, rainfall pattern, carbon emission, flood intensity, trade policies, government stability and corruption perception index, irrigation capacity and NASPA. While, β_i represents the parameters to be estimated for the ith state, and β_0 represents the constant or time-invariant individual disturbance parameter. For the null hypothesis, the error term U_{it}

is considered as independent as well as identically distributed (iid) across the time periods and the AEZs. Whereas in case of the alternative, U_{it} could be correlated across AEZs or cross sections, although the assumption of non-existence of serial correlation is also maintained (Hoyos & Sarafidis, 2006).

Specifically, the Pesaran (2004) proposed a CD test which is estimated as specified in equation (4.13):

$$CD = \sqrt{\frac{2T}{N(N-1)}}\left(\sum_{i=1}^{N-1}\sum_{J=i+1}^{N}\hat{\rho}_{ij}\right) \tag{4.13}$$

The test examines the null hypothesis of cross-sectional independence or no CSD. The CD test by Pesaran (2004) shows that under the null hypothesis of no cross-sectional dependence CD $\overset{d}{\rightarrow}$ N (0, 1) for N → ∞ and T sufficiently large.

Therefore, for CSD the hypothesis is specified as:

$H_0 : \rho_{ij} = \rho_{ji} = cor(u_{it}, u_{jt}) = 0$ for $i \neq j$

$H_1 : \rho_{ij} = \rho_{ji} \neq 0$ for some $i \neq j$

Whereby, ρ_{ij} represent the "product-moment correlation coefficient" or pairwise correlation of the disturbances which is given by;

$$\rho_{ij} = \rho_{ji} = \frac{\sum_{t=1}^{T} u_{it}u_{jt}}{(\sum_{t=1}^{T} u_{it}^2)^{1/2}(\sum_{t=1}^{T} u_{jt}^2)^{1/2}} \tag{4.14}$$

Whereby, u_{it} implies the value of the error term u_{it}; ρ_{ij} is the estimated pairwise correlation of the residuals from equation (4.12). The achievable number of pairings (u_{it}, u_{jt}) rises as N increases.

While the second approach is the Breusch and Pagan (1980) LM statistic. This is valid in the case of fixed number of cross sections (N) while the time period (T) tends to infinity. The LM statistics test is given by:

$$LM = T \sum_{I=1}^{N-1} \sum_{J=I+1}^{N} \hat{\rho}_{IJ}^{2} \tag{4.15}$$

$$\hat{\rho}_{ij} = \hat{\rho}_{ji} = \frac{\sum_{t=1}^{T} \hat{u}_{it}\, \hat{u}_{jt}}{\left(\sum_{t=1}^{T} \hat{u}_{it}^{2}\right)^{1/2} \left(\sum_{t=1}^{T} \hat{u}_{jt}^{2}\right)^{1/2}} \tag{4.16}$$

Whereby, $\hat{u}_{it}$ implies the estimated value of the error term u_{it}; $\hat{\rho}_{ij}$ is the estimated pairwise correlation of the residuals from equation (4.16). LM statistics is asymptotically distributed as χ^2 with $N(N-1)/2$ degrees of freedom under the null hypothesis.

4.9.2 Panel Unit Root Test

As the paper by Levin and Lin (1993) emerged, the examination of unit root for panel data consequently becomes widespread in the field of research, coupled with accessibility to panel data. More so, there is a general consensus that the normal time-series tests for unit root such as; the Dickey-Fuller (DF), Phillips-Perron (PP) as well as augmented Dickey-Fuller (ADF) tests are weak in terms of differentiating the null of unit root with its stationary alternatives (Maddala & Wu, 1999). Whereas, the use of unit root tests for panel data are considered much stronger approach to tests. Base on the suggestion of Monte Carlo simulations, the panel unit root tests have much more power than time-series unit, since the power of unit root tests increases by including cross sections (Levin et al., 2002).

Two broad categories of panel data unit root tests exist in literature. The first-generation panel unit root tests (the Levin-Lin-Chu (LLC) test (2002), Im-Pesaran-Shin (IPS) test (1997), Fisher type test). The other category is the second generation unit root tests which includes; the Breitung and Das test (2005), Moon and Perron test (2004) and also, the second generation unit root by Pesaran (2007). These tests have improved over the first-generation by allowing for CSD for all variables (Bangake & Eggoh, 2010). That is, one of the advantages of the second generation unit root test is the ability to examine the unit root in the presence of CSD.

As none of these panel unit root tests is devoid of statistical shortcomings in terms of size and power properties, it is very common as robust approach that researchers conduct numerous unit root tests then compares the results (Lau, Ng, Cheah, & Choong, 2019). Therefore, to examine the level of integration of the study variables, both the first-generation (IPS and LLC tests) and second generation (Breitung & Das, 2005) were specified for this study. The general form of the panel unit root tests is specified as follows based on univariate regression:

$$\Delta\gamma_{it} = \rho_i\gamma_{i,t-1} + \acute{z}_{it}\gamma + \mu_{it} \qquad (4.17)$$

Whereby: γ_{it} is the regressors in the study (temperature, rainfall pattern, carbon emission, flood intensity, trade policies, government stability and corruption perception index, irrigation capacity and NASPA).

Also, $\Delta\gamma_{it} = \gamma_{it} - \gamma_{i,t-1}$; ρ_i is the stationarity coefficient; i = 1,2,..., *6* is the individual cross section or state, for each individual t = time series observations (that is, 1,2,...,*39*), $\acute{z}_{it}$ is the deterministic component and μ_{it} is a stationary process. Also $\acute{z}_{it}$ could be zero, one, the fixed effects (μ_{it}), or fixed effect as well as a time trend (t).

$$H_0 : \rho_i = 0$$

Haven provided an overview on panel unit root test, and specified the general form of the unit root model specification, the study goes further to present the unit root models employed to check for stationarity of variables in this study.

4.9.2.1 Im, Pesaran and Shin (2003) Test

The Im, Pesaran and Shin (2003) (IPS) is used to test for unit root in this study. The IPS test is considered as a flexible approach because of the simplicity of the procedure for computing the panel unit root test (which is referred as t-bar statistic). It allows for simultaneous stationary and non-stationary series implying that, ρi can differ between factors. Moreover, this test allows for residual serial correlation and heterogeneity of the dynamics and error variances across groups. Instead of pooling the data, IPS consider the mean of ADF statistics computed for each AEZ in the panel when the error term μ_{it} of model (4.17) is serially correlated, possibly with different serial correlation patterns across cross-sectional units.

$$\Delta\gamma_{it} = \mu_i + \beta_i t + \rho_i \gamma_{i,t-1} + \sum_{m=1}^{k_i} \alpha_{im} \Delta\gamma_{i,t-m} + e_{it} \quad (4.18)$$

Whereby, t measures the time trend, k refers to the lag length and e_{it} is the error term. Under the assumption of homogeneity of the dynamics of autoregressive components of equation (4.18) and also the cross-sectional independence across panels or AEZs, the following hypotheses are proposed by Levin et al., (2002):

$$H_0 : \rho_i = 0 \quad (4.19)$$

$$H_1 : \rho_i < 0$$

This implies that when the H_0 is not rejected, then the series is considered non-stationary.

4.9.2.2 Levin-Lin-Chu (LLC) test (2002)

For robustness check, another first-generation unit root test used in this study is the Levin-Lin-Chu (LLC) test (2002). The LLC tests restricts ρ_i to be identical across all AEZs, therefore removing the AEZ subscript from ρ_i in equation (4.17) we have:

$$\Delta\gamma_{it} = \mu_i + \beta_i t + \boldsymbol{\rho} \boldsymbol{\gamma}_{i,t-1} + \sum_{m=1}^{k_i} \alpha_{im} \Delta\gamma_{i,t-m} + e_{it} \quad (4.20)$$

Equation (4.20) assumes a common unit root across all the panels (AEZs). Then, the hypotheses are specified thus:

$$H_0 : \rho_1 = \rho_2 = \ldots = \rho = 0 \quad (4.21)$$

$$H_1 : \rho_1 = \rho_2 = \ldots = \rho < 0$$

The corresponding t-test statistic is computed as $t_\rho = \frac{\hat{\rho}}{SE(\hat{\rho})}$. The Monte Carlo exercise in Levin and Lin (1993) indicated that when there is no individual- specific fixed effect, the standard normal distribution may provide a good approximation for the empirical distribution of the test statistic in relatively small samples. As Levin et al. (2002) noted, their panel-based unit root tests are more relevant for the panels that are in moderate size (i.e., 10 < N < 250 and 25<T<250).

4.9.2.3 Breitung and Das test (2005)

Furthermore, to ensure robustness, the Breitung and Das test (2005) second generation unit root test is also employed to examine the stationarity of the variables in this study. These tests present a new and simple procedure for testing unit roots in dynamic panels without been affected by the possibility of CSD issue and serially correlated errors among AEZs. In this approach, the observations y_{it} are supposed to be generated according to a simple dynamic linear heterogeneous panel data model:

$$y_{it} = (1 - \rho_i)\mu_i + \delta_i y_{it-1} + u_{it} \quad (4.22)$$

$$u_{it} = \lambda_i f_i + \varepsilon_{it}$$

The idiosyncratic shocks, ε_{it} are assumed to be independently distributed both across i and t with zero mean, variance, and finite forth-order moments. The unobserved common factor f is serially uncorrelated with zero mean, constant variance and finite forth-order moment.

After the panel unit root tests, the order of integration of the variables are then determined and the study proceeded to the subsequent stage in the methodological design of this study that is the cointegration tests.

4.9.3 Panel Cointegration Test

The production theory does not indicate if the variables have stochastic trends or not and whether such trends are common between variables; therefore, cointegration test was performed after unit root tests to explore long-run cointegration among variables (Lim & McAleer, 2001). Even though, the modelled variables may disperse in the short-run they are also likely to converge or move towards equilibrium in the long-run (that is existence of long-run cointegration). That is, when at individual level the variables may not be stationary but could exhibit stationarity property in a linear combination hence, they can be regarded to be cointegrated. Hence, this study applies the pooled data to carry out the panel cointegration tests to demonstrate the existence of long-run relationship before proceeding to estimation of the model of the study. The commonly used tests of panel cointegration are as follows: the Kao Panel Cointegration Test (1999); Westerlund Cointegration tests; and Pedroni Panel Cointegration tests. Also, the cointegration can also be inferred when the ECT is negative and significant. This study relies on the later that is the sign of the ECT in the ARDL estimate.

This study applied the alternative rule relating to the existence of long-run cointegration in the rice productivity model based on the statistical significance of the error correction term (ECT) in the PMG estimation (Harris & Sollis, 2003; Baek, &

Choi, 2017). When the coefficient of the ECT is negative and significant then, a long-run cointegration exist in the model for the current study. A negative sign indicates a long-run reversal to equilibrium in the event of a shock in the short-run. Whereas, when the ECT coefficient is not significant or has a positive sign then, the model is said to exhibit no long-run cointegration. This later procedure for determining cointegration is favoured in this study considering the limitation of maximum number of regressors in the case of both Kao cointegration test and the Pedroni cointegration test. After estimating the long-run equilibrium relationship given by the Error Correction Term (ECT), which is a measure of the extent by which the observed values in time $t-1$ deviate from the long-run equilibrium relationship.

After all the preliminary assessments carried out on the variables of this study such as the CSD tests, the unit root tests and lastly establishing cointegration among the variables in the rice productivity model, this study selected the appropriate estimation method to be used. That is, after fulfilling all necessary criteria, the study extends further by specifying the panel ARDL model to be used for estimation. This is presented in the next subsection of the study.

4.9.4 Model Selection for Panel ARDL

Considering that the static estimation approaches are less robust, as emphasized by Loayza and Ranciere (2006) that the static panel estimators do not take advantage of the panel dimension of the data by distinguishing between the short and long-run relationships. Considering this factor, the dynamic heterogenous panel regression (MG, PMG and DFE) has been applied in this study. Based on Pesaran et al. (1999), the dynamic heterogeneous panel regression can be incorporated into the error correction model (ECM) using the autoregressive distributed lag ARDL (p, q) technique, where p is the lag of the dependent variable and q is the lag of the independent variables. Consequently, the following general form of the dynamic heterogenous equation is specified for the rice productivity model based on Pesaran et al. (1999):

$$\text{lnRP}_{\text{it}} = \sum_{j=1}^{p} \propto_{1,j} lnRP_{i,t-j} + \sum_{K=0}^{q} \propto_{2,k} X_{i,t-k} + \mu_i + \varepsilon_{i,t} \quad (4.23)$$

where RP is the rice productivity, X is a set of independent variables including the land area, labour, mechanisation, fertilizer nutrient, temperature, rainfall pattern, carbon emission, flood intensity, Trade policies, Government instability, Corruption perception index, Adaptation technologies Irrigation capacity and NASPA. Also, μ_i is the unobserved state specific effect. The subscripts i and t represent states and time indexes, respectively. Where p and q are the lag orders for both dependant and independent variables.

Base on the assumption of cointegration between the model variables, that is, the likelihood of the model to revert back to equilibrium in the long-run after any form of error or distortion in the short-run. The error correction model of equation (4.23) is specified based on equation (4.10) in which the short-run dynamics of variables are affected by the deviation from equilibrium.

$$\Delta lnRp_{it} = \emptyset_i\big(lnRp_{i,t-1} + \beta_{i,1}lnLA_{i,t-1} + \beta_{i,2}lnMAC_{i,t-1} + \beta_{i,3}lnNUT_{i,t-1} + \beta_{i,4}lnLAB_{i,t-1} + \beta_{i,5}lnTMP_{i,t-1} + \beta_{i,6}lnPPT_{i,t-1} + \beta_{i,7}lnCRN_{i,t-1} + \beta_{i,8}lnFLD_{i,t-1} + \beta_{i,9}lnTRAD_{i,t-1} + \beta_{i,10}lnINS_{i,t-1} + \beta_{i,11}lnCor_{i,t-1} + \beta_{i,12}lnNASPA_{i,t-1} + \beta_{i,13}lnIRR_{i,t-1}\big) + \sum_{j=1}^{p-1} \propto_{1,j} \Delta lnRp_{i,t-j} + \sum_{j=1}^{q-1} \propto_{2,j} \Delta lnLA_{i,t-j} + \sum_{j=1}^{q-1} \propto_{3,j} \Delta lnMAC_{i,t-j} + \sum_{j=1}^{q-1} \propto_{4,j} \Delta lnNUT_{i,t-j} + \sum_{j=1}^{q-1} \propto_{5,j} \Delta lnLAB_{i,t-j} + \sum_{j=1}^{q-1} \propto_{6,j} \Delta lnTMP_{i,t-j} + \sum_{j=1}^{q-1} \propto_{7,j} \Delta lnPPT_{i,t-j} + \sum_{j=1}^{q-1} \propto_{8,j} \Delta \ln CRN_{i,t-j} + \sum_{j=1}^{q-1} \propto_{9,j} \Delta lnFLD_{i,t-j} + \sum_{j=1}^{q-1} \propto_{10,j} \Delta lnTRAD_{i,t-1} + \sum_{j=1}^{q-1} \propto_{11,j} \Delta lnINS_{i,t-j} + \sum_{j=1}^{q-1} \propto_{12,j} \Delta lnCor_{i,t-j} + \sum_{j=1}^{q-1} \propto_{13,j} \Delta lnNASPA_{i,t-j} + \sum_{j=1}^{q-1} \propto_{14,j} \Delta lnIRR_{i,t-j} + \lambda_i(t) + u_{i,t} + \varepsilon_{i,t} \qquad (4.24)$$

Where i = 1,..., 6 and t = 1980,..., 2018. The variables RP, LA, MAC, NUT, LAB, TMP, PPT, CRN, FLD, TRAD, INS, COR, NASPA, and IRR are: rice productivity, land area, mechanisation, fertilizer, labour, temperature, average annual rainfall, carbon emission, flood intensity, trade policy, political instability, corruption perception index, NASPA, and irrigation capacity respectively. The β_i, represents long-run coefficients; Also, $\propto_1$ to $\propto_{14}$ are short-run coefficients parameters to be estimated. Whereas, the parameter $\emptyset_i$ represent a measure for the error-correcting speed of adjustment. A negative sign and significance of the coefficient $\emptyset_i$ implies that the variables in the rice productivity model demonstrate long-run relationships (Enders, 2008).

Equation (4.24) can be estimated by three different estimators: the mean group (MG) model of Pesaran and Smith (1995), the pooled mean group (PMG) estimator developed by Pesaran et al. (1999), and the dynamic fixed-effects (DFE) estimator. All three estimators consider the long-run equilibrium and the heterogeneity of the dynamic adjustment process (Demetriades & Law, 2006). However, to choose among the MG, PMG and DFE methods, the Hausman test is employed to confirm whether there is a significant difference between these estimators and to make a choice regarding the appropriate estimator for this model.

4.9.5 Hausman Test

Following the outcome of the preliminary or pre estimation tests, the study proceeded and established the appropriate choice among the three alternative ARDL estimators. That is, the mean group estimator (MG) of Pesaran and Smith (1995), the pooled mean group estimator (PMG) and the dynamic fixed-effects (DFE) estimator developed by Pesaran et al. (1999). Thus, Equation (4.24) is estimated for the whole sample with PMG, MG, and DFE. As the study considers the shocks of climate change across AEZs, it is expected that the sample will be homogenous with respect to productivity growth in the long-run. However, in the short-run, there is bound to be state-specific heterogeneity as the study considers climate change shocks across AEZs.

The null of this test is that the difference between PMG and MG or PMG and DFE estimation is not significant. If the null is not rejected, the PMG estimator is recommended as the efficient model. The alternative is that there is a significant difference between PMG and MG or PMG and DFE and the null is rejected. The PMG will be used if the P-value is insignificant at the 5% level. On the other hand, if it happens to have a significant P-value, then the use of a MG or DFE estimator is appropriate. Another important issue is that ARDL lag structure should be determined by some consistent information criterion.

4.9.6 Lag Length Selection

Selecting the lag length structure in this study follows the technique of lag selection developed by Kripfganz, and Schneider (2018). The technique involves obtaining an optimal lag structure for each state separately, and then for each variable, the most frequent lag length obtained across the states is selected for that variable, while the optimal lag length selection criteria is based on the Bayesian information criterion (BIC). Also considering that lag structure could be imposed according to the data limitation specifically, when the time dimension is not long enough to overextend the lags, one can impose a common lag structure across countries (Pesaran *et al*, 1999; Loayza & Ranciere, 2006; Demetriades & Law, 2006).

4.9.7 Model Estimation Technique

Following the outcome of the Hausman tests, the study proceeded to estimate the rice productivity model in equation (4.24) using the ARDL (PMG) estimator. Also, the chosen lag length for each factor based on the technique described in the preceding section is considered in the estimation process. The PMG estimator constrains the long-run parameters to be homogenous or the same across AEZs. That is in PMG, the long-run coefficients are constant across the groups and only the short-run coefficients are allowed to differ across groups that make up the panel.

4.10 Summary of Chapter

The panel data was used for the preliminary or specification test such as the panel unit root test. Unit root tests were conducted using the Levin-Lin-Chu (LLC) test (2002) and Im-Pesaran-Shin (IPS) (1997) methods. These tests are employed for checking stationarity and ensuring that variables in the regression are not having spurious correlation. Consequently, on the bases of the specification test, suitable method for assessing the short and long-run association among the variables in the model was adopted. This includes methods such as cointegration test, Error Correction Model (ECM) and Autoregressive Distributed Lag (ARDL) (PMG, MG and DFE). The difference between the three estimators are that: the PMG estimator constrains the long-run parameters to be homogenous or the same across AEZs. That is in PMG, the long-run coefficients are constant across the groups and only the short-run coefficients are allowed to differ across groups that make up the panel. In the case of MG estimator, it allows both the long-run and short-run coefficients to differ across states (Yamarik, El-Shagi & Yamashiro, 2016). The last specification is the DFE model where all coefficients are constrained to be equal or homogenous across the groups.

Table 4. 3
Summary of Methods for each Objectives

Research Objective	Method	Independent Variable
1. To identify the types of climate changes, policies, and adaptation technologies influencing rice productivity in the AEZs of Nigeria	Descriptive analysis	Climate Change, Government Policies and Adaptation technologies
2. To assess the impacts of climate change, adaptation technologies and Government policies on rice productivity	Panel ARDL (PMG long-run effect)	Climate variables (Rainfall, Temperature, Carbon emission and flood); Adaptation technologies (Irrigation capacity and NASPA);

			Government Policies (Trade policy, Instability and Corruption index)
3.	To assess the dynamism in the impact of climate change, government policies and adaptation technologies on rice productivity across the different AEZs of Nigeria	Panel ARDL (PMG short-run dynamic effect)	Rainfall, Temperature, Carbon emission and flood; Trade policy, Instability and Corruption index; Irrigation capacity and NASPA

CHAPTER FIVE

RESULT ANALYSIS AND DISCUSSIONS

5.1 Introduction

The chapter presents the results based on the methodological design of this study. The chapter constitute sections; (5.2) result of descriptive analysis for factors in the rice productivity model; (5.3) pre-estimation results (CSD result, unit root test result, cointegration test result and Hausman's test result); (5.4) long-run estimate result and (5.5) the short-run estimate result. Through these sections the main objectives of this study was achieved which involves estimation of impact of climate change, policies and adaptation technologies on rice productivity in AEZs of Nigeria. The results are presented based on the specific objectives of the study. Lastly the summary of results and prospects for rice productivity growth across the AEZs in Nigeria is highlighted.

5.2 Descriptive Analysis Result

In this section, by way of a descriptive analysis such as mean, standard deviation, minimum and maximum, the study presents a descriptive account of the different climate change factors, policy factors and adaptation technologies affecting rice productivity across the selected states. The descriptive results are presented in Table 5.1. This was used to achieve the first objective of the study, which are to describe the different forms of climate change, policies and adaptation technologies affecting rice productivity in Nigeria.

Table 5. 1

Descriptive Analysis of variables across Six AEZs from (1980 -2018)

Variable	All States	Benue	Niger	Kaduna	Kano	Borno	Ebonyi
PRODUCTIVITY (MT/Ha)							
Mean	2.02	2.02	2.79	2.16	2.12	1.55	1.49
Std. Dev.	0.87	0.83	1.10	0.52	0.98	0.54	0.29
Min	0.52	0.74	1.55	1.03	0.68	0.52	1.08
Max	6.42	3.43	6.42	3.41	4.80	2.48	2.27
LAND AREA (000' Ha)							
Mean	505.19	53.99	211.37	2534.71	139.90	128.10	63.09
Std. Dev.	2368.22	51.51	197.17	5404.81	194.85	13.52	30.71
Min	0.44	8.19	19.38	19.38	12.70	0.44	33.23
Max	16853.10	147.13	944.98	16853.1	1780.00	1453.01	1160.20
FERTILIZER (Kg/Ha)							
Mean	56.60	54.82	52.52	65.59	53.30	48.33	65.06
Std. Dev.	27.46	33.02	27.25	20.17	29.71	22.91	26.78
Min	5.33	10.68	21.80	19.49	5.33	19.79	26.76
Max	134.00	134.00	105.52	96.94	125.61	93.01	124.20
LABOUR (Number/Ha)							
Mean	6.86	8.40	8.74	13.88	12.64	19.56	8.53
Std. Dev.	9.55	4.41	7.15	17.12	7.91	12.66	5.96
Min	0.01	0.09	0.40	8.89	2.12	0.56	2.37
Max	55.15	21.21	27.22	33.09	30.52	38.79	22.54
MECHANIZATION (Machinery number/100 Ha)							
Mean	5.89	5.75	5.75	6.01	6.35	5.75	5.75
Std. Dev.	0.81	0.86	0.86	0.65	0.59	0.86	0.86
Min	4.20	4.20	4.20	5.06	5.06	4.20	4.20
Max	6.99	6.99	6.99	6.99	6.99	6.99	6.99
CARBON (Kilo tonnes)							
Mean	45989.93	46203.33	46241.65	45723.56	45824.50	45740.13	46206.39
Std. Dev.	14900.54	15344.95	15419.54	14711.66	14796.83	14723.82	15350.79
Min	22159.45	22159.45	22159.45	22159.45	22159.45	22159.45	22159.45
Max	76142.27	75612.27	76142.27	75612.27	75612.27	75612.27	75612.27
TEMPERATURE (Degree Celsius)							
Mean	33.09	31.44	34.40	31.99	33.67	39.21	27.86
Std. Dev.	3.57	1.64	0.96	0.37	0.74	0.90	0.70
Min	27.02	28.06	32.30	31.01	31.45	36.80	27.02
Max	41.20	33.38	36.50	32.73	36.13	41.20	31.40
ANNUAL RAIN (Millimetre)							
Mean	681.43	290.61	195.52	1226.67	1033.13	142.76	1299.91

Variable	All States	Benue	Niger	Kaduna	Kano	Borno	Ebonyi
Std. Dev.	540.39	415.05	33.43	239.44	353.15	38.74	169.54
Min	61.80	61.80	99.91	827.90	478.70	88.10	801.00
Max	1872.30	1419.90	1255.42	1788.40	1872.30	1273.16	1534.40
FLOOD INTENSITY (Index)							
Mean	0.36	0.32	0.35	0.35	0.42	0.33	0.40
Std. Dev.	0.51	0.51	0.49	0.49	0.51	0.49	0.58
Min	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Max	1.50	1.50	1.50	1.50	1.50	1.50	1.50
TRADE POLICY (Percentage tariff)							
Mean	46.13	46.13	46.13	46.13	46.13	46.13	46.13
Std. Dev.	44.08	44.56	44.56	44.56	44.56	44.56	44.56
Min	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Max	150.00	150.00	150.00	150.00	150.00	150.00	150.00
IRRIGATION CAPACITY (Ha)							
Mean	221.86	254.90	339.86	226.58	135.95	169.93	203.92
Std. Dev.	74.54	40.15	53.54	35.69	21.42	26.77	32.12
Min	106.67	200.00	266.67	177.78	106.67	133.33	160.00
Max	390.67	293.00	390.67	260.44	156.27	195.33	234.40

From the descriptive analysis, the mean, standard deviations, minimum and maximum values of the variables in this study are presented in Table 5.1. According to the result from the pooled panel, the mean productivity of rice in Nigeria stands at 2.02 MT/ha. Also, the minimum rice productivity in Nigeria is as low as 0.52 MT/ha. On the other hand, the maximum or best productivity recorded is about 6.42 MT/ha. These results indicate the wide gap between the maximum productivity and the mean productivity. Hence, there is high potential which can be utilized by improving productivity to the maximum potential in Nigeria.

The findings of the study revealed the analysis of the rice productivity trend from 1980 to 2018 at the individual state levels. Niger state has a mean productivity of 2.76 MT/ha which is the highest mean productivity compared to other states. While, Kaduna, Kano, Benue, Borno are ranked as the 2^{nd}, 3^{rd}, 4^{th} and 5^{th} states respectively in terms of mean rice productivity, while Ebonyi state has the lowest mean productivity value of 1.49 MT/ha. The standards deviations are 0.83, 1.10, 0.52, 0.98, 0.54 and 0.29 for Benue, Niger, Kaduna, Kano, Borno and Ebonyi respectively. Similarly, between 1980- 2018, Niger state had the highest maximum productivity of 6.42 MT/ha. Also, Kano, Benue, Kaduna, and Borno are ranked as 2^{nd}, 3^{rd}, 4^{th}, and 5^{th} states respectively in terms of the maximum rice productivity across the six states. Again, among the entire states, Ebonyi has the lowest maximum productivity value of 2.27 MT/ha.

Results of the descriptive analysis of the data for land area from 1980 to 2018 using the pooled data and individual states is presented in Table 5.1. The pooled panel result indicates that, the mean value of land area under rice production between the period of 1980 and 2018 in Nigeria stands at 505.19 thousand ha while the maximum land area under rice cultivation is 1.685 million ha. This implies land area cultivated to rice increased from 505.19 thousand ha from 1980 to 1.685 million ha in 2018. Indicating a continuity in land expansion activity for rice cultivation in the country. This result indicates that land expansion had been continually employed to support rice production in Nigeria.

Also, based on individual states, the result of analysing the land area under rice cultivation indicated that Kaduna state has the highest mean land area of 253.4 thousand ha. Again Niger, Kano, Ebonyi and Benue are ranked as the 2^{nd}, 3^{rd}, 4^{th} and 5^{th} states in terms of the mean land area under rice cultivation, while Borno state has the lowest mean land area under rice cultivation of 28.1 thousand ha. The standard deviations are 51.51, 197.17, 5404.81, 194.85, 13.52 and 30.71 for Benue, Niger, Kaduna, Kano, Borno and Ebonyi respectively. In terms of the maximum land area cultivated to rice, Kaduna state is presented to have the largest cultivated area of 1.685 million ha. Whereas, Kano, Borno, Ebonyi, Niger and Benue are ranked as 2nd, 3rd, 4th, 5th and 6th states respectively in terms of the maximum land area cultivated to rice.

In terms of mean fertilizer usage in kg, the result of pooled data shows that the mean fertilizer used is 56.60 kg/ha, with a standard deviation of 27.46. The minimum fertilizer used is estimated as 5.33kg/ha, while the maximum is 134.kg/ha. The comparison between individual states in the sample reveals that in terms of mean fertilizer usage, Kaduna has the highest fertilizer usage with 65.59kg/ha. The second state in terms of quantity of fertilizer usage is Ebonyi with mean of 65.06kg/ha, followed by Benue (56.6kg/ha), Niger (54.82kg/ha), then, Kano (53.30 kg/ha) and Borno (48.33kg/ha) are at the 5th and 6th position respectively. That is, in terms of highest amount of fertilizer usage the leading state is Benue while Kano, Ebonyi, Niger Kaduna Borno are ranked as the 2nd, 3rd, 4th and 5th states respectively. The lowest fertilizer usage also found to be in Kano (5.33kg/ha), while in ascending order, the 2nd, 3rd, 4th and 5th states with low fertilizer usage are Benue, Kaduna, Borno, Niger, and Ebonyi respectively.

For labour usage per hectare of land, based on the pooled data, the average was found to be 7 persons per ha, the maximum employee per ha is 55 persons while the minimum is 1 person and the standard deviation is found to be 10 persons per ha. Furthermore, ranking the states based on the mean number of labours employed per, the result indicates as follows: Borno, Kaduna, Kano, Niger, Ebonyi and Benue in decreasing order of the mean number of labours per ha respectively. Also, in terms of the maximum number of labours the result is spread from highest to lowest as follows: Borno, Kaduna, Kano, Niger, Ebonyi and Benue respectively which is the same with the mean distribution. The result further reveals that in terms of the minimum labour employee per ha, three states (Benue, Niger and Borno) employ one person per ha. While, Kaduna, Kano and Ebonyi employ 9 persons/ha, 2 persons/ha and 3 persons/ha respectively.

The level of mechanisation is proxied by the total number of tractors per 100 ha. The descriptive analysis of the number of tractors per 100 ha shows a common value for the mean, minimum, maximum and standard deviation across the states. This also applies to the national averages as depicted from the pooled data of the study. Given the results, there is low level of mechanisation across the state and at the national level in general.

In terms of mean temperature, the result from pooled data shows the mean temperature over the period of 1980– 2018 to be 33.09 degree Celsius, while the maximum temperature stands at 41.20 degree Celsius with a standard deviation of 3.57. The comparison between individual states in the sample reveals that Borno state has the highest mean temperature of 39.21 degree Celsius. Niger, Kano, Kaduna, Benue and Ebonyi are ranked as the 2^{nd}, 3^{rd}, 4^{th}, 5^{th} and 6^{th} states in descending order of mean values of temperature for the period of 1980-2018. The standards deviations are 1.64, 0.96, 0.37, 0.74, 0.90, and 0.70 for Benue, Niger, Kaduna, Kano, Borno and Ebonyi respectively. Similarly, Borno has the highest maximum temperature of 41.20 degree Celsius and Ebonyi has the lowest maximum average temperature among the six states.

The descriptive result of the average annual rainfall reveals that; from the pooled data, the mean value of rainfall over the period of 1980–2018 is at 681.43 mm, while the maximum annual rainfall stands at 1872.30 mm and the standard deviation is 540.39. The comparison between individual states in the sample reveals that Ebonyi state has the highest mean annual rainfall of 1299.91 mm. Kaduna, Kano, Benue, Niger and Borno are ranked as the 2nd, 3rd, 4th, 5th and 6th states in descending order of mean values of rainfall for the period of 1980–2018. The standard deviations are 415.05, 33.43, 239.44, 353.15, 38.74, and 169.54 for Benue, Niger, Kaduna, Kano, Borno and Ebonyi respectively. Similarly, for maximum annual rainfall, Kano, Kaduna, Ebonyi, Benue, Borno and Niger are ranked as 1st, 2nd, 3rd, 4th, 5th and 6th states in descending order of maximum annual rainfall.

5.3 Correlation and Multicollinearity Analysis

This section analyses the inter correlation between important factors in the model. This is done to measure the strength and direction of the linear relationship between the variables. The result of the correlation coefficient ranges between -1 and +1, representing a negatively perfect relationship and positively perfect relationship respectively. While the value of 0 indicates no relationship between the variables, the values below 0.3 indicate low relationship, while between 0.3 to 0.7 is moderate correlation and above 0.7 indicates strong correlation. The result is presented in 5.2.

Table 5. 2

Correlation among Variables

Variables	Rp	La	Fert	Lab	Mech	Co2	Temp	Rain	Flood	Trad pol	Gov stab	Cor	Irri	NASPA
Rp	1													
La	0.15	1												
FERT	0.34	0.21	1											
Lab	-0.19	-0.10	-0.06	1										
Mech	-0.11	0.02	-0.08	-0.64	1									
CO_2	0.44	0.25	0.60	-0.36	0.25	1								
Temp	-0.41	-0.06	-0.07	0.05	0.05	0.00	1							
Rain	0.34	0.26	0.28	0.21	-0.06	0.18	-0.50	1						
Flood	0.04	-0.08	0.14	-0.01	-0.08	-0.04	0.02	0.07	1					
Trad pol	0.22	0.17	0.41	-0.27	0.27	0.72	0.02	0.11	0.00	1				
Gov stab	0.13	0.04	0.21	-0.33	0.28	0.58	0.04	0.11	0.00	0.51	1			
Cor	-0.19	-0.08	-0.26	0.23	-0.31	-0.62	-0.04	-0.08	0.02	-0.69	-0.63	1		
Irri	0.50	0.18	0.22	-0.44	0.06	0.52	-0.42	-0.03	-0.06	0.41	0.37	-0.42	1	
NASPA	0.40	0.33	0.53	-0.09	0.03	0.68	-0.04	0.22	-0.01	0.41	0.02	-0.18	0.27	1

From the result in Table, Irrigation has the highest correlation (r=0.5), with rice productivity, this is followed by CO_2 (r=0.44), then temperature (r=-0.41), while the strength of relation between NASPA and rice productivity was moderate (r=0.40) and fertilizer was also moderate (r=0.34). Overall, the result of the correlation analysis reveals non-existence of high correlation between variables (see Table 5.2); therefore, this model is not prone to the problem of multicollinearity.

5.4 Pre-estimation Tests

The pre-estimation tests section entails the test of CSD, unit root test, lag length selection and cointegration test. All these steps are followed accordingly as highlighted in the methodological section of this study to establish the suitable model for analysis of the data and the results are presented as follows.

5.4.1 Cross-Sectional Dependency Test

The result of the CSD test was based on the CD test proposed by Pesaran (2004) as specified in section 4.7.1 in the methodological chapter. This test is considered to be more robust as it recognizes the shortcoming of the earlier Breusch and Pagan's LM test in treating panel data with Large N and Small T. Also the study considered the robustness of Pesaran CD test, regarding its power against spatial dependence, and the fact that its power is unaffected along the cross-sectional dimension as explained in section 4.7.1 on the methodology chapter. The result of the Pesaran (2004) test under the null of cross-sectional independence in the residuals of the regression model is presented in Table 5.3.

Table 5. 3
Cross-sectional Dependence Tests in All Countries Model

CSD tests	t-value	p-value
Pesaran's test	-0.218	0.8827

H_0 : No cross-sectional dependence
Source: Author's own calculations using STATA.

The resulting test statistic (t= -0.218, Prob = 0.8277) strongly shows that there is no presence of cross-sectional dependence in the model. That is, the study fails to reject the null of cross-sectional independence as shown in Table 5.3. This therefore implies the assumptions of the first-generation unit root test is satisfied. Hence, the study proceeded to employ the first-generation unit root test for examining the stationarity of the data.

5.4.2 Unit Root Test

As indicated in section 4.7.2 of the methodological chapter, this study examined the stationarity of the variables in rice productivity model base on two first-generation panel unit root tests (the LLC, and IPS test) and the Breitung and Das (2005) as a second-generation panel unit root tests to ensure robustness. The detailed results of the panel unit root tests conducted for all variables in the study are presented in Table 5.4.

Table 5. 4
Unit Root Test

	Levels			**First Difference**			
	IPS	LLC	Breitung	IPS	LLC	Breitung	
Variable	Statistic W-t-bar	Statistic W-t-bar	Statistic lambda*	Statistic W-t-bar	Statistic W-t-bar	Statistic lambda*	Order
RP	0.112	0.865	1.36	-11.17***	-8.969***	-5.717***	I(1)
Land Area	-1.797**	-2.399***	0.422	-9.579***	-6.779***	-5.856***	I(0)
Fertilizer	0.221	-0.636	-0.43	-6.342***	-5.544***	-7.362***	I(1)
Labour	1.336	-1.253	-0.47	-4.100***	-3.251***	-2.818***	I(1)
Mechanisation	0.526	-0.666	-1.25	-5.579***	-2.251**	-5.061***	I(1)
Carbon	-3.274***	-0.593	0.95	-7.904***	0.364**	-4.900***	I(0)
Temperature	-7.447***	-5.290***	-4.04***	-16.26***	-9.479***	-5.095***	I(0)
Ave Rain	-2.357***	-1.774**	-2.17**	-10.95***	-8.175***	-8.989***	I(0)
Flood int	-5.492***	-4.608***	-4.99***	-13.12***	-9.340***	-10.22***	I(0)
Trade policy	-0.932	-1.687**	-0.82	-6.968***	-5.423***	-4.696***	I(1)
Irri Cap	1.117	0.931	0.62	-4.319***	-3.665***	-5.390***	I(1)
NASPA	2.096	-0.369	0.00	-6.643***	-5.854***	-4.183***	I(1)
Gov. Stab	-0.203	-2.239**	-1.14	-4.202***	-4.153***	-3.431***	I(1)
Corruption	0.534	-0.377	-0.94	-4.708***	-5.056***	-3.884***	I(1)

*, **, and *** indicate significance at 10 %, at 5 %, and at 1 %.
Estimations are done by using (xtpmg) routine in Stata.
The lag structure is ARDL (1, 1, 1, 0, 1, 1, 1, 1, 1, 0, 1, 1) and the order of variables is: RP, LA, C, Tem, RN, Fld, TP, Irr, NASPA, GS, Cor for all states or AEZs, with annual data 1980–2018.

The results for the models specified showed that the variables are stationary in mixed order that is, first difference I(1) and levels I(0). Applying the three tests at levels of the variables in the rice productivity model shows that variables such as carbon, temperature, average rain, flood intensity and land area which are all significant that is, they are stationary at I(0). This implies, the calculated t-statistics of the variables are significant at 1% and 5% level of significance for IPS, LLC and Bruiteng test statistics. While, the other variables in the model are non-stationary at levels. That is, the null hypothesis of unit root for rice productivity, fertilizer, labour, mechanisation, trade policy, irrigation capacity, NASPA and Government stability, corruption index cannot be rejected at least at 10% level of significance. While the null hypothesis is rejected for the other variables.

Thus, the first difference unit root test is carried out again on all variables and in this case, the result provide evidence to reject the null hypothesis of unit root at 1% significance level. The outcome from the first difference unit root test using the three methods indicated that all variables have become stationary after first differencing I(1). Thus, from Table 5.4, the findings revealed that the specified model includes variables stationary at a mixture of I (0) and I (1) variables. This confirms the suitability of the data for ARDL estimation and consequently, the study proceeded to the determination of appropriate lag lengths for the model, followed by long-run cointegration test.

5.4.3 Cointegration Test

The cointegration test followed the outcome of the stationarity test which indicated that the variables in this model have a mixed order of integration. Thus, to confirm the existence of long-run cointegration, the method discussed in section 4.7.3 of the methodology chapter was applied. As explained in section 4.7.3, using the alternative method, cointegration or long-run relationship is determined when the ECT has a negative sign and also significant (Harris & Sollis 2003; Baek & Choi, 2017). The results of ECT which indicates the adjustment coefficient in the three ARDL models are reported in Table 5.5.

Table 5. 5
Cointegration Test for Alternative ARDL Models

	PMG		**MG**		**DFE**	
Variables	**Coeff**	**P-value**	**Coeff**	**P-value**	**Coeff**	**P-value**
ECT	-0.697	0.064	-0.196	0.000	-0.157	0.006
RP						
LD.	0.158	0.533	0.660	0.131	-0.201	0.012
Land Area						
D1.	-0.004	0.123	-0.006	0.365	-0.30×10^{-4}	0.097
Fertilizer						
D1.	-0.004	0.141	-0.008	0.125	-0.60×10^{-3}	0.801
Labour						
D1.	-0.033	0.316	-0.113	0.140	0.002	0.516
Mechanisation						
D1.	-0.110	0.313	-0.488	0.009	0.046	0.572
Carbon						
D1.	-0.25×10^{-4}	0.430	-0.70×10^{-4}	0.292	-0.27×10^{-5}	0.819
LD.	0.18×10^{-4}	0.526	-0.60×10^{-4}	0.325	0.20×10^{-4}	0.250
Temperature						
D1.	-0.119	0.001	0.014	0.971	-0.069	0.040
Ave Rain						
D1.	-0.91×10^{-4}	0.197	-0.001	0.312	0.22×10^{-3}	0.182
LD.	-0.002	0.068	-0.002	0.145	-0.90×10^{-4}	0.563
Flood int						
D1.	0.214	0.035	0.829	0.065	0.035	0.666
LD.	0.059	0.473	0.370	0.186	-0.020	0.722
Trade policy						
LD.	-0.83×10^{-4}	0.637	1.39×10^{-3}	0.621	-1.14×10^{-3}	0.362
D1.	-0.003	0.050	-0.002	0.671	-0.002	0.151
Gov. Stab						
LD.	-0.111	0.032	0.117	0.522	-0.026	0.590

	PMG		MG		DFE	
Variables	Coeff	P-value	Coeff	P-value	Coeff	P-value
D1.	0.048	0.290	0.260	0.019	-0.025	0.624
Corruption						
LD.	0.180	0.597	-1.086	0.115	0.012	0.963
D1.	-0.144	0.749	-0.270	0.763	-0.267	0.300
Irrigation Capacity						
D1.	-9.31 x10^{-3}	0.086	0.006	0.692	-2.43 x10^{-3}	0.569
NASPA						
D1.	0.510	0.539	0.368	0.867	-0.526	0.024
LD.	1.370	0.119	2.107	0.372	-0.011	0.962
_cons	-5.315	0.064	-5.849	0.725	-1.368	0.391

*, **, and *** indicate significance at 10 %, at 5 %, and at 1 %.
Estimations are done by using (xtpmg) routine in Stata.
The lag structure is ARDL (1, 1, 1, 0, 1, 1, 1, 1, 1, 0, 1, 1) and the order of variables is: RP, LA, C, Tem, RN, Fld, Irr, NASPA, TradPol, GS, Cor for all states or AEZs, with annual data 1980–2018.
ECT: error correction term.
Source: Authors' estimations.

The coefficients of ECT for this study is presented in Table 5.5. The result for this study shows that the ECT is statistically significant and negative for the three alternative ARDL models. This implies that long-run relationship exists between determinants of the rice productivity model in Nigeria. Also, the negative signs of the ECT for the three ARDL estimation shows that long-run reversal or adjustment to equilibrium occurs in the negative direction. Moreover, this is an indication of cointegration relationship among rice productivity, climate change, policies and adaptation technologies. The PMG, MG and DFE estimations shows an annual reversal at a speed of 69.7%, 19.6% and 15.7% respectively.

The value of ECT coefficients strongly suggests that in case of any deviation of the rice productivity model from the equilibrium value or steady state caused by the previous year's shocks, the explanatory variables in the model bring about a correction in the opposite direction in the long-run. According to the estimate of the PMG about

69.7% of the disequilibrium in the short-run will be corrected annually; therefore, a long-run equilibrium will be achieved by the second years (within one and half year). Given this significance and the negative sign of the ECT in the PMG estimate, the rice productivity model in this study is considered to attain stability in the long-run (Kripfganz & Schneider, 2019). That is, in the event of any shock in the model such as, policy change, climate change and technology, the model will still converge to equilibrium in the long-run.

5.4.4 Lag Length Selection

Selecting the lag length structure in this study follows the technique of lag selection developed by Kripfganz, and Schneider (2018) as explained in section 4.7.6 in the methodology chapter. Furthermore, considering the limitation imposed by the data used for this study such as the issue of collinearity when higher lag values were used, the study restricted the estimation of lag length to a maximum lag of one. Consequently, the study proceeded to determine the lag structure for each variable in each state using the BIC criteria and the result in reported in Figure 5.6.

Table 5. 6
Lag Length Selection

Variables	Benue	Niger	Kaduna	Kano	Borno	Ebonyi	Lag Length
Productivity	1	1	1	1	1	1	1
Land Area	0	0	1	0	1	0	0
Fertilizer	0	1	0	1	0	0	0
Labour	1	0	1	0	0	0	0
Mechanisation	0	0	0	0	1	0	0
Carbon	1	1	1	0	0	1	1
Temperature	0	1	0	0	0	1	0
Ave Rain	1	0	1	0	1	0	1

Flood int	0	1	1	1	1	0	1
Trade policy	1	0	1	1	1	1	1
Irrigation Cap	1	1	0	1	1	1	1
NASPA	0	1	1	1	1	0	1
Gov. Stab	0	0	0	1	1	0	0
Corruption	1	1	1	1	0	1	1

Based on the result, for each variable, the most frequent lag length across the states was selected. Table 5.6 presents the selected lag length for each variable in the model. The number of lags selected for each variable in the model was determined by considering the lag length that is most frequent across the states for the particular variable (Kripfganz, & Schneider, 2018). The productivity factor has a lag length of 1 across the six states, implying 1 lag length is optimal for productivity. Land area has 1 lag length suggested in 2 states while others have zero (0) lag length thus, 0 lag length is the optimal selected for land area.

Similarly, for other states, the lag length was determined based on the frequent lag number across the states. Thus, from the Table 5.6 lag length for the model is specified as (1, 0, 0, 0, 0, 1, 0, 1, 1, 1, 1, 1, 0, 1) for rice productivity, land area, fertilizer, labour, mechanisation, carbon, temperature, average rain, flood intensity, trade policy, irrigation capacity NASPA, Government stability and corruption. That is, ARDL (PMG) (1, 0, 0, 0, 0, 1, 0, 1, 1, 1, 1, 1, 0, 1) in differences of the variables has been chosen by BIC using maximum lag of 1 in levels. Thus, the result of the Hausman test to decide the better estimator between the three models (PMG, MG and DFE) is presented next.

5.4.5 Hausman Test between PMG, MG and DFE Models

In further compliance with the methodological design and to ensure robustness, the study proceeded to check for the most consistent and reliable ARDL estimates. This step involved comparing results from the alternative ARDL estimators (MG, PMG and DFE) using the Hausman (1978) test as specified in section 4.7.5 in the methodology chapter. The results are reported in Table 5.7 for comparison.

Table 5. 7
Result of PMG, MG and DFE with Hausman Test

	PMG		**MG**		**DFE**	
Variables	**Coeff**	**P-value**	**Coeff**	**P-value**	**Coeff**	**P-value**
Land Area	$0.38\text{x}10^{-5}$	0.940	0.004	0.366	$-0.11\text{ x}10^{-4}$	0.920
Fertilizer	-0.007	0.000	0.007	0.367	-0.0011	0.918
Labour	0.009	0.000	0.002	0.787	0.0019	0.720
Mechanisation	-0.234	0.000	-0.257	0.200	-0.383	0.196
Carbon	$0.14\text{x}10^{-4}$	0.019	$0.35\text{ x}10^{-4}$	0.351	$0.32\text{ x}10^{-4}$	0.613
Temperature	0.160	0.000	0.108	0.804	0.333	0.231
Ave Rain	$0.40\text{ x}10^{-3}$	0.000	$-0.90\text{ x}10^{-4}$	0.816	$-0.53\text{ x}10^{-3}$	0.576
Flood int	-0.064	0.246	-0.554	0.326	0.329	0.617
Trade policy	$0.23\text{ x}10^{-2}$	0.083	$0.49\text{ x}10^{-3}$	0.908	$0.46\text{ x}10^{-4}$	0.997
Gov. Stab	0.039	0.245	-0.335	0.041	-0.121	0.712
Corruption	0.461	0.003	0.257	0.560	0.400	0.766
Irri Cap	0.019	0.000	0.0088	0.700	0.0054	0.751
NASPA	0.149	0.249	-1.624	0.198	1.297	0.361
Hausman Test			**(3.900)**	0.860	**(0.340)**	0.993

Notes: P-values for Hausman tests are reported in brackets.
*, **, and *** indicate significance at 10 %, at 5 %, and at 1 %.
Estimations are done by using (xtpmg) routine in Stata.
The lag structure is ARDL (1, 1, 1, 0, 1, 1, 1, 1, 1, 0, 1, 1) and the order of variables is: RP, LA, C, Tem, RN, Fld, TP, Irr, NASPA, GS, Cor for all states or AEZs, with annual data 1980–2018.
Source: Authors' estimations.
PMG is more efficient estimation than MG under null hypothesis.
PMG is more efficient estimation than DFE under null hypothesis.

The outcome of the three alternative estimators are reported in Table 5.7 along with the Hausman test to measure their comparative efficiency and consistency. From the p-value of 0.860 which is greater than 0.05 in the case of the Hausman test for comparison between PMG and MG, the study does not reject the null hypothesis of the long-run homogeneity restriction of PMG. Therefore, the Hausman test indicates that the PMG model is more consistent and reliable estimator. Similarly, the outcome of the comparison between the PMG and the DFE model also confirmed the suitability of the PMG model in the analyses of the variables in this study. This is confirmed from the Hausman statistics of 0.340 with p-value of 0.993. Hence the PMG model was chosen as the most appropriate technique in the current study.

The outcome of the Hausman tests both indicated the preference for PMG estimator, and it conforms to literature (Pesaran, et al., 1999; Islam, Tarique & Sohag, 2014). According to the literature the short and long-run effects could behave in different ways for three reasons: First, the dynamism in the nature climate change and its impact could make it difficult for regions to react uniformly to sudden changes in climate variables; while secondly, the issue could be linked to the variation of the states in terms of adaptation capacities such as irrigation technology use, lack of climate information or early warning system in the short term among developing countries such as Nigeria.

Furthermore, some regions have peculiar soil and climate characteristics that do not differ over time that is, there are uniqueness in some characteristics of each AEZ and this does not vary over time. Consequently, AEZs are likely to make some errors in their decisions in the short-run, but with appropriate information they could enact policies to make rational decisions in the long-run. The study therefore proceeded to estimate the model of this study base on ARDL (PMG) estimation technique and the specified lag length for each of the variables.

5.5 The ARDL (PMG) Model Estimation

Subsequent to establishing the poolability of the data and consistency of the PMG estimator based on Hausman test, in the next procedure the PMG estimator is employed to analyse the impact of climate change (carbon emission, average annual temperature, average rainfall and flood intensity), policy variables (trade policy, government stability and corruption) and adaptation technologies (irrigation capacity and NASPA) on rice productivity in Nigeria. These was used to achieve objectives 2, and 3 in this study. The PMG model was estimated using a balanced panel data of 6 selected states representing the AEZs in Nigeria. The data span for the period of 1980 to 2018, implying 234 observations. The outcome of the ARDL (PMG) with lag length chosen by BIC criteria is also presented in Table 5.8 and 5.9. The long-run estimate result that is the same across AEZs is presented in Table 5.8. While the short-run result which shows the dynamism in the impact of the factors in model across the AEZs is presented in Table 5.9.

5.5.1 Long Run Estimates of the ARDL (PMG) Model

The long-run result of the PMG estimates is fixed across all the cross-sectional components in the panel, since PMG constrains the long-run coefficients to be equal across groups (Pesaran, Shin & Smith, 1997; 1999). Thus, our PMG model estimation allows for common long-run response of rice productivity to climate change, Government policies and adaptation technologies across the panels or AEZs. These long-run estimates are presented in Table 5.8.

Table 5. 8
Long Run Estimates of the PMG

Variable	**Coefficient**	**Std. Err.**	**z**	**P>|z|**
Land area	$0.4x10^{-4}$	0.000050	0.0800	0.940
Fertilizer	-0.007295***	0.001080	-6.7600	0.000
Labour	0.009058***	0.001203	7.5300	0.000
Mechanisation	-0.234093***	0.028695	-8.1600	0.000
Carbon	$0.14\ x10^{-4}$**	0.000006	2.3400	0.019
Temperature	0.160319***	0.022813	7.0300	0.000
Average rain	$0.399x10^{-3}$***	0.000072	5.5600	0.000
Flood intensity	-0.063761	0.054948	-1.1600	0.246
Trade policy	0.002268*	0.001307	1.7400	0.083
Gov. Stability	0.038722	0.033305	1.1600	0.245
Corruption	0.461418***	0.156545	2.9500	0.003
Irrigation capacity	0.018816***	0.002008	9.3700	0.000
NASPA	0.149081	0.129400	1.1500	0.249
No. of Observation	222	222	222	

Number of Observation is 222
Number of groups is 6
Observation per group is 37
Note: ***, **, * indicate significance at the 1%, 5% and 10% levels respectively.
Source: Author's own calculations using STATA.

5.5.1.1 Long-run Impact of Inputs on Rice Productivity in Nigeria

Table 5.8 indicates the results of the long-run estimates of the coefficients for the model of this study. The inputs (land area, fertilizer, labour and mechanisation) are considered as control variables in this study. The result for each of this factor is presented next.

Among these factors, only land area was shown to have no significant effect on the rice productivity in Nigeria in the long-run. The insignificant effect of land on productivity could also be partly as a result of the fact that land area only indicates the size hence less important than the other characteristics if the land such as fertility, topography, quality, soil type and water retention capacity. This insignificant result is also supported by the findings of Paudel et al. (2019) (for non-adopters of mini tiller); Alam, Siwar, Talib and Toriman (2011).

The quantity of fertilizer is found to be significant, although the coefficient is negative in the long-run. Against a priori expectations, the result implies that increase in fertilizer usage results to a decrease in rice productivity. These studies found that as the total annual fertilizer consumption increases in Nigeria, the lesser the rice productivity. This can generally be attributed to the issue of wrong usage of fertilizers such as over application, wrong timing of fertilizer application and over reporting of the value of fertilizer used in the AEZs.

Also, considering that most of the farmers' surfer from resource constraint which necessitate government support inform of fertilizer subsidy, the access and use might be constraint as a result of governance factors such as corruption and high bureaucracy (Anik & Bauer, 2017). Thus the unexpected findings could also be accounted for by the corrupt practices of over reporting the value of fertilizer use by farmers and officials in order to assess more funds from the government. In support of the findings of this study, Purbajanti, Slamet, Fuskhah and Rosyida (2019); Amoah, Miyagawa and Kawakubo (2012) asserted that fertilizers (Inorganic) is associated with reduction in crop productivity over time. Whereas, Koirala, Mishra and Mohanti (2014); Paudel et al. (2019) found that fertilizer has an insignificant effect.

The quantity of fertilizer is found to be significant for Benue, Kaduna and Ebonyi states and the coefficients were all negative for the three states. Against a priori expectations, the result implies that increase in the fertilizer usage in Nigeria leads to a decrease in rice productivity. This finding can imply the wrong use of fertilizer, washing away of fertilizer by flood, or diminishing utility from fertilizer. Also, considering that most of the farmers surfer from resource constraints which necessitate government support inform of fertilizer subsidy, the access and use might be constraint as a result of governance factors such as corruption, bribery and high bureaucracy.

Thus, the findings of this study, which indicates that the increased supply of fertilizer in Nigeria is not reflected on the rice productivity. This is in agreement with the studies by Purbajanti, Slamet, Fuskhah and Rosyida (2019); Anik and Bauer, (2017); Apiors, Kuwornu, and Kwadzo, (2016); Amoah, Miyagawa and Kawakubo (2012) asserted that fertilizers (Inorganic) is associated with reduction in crop productivity over time. On the contrary, the fertilizer is insignificant in the cases of Niger, Kano and Borno. This is supported by findings of Anik, Breustedt, and Bauer (2011); Koirala, Mishra and Mohanti (2014); Paudel et al. (2019) where they found that fertilizer has an insignificant effect.

Concerning labour, the amount of labour usage was significant, and the coefficient is positive. This implies an increase in the number of labours for rice production increases rice productivity. Indicating labour contributes to more efficient use of land by improving its unit productivity. Similarly, the level of mechanisation measured by the farm machinery available was significant, while contrary to apriori expectation, the coefficient was negative. The negative coefficient for mechanisation implies higher levels of mechanisation lead to a drop in the rice productivity per unit of land. Arguably, this can be accounted for by the generable challenge attributed to the lack of suitability or adaptability of the available machineries among small-scale farmers due to the fragmented and small land sizes. The negative finding is supported by previous studies such as Hormozi, Asoodar, and Abdeshahi, (2012). Although, this contradicts the some existing studies such as Paudel et al. (2019); Alam, Siwar, Talib and Toriman (2011); Verma, (2008) affirming that farm mechanization enhances the production and productivity of different crops due to timeliness of operations, better quality of operations and precision in the application of the inputs.

Furthermore, the result of the long-run estimate for the impact of climate change, policies and adaptation technologies on rice productivity in Nigeria are presented in the next subsections.

5.5.1.2 Long-run Impact of Climate Change Factors on Rice Productivity in Nigeria

The assessment of the impact of climate change on rice productivity in Nigeria was measured using factors that includes, carbon emission, average annual temperature, average rainfall and flood intensity. The long-run results of carbon emission were highly significant, while the coefficient was found to be positive (0.14×10^{-4}). This confirms the positive effect of carbon emission on rice productivity. Thus, implying that a 1 unit increase in carbon emission will lead to 0.14% increase in rice productivity all other things been equal. This finding is in tandem with other studies (Li et al., 2017;

IPCC, 2007; Wang et al., 2016 and Kimball, 2006). These studies support our findings by affirming the positive impact of carbon emission on productivity in some regions. These studies have asserted that, higher carbon fertilization in the atmosphere enhances the photosynthetic capacity of plants, thus enhancing the ability to manufacture food. Also, considering that rice is a C3 photosynthetic planted it has the ability to maximise carbon fertilization.

Although, the positive findings also contradict with the assumption by few earlier studies such as; Mulatu et al., (2016); Edoja et al., (2016) Li et al., (2017) that higher emission of carbon exerts negative impact on agriculture or rice productivity. To further explain this inconsistency, it is highlighted that the negative effect of carbon emission is possible in the event of combination of high temperature with carbon emission (Islam, Tarique & Sohag, 2014; Daniel et al., 2009). That is, when temperature is higher than the optimum or threshold value, then higher carbon emission can lower productivity.

The second measure of climate change which is temperature was found to be significant, while the coefficient was shown to be positive. This implies higher temperature in Nigeria have positive implication on rice productivity. Based on the coefficient a 1% increase in temperature result to 16% increase in rice productivity. Similar findings on the positive impact of temperature on rice productivity has also been reported in a few earlier studies like Benhin, (2008), Apata et al., (2009) and irrigated rice production in Ajetunmobi et al., (2010). These studies indicated that positive effect of temperature on rice productivity is possible in areas with existing lower temperature. This result can be explained by the fact that the majority of the rice producing regions in Nigeria are in the lowland ecology which have a relatively cooler temperature compared to the upland areas. Similarly, sunlight is one of the necessary conditions for plant photosynthesis, thus the positive effect.

Whereas this finding also contradicts the apriori expectation base on the findings of some studies such as van Oort and Zwart (2017); Aggrawal et al., (2010); Basak et al., (2010); Misha & Sahu, (2014), Deressa & Hassan, (2009), Ayinde et al., (2011), dry season rice production in Ajetunmobi et al., (2010). These mixed findings can be explained by a number of factors; first, the studies have been carried out in different regions with different existing temperature values. Secondly, van Oort and Zwart (2017) indicated that the direction of effect of temperature depends on the use or none use of adaptation technologies. Thus, rice produced under irrigation have been shown to be more tolerant to temperature than a rainfed rice (Ajetunmobi et al., 2010). Furthermore, different growth stages of rice plant react differently to temperature change, thus direction of the impact could vary based on the growth period in which the temperature change was experienced.

The third measure of climate change is the annual volume of rainfall. This study provides evidence from the coefficient of the long-run estimates of the model that, rainfall is significant, while the coefficient ($0.399x10^{-3}$) is positive. This implies rainfall impact positively on rice productivity in the long-run. That is 1% increase in rainfall amount result to 0.040% increase in rice productivity in the long-run all other condition been equal. This long-run result is in accordance with the expected outcome of this study. Furthermore, it is supported by the majority of findings in earlier studies such as Basak et al., (2010), Misha & Sahu, (2014), Benhin, (2008), Ayinde et al., (2011) and Idumah et al., (2016). This positive effect is justified by the fact that rice is a high water demanding plant and thus thrive better when it have sufficient water. Also, rice has the ability to thrive in flooded or submerged condition. Although, it is also contrary to a few studies such as Aggrawal et al., (2010) and Deressa and Hassan, (2009).

Finally, the long-run coefficient of flood intensity was found to be insignificant to impact rice productivity of Nigeria in the long-run, although it has the expected negative sign. This finding conforms to extant literature (Juraimi, Saiful, Begum, Anuar & Azmi, 2009) affirming that flooding or excessive water only affect the vegetative growth of rice but not the productivity, especially when the flood is not at the early stage of the plant growth. Also, this finding contradicts the a priori expectation of the current study and some extant studies like: Dar, Chakravorty, Waza, Sharma, Zaidi, Singh, Singh and Ismail (2017); Bhowmick et al. (2014).

5.5.1.3 Long-run Impact of Adaptation Technologies on Rice Productivity in Nigeria

Another factor examined in the model of the current study is the climate change adaption technologies employed in the improvement of rice productivity in Nigeria. Due to data limitation only two factors were examined, which are the irrigation capacity and the NASPA (dummy).

Irrigation capacity measure is described as the total capacity of land that is under irrigation in Nigeria. According to the long-run coefficient of the PMG estimate, irrigation capacity was found to have a significant impact on rice productivity in Nigeria, also the coefficient is positive. This implies irrigation capacity positively impact on rice productivity and that a 1% increase in irrigation capacity results to 1.9% increase in rice productivity in Nigeria. This finding conforms to a priori expectation on the positive effect of irrigation on rice productivity. Although, most irrigation systems in Nigeria have a short lifespan as result of improper construction, inadequate planning and poor maintenance. Therefore, more efforts are required by Nigeria government to restore the dilapidated or completely damaged irrigation facilities across the country. This will enhance the effectiveness of the irrigation schemes in contributing to rice productivity growth in Nigeria. Similarly, the findings are supported by several earlier studies like Li et al., 2017; Salazar & Rand, 2016; Ajetomobi, Joshua, Abiodun, Ajiboye and Hassan, (2011); Seo *et al* 2005; Liu et al., 2004; García et al. (2020).

On the other hand, the study also assessed the impact of NASPA which was introduced in 2012 as the main policy that defines the national adaptation strategies employed in adapting agriculture to climate change. Using NASPA as a dummy, the study examined the impact of NASPA by comparing the period before and post implementation of NASPA. The long-run coefficient of the PMG estimate was found to be insignificant. Thus, it is considered to have no significant impact on rice productivity in Nigeria. This implies there is no difference in adaptive capacity between the period before NASPA and after NASPA hence, no significant effect on rice productivity. This indicates also that NASPA have not been efficient enough to mitigate the impact of climate change in Nigeria. Therefore, suggesting the need for more robust strategies and plan for adapting the rice sector to climate change. This is supported by studies that emphasized that most adaptation efforts in Africa are not successful (USAID, 2013; FAO, 2017).

5.5.1.4 Long-run Impact of Government Policies on Rice Productivity in Nigeria

The model of this study also considered the impact of government policies on rice productivity in Nigeria. This was measured using the variables of trade policy, government stability and corruption perception index. The trade policy was assessed as the tariff percentage charged on imported rice annually. Government stability concerns the stability of government and policies (measured as an index) while, corruptions concerns the level of corruption in government institutions as measured as an index. The result from the long-run coefficients of PMG estimates of the model in this study shows as follows:

In the long-run, trade policy (import tariff rates) was found to exert a significant impact on rice production in Nigeria. Also, the coefficient of trade policy was positive (0.0023) implying, the higher the import tariff rates the higher the domestic rice productivity. In the event of 1% increase in trade policy (tariff percentage), there will be 0.23% increase in rice productivity in Nigeria. This is in conformity with the a priori expectation, since higher import tariff serve as import barrier to discourage import and encourage investment in efforts to improve domestic rice productivity. This study consequently provides evidence to support the positive impact of higher import tariffs on domestic rice production in the long-run. This is also in line with the findings of some existing studies such as: Weibe et al., 2015; World Bank, 2001; Krishna and Mitra, 1998; Edward, 1997 and Harrison 1994. Conclusively, the result has shown that a trade protectionism policy favours domestic rice productivity growth in Nigeria in the long-run. Thus, the investment in machineries, optimal input usage during high import tariffs is evident in this study to have positive implications on rice productivity.

Although, there are also a few studies that reported contrary findings, these include: Adedeji et al., 2016; Kazungu, 2009; Rakotoarisoa, 2011 and Mitchell and Baffes, 2002. These contrary findings or negative effect can result from the inability to transfer investment towards technologies or innovative approaches that can enhance domestic productivity. That is diversification of capital to other sectors rather than investment in enhancing the domestic rice productivity.

The Government instability index measures political instability or inconsistencies in Government policies. This is assessed by the comprehensive index from the International Country Risk Guide (2007) that includes both political and economic risk. Although, the political instability also reflects the inconsistencies in policy direction experienced in the agricultural sector in Nigeria, there is scarcity of studies examining the impact of government instability on agricultural productivity in general. The result from this study pointed out that political instability is insignificantly related to rice productivity. Though coefficient of the long-run estimate is positive (0.039). This implies that Nigeria rice productivity is not responsive to the issue of political instability. This can be attributed to the fact that the Nigerian Government have neglected the agriculture sector for a long time since the discovery of the oil sector, a situation described as the Dutch disease.

Whereas related studies in literature affirm that, in countries without a stable basis for executive power, businesses face a host of challenges including increased policy or regulatory inconsistencies and the potential for increased production costs. Simultaneously, existing studies indicates that political instability (such as wars or other forms of civil strife) is considered to negatively influence economic sector (Musibau, et al., 2017) including the food production (Kimenyi et al., 2014). Thus leading to food insecurity as can be seen in the 1998 case of Indonesia (McBeth, 1998; Asia-Pacific Center for Security Studies, 1998).

The outcome of corruption impact on rice productivity assessed using the Nigeria's corruption perception index shows that rice productivity is strongly influenced by corruption in the country and the coefficient was found to be positive. This implies an increase of 1% in the level of corruption result into 46.1% increase in rice productivity in Nigeria. Although corruption has been widely acknowledged as a general practice within institutions in the country, the positive effect was unanticipated. This finding is supported by some existing studies in the agricultural sector (Anik, Breustedt, & Bauer, 2011; Anik, & Bauer, 2017). Again, this result further justifies existing findings on the positive effect of corruption in other sectors of the economy notably: Musibau *et al*, 2017; Shittu et al., 2020; De Rosa, Gooroochurn & Görg, 2010 where they found that corruption has a positive effect on economic growth in Africa.

Also based several studies have highlighted this positive effect of corruption based on theoretical derivation. According to Huntington (1968), "corruption greases the wheels where bureaucracy is sluggish and ineffective". The practices of bribery as an incentive for faster services are common among dishonest bureaucrats and government officials in charge of input supply (Anik & Bauer, 2017; Leff, 1964). Thus bribe work as "speed money" which consequently ensures technology transfer (Méon & Weill, 2005).

Similarly, in Nigeria, there is the institutionalization of corruption in all the governance processes. Hence, it is considered as a norm, which can reduce bureaucracies in government institutions and procurement processes. Thus, corruption facilitate the processes in governance in such countries without which most project could not be successfully implemented. That is, corruption enhances the ability of farmers to access more inputs or production incentives, while increased use of inputs such as hybrid seeds and fertilizer acquired through corrupt practices result to increased rice productivity. This is especially applicable to the large farms owned by the rich or political classes.

Alternatively, the result contradicts studies such as Velazco (2001); Zerfu (2007); Lio and Liu (2008); Bayyurta and Yilmaz, (2012); Camposs et al. (1999); Staatz and Dembélé (2008). Although most of these studies are carried out in different countries with differences in socio economic backgrounds. This contradictory finding could therefore result from the diversification of project funds or inferior quality of input supply or services resulting from corruption in the system.

5.5.2 Short-Run Dynamic Estimates for Determinants of Rice Productivity across States

The PMG estimator allows for heterogeneous short-run dynamics that is the estimator allows short-run coefficients to differ across the groups. This implies, the short-run estimates of PMG are dynamic across the sampled states or AEZs in this study. Hence, this was employed to assess how the impact of climate change, policies and adaptation technologies varies across the states representing the AEZs in Nigeria. Through this dynamic property of the PMG estimator, the fifth objective of this study was achieved. That is, the assessment of the dynamics of the impacts of climate change, policies and adaptation technologies on rice productivity across the AEZs in Nigeria. The findings on the short-run coefficients across the AEZs are as presented in Table 5.9.

Table 5. 9
Short-Run Dynamic Estimates by States (Agro Ecological Zone)

	Benue	**Niger**	**Kaduna**	**Kano**	**Borno**	**Ebonyi**
Variable						
ECT	-1.80560	-0.10374	-0.15861	-0.13539	-0.01929	-1.95958
	0.000	0.0326	0.001	0.042	0.0449	0.000
RP						
LD.	1.04702	0.41981	-0.09347	-0.53082	-0.44714	0.54965
	0.000	0.022	0.402	0.000	0.001	0.007
Land Area						
D1.	-0.01737	0.00054	-0.00003	-0.00165	-0.00448	-0.00230
	0.009	0.713	0.010	0.047	0.139	0.337
Fertilizer						
D1.	-0.01260	0.00174	-0.01083	0.00508	-0.00269	-0.00574
	0.019	0.779	0.003	0.142	0.443	0.047
Labour						
D1.	-0.19691	-0.01508	0.00502	0.00107	0.01425	-0.00711
	0.000	0.710	0.212	0.679	0.160	0.121

	Benue	Niger	Kaduna	Kano	Borno	Ebonyi
Mechanisation						
D1.	0.28446	-0.13978	0.08538	-0.12554	-0.30186	-0.46050
	0.006	0.302	0.466	0.469	0.068	0.009
Carbon						
D1.	0.00006	0.00002	0.00000	-0.00004	-0.00002	-0.00016
	0.011	0.520	0.866	0.069	0.028	0.000
LD.	-0.00011	0.00008	0.00008	0.00002	0.00004	-0.00001
	0.002	0.032	0.000	0.487	0.051	0.694
Temperature						
D1.	-0.19659	-0.09197	0.00101	-0.24676	-0.06727	-0.11341
	0.001	0.202	0.989	0.007	0.032	0.001
Ave. rain						
D1.	-0.00442	-0.00012	-0.00033	-0.00009	-0.00009	-0.00039
	0.000	0.713	0.132	0.709	0.934	0.061
LD.	-0.00509	-0.00013	-0.00028	-0.00001	-0.00333	-0.00066
	0.000	0.704	0.288	0.972	0.003	0.000
Flood intensity						
D1.	-0.07748	0.32864	0.06852	0.24680	0.08752	0.63240
	0.479	0.007	0.267	0.002	0.220	0.000
LD.	-0.00829	0.21492	-0.07226	-0.00638	-0.15816	0.38424
	0.916	0.074	0.232	0.943	0.024	0.000
Trade policy						
LD.	0.00205	0.00333	0.00031	-0.00750	-0.00475	0.00159
	0.315	0.124	0.748	0.001	0.000	0.390
D1.	-0.00212	-0.00092	0.00028	-0.00951	-0.00015	-0.00691
	0.345	0.652	0.776	0.000	0.901	0.000
Gov. Stab						
LD.	-0.34549	-0.02783	-0.03562	-0.14369	-0.11237	-0.00147
	0.000	0.743	0.310	0.035	0.036	0.973
D1.	0.18617	-0.10502	0.02793	0.16763	-0.02005	0.03239
	0.013	0.147	0.399	0.025	0.673	0.438
Corruption						
LD.	-1.09705	0.17497	-0.42180	0.97390	0.35821	1.09411
	0.001	0.636	0.104	0.005	0.241	0.000
D1.	-1.02669	-0.26570	-0.79011	-0.99324	0.38830	1.82264
	0.008	0.535	0.000	0.006	0.195	0.001
Irrigation capacity						
D1.	-0.00774	-0.00300	-0.01901	-0.01387	0.01263	-0.02484
	0.329	0.515	0.002	0.366	0.267	0.018

	Benue	Niger	Kaduna	Kano	Borno	Ebonyi
NASPA						
D1.	4.38691	-1.24012	-0.26693	0.95383	-0.07080	-0.70106
	0.000	0.159	0.270	0.004	0.758	0.002
LD.	5.62079	1.18907	-0.31747	0.99025	0.23673	0.50338
	0.000	0.284	0.229	0.035	0.274	0.104
Constant	-14.55005	-0.80444	-1.25352	-0.85917	-0.23169	-14.18944
	0.000	0.306	0.003	0.103	0.308	0.000

*, **, and *** indicate significance at 10 %, at 5 %, and at 1 %.
Estimations are done by using (xtpmg) routine in Stata.
The lag structure is ARDL (1, 1, 1, 0, 1, 1, 1, 1, 0, 1, 1) and the order of variables is: RP, LA, C, Tem, RN, Fld, TP, GS, Cor, Irr, NASPA for all states or AEZs, with annual data 1980–2018.
Source: Authors' estimations.

The result in Table 5.9 includes the first lag of the dependent variable (productivity), the control variables (land area, fertilizer, labour and mechanisation); climate change factors (carbon, temperature, rainfall, and flood); adaptation technology (irrigation and NASPA); and Policies (trade policy, gov. stab and Corruption).

5.5.2.1 Short-run Impact of the Control Variables on rice productivity Across AEZs

The result shows the short-run coefficient of the first lag of rice productivity to be significant for five (5) states including Benue, Niger, Kano, Borno and Ebonyi. Among the five (5) states, the coefficients were positive for Benue, Niger and Ebonyi, while it is negative for Kano and Borno. On the contrary, the coefficients of the first lag of productivity were found to be statistically insignificant and negative for Kaduna. These significant impact of the previous year's productivity on the current year productivity might be as a result of the spill over effect of the management practices in the previous year such as the land clearing, fertilizer application which can be stored in the soil and thus affecting subsequent year's productivity. This is typically possible since some farmers in Nigeria are fond of the practice of maintaining previous year land management and also application of fertilizer only once in two years. Thus, implying that a positive effect (as in Benue, Niger and Ebonyi) or negative impact (Kano and Borno) can result depending on whether high or low level of inputs were used in the previous year respectively.

The control or input variables in this study are: land area, fertilizer, labour and mechanisation. Accordingly, the result shows the short-run coefficient of land area is found to be significant for Benue, Kaduna and Kano states and the coefficients were all negative. Implying that increase in land area results to a decrease in rice productivity. This implies increasing land area under rice cultivation reduces rice productivity for those AEZs, indicating less efficient use of land in such AEZs. These studies agreed with the theoretical hypothesis that larger farms are less productive in terms of land use compared to smaller farms. Also, the negative effect is supported by Koirala, Mishra and Mohanti (2014); Paudel et al. (2019) (for adopters of mini tiller in rice production). On the contrary, the land area is insignificant in the cases of Niger, Borno and Ebonyi. The insignificant effect of land on productivity could also be partly as a result of the fact that land area is less important than the other characteristics if the land such as fertility, topography, quality, soil type and water retention capacity. This insignificant result is also supported by the findings of Paudel et al. (2019) (for non-adopters of mini tiller); Alam, Siwar, Talib and Toriman (2011).

The quantity of fertilizer is found to be significant for Benue, Kaduna and Ebonyi states and the coefficients were all negative for the three states. Against a priori expectations, the result implies that increase in the fertilizer usage in Nigeria leads to a decrease in rice productivity. This finding can imply the wrong use of fertilizer, washing away of fertilizer by flood, or diminishing utility from fertilizer. Also, considering that most of the farmers surfers from resource constraint which necessitate government support inform of fertilizer subsidy, the access and use might be constraint as a result of governance factors such as corruption and high bureaucracy. Thus, the findings of this study, which indicates that the increased supply of fertilizer in Nigeria is not reflected on the rice productivity. This is in agreement with the studies by Purbajanti, Slamet, Fuskhah and Rosyida (2019); Apiors, Kuwornu, and Kwadzo, (2016); Amoah, Miyagawa and Kawakubo (2012) asserted that fertilizers (Inorganic) is associated with reduction in crop productivity over time. On the contrary, the fertilizer is insignificant in the cases of Niger, Kano and Borno. This is supported by findings of Anik, Breustedt, and Bauer (2011); Koirala, Mishra and Mohanti (2014); Paudel et al. (2019) were they found that fertilizer has an insignificant effect.

The amount of labour usage was only significant for Benue and the coefficient is negative. Implying a negative correlation amongst labour and rice productivity in Benue. This, implies that increase in labour results to a decrease in rice productivity. On the contrary, the quantity of labour is insignificant for Niger, Kaduna. Kano, Borno and Ebonyi. This could happen when labour is at the point of diminishing marginal utility such that an additional increase in the unit of labour result to no significant contribution to the rice productivity. Indicating less efficient use of labour factor in rice productivity. This insignificant effect of labour is supported by the findings of Apiors, Kuwornu, and Kwadzo, (2016); Hormozi, Asoodar, and Abdeshahi, (2012).

The level of mechanisation usage was significant for Benue, Borno and Ebonyi and the coefficient is positive for Benue and negative for both Borno and Ebonyi. The positive coefficient for mechanisation in Benue implies, higher level of mechanisation improve rice productivity in Benue. This positive effect of mechanization is also supported by Paudel et al. (2019); Park, McDonald, Devkota, and Davis, (2018); Alam, Siwar, Talib and Toriman (2011); Verma, (2008) affirming that farm mechanization enhances the production and productivity. Whereas, the effect of Mechanisation is negative on rice productivity in Borno and Ebonyi. The negative finding is supported by previous studies such as Hormozi, Asoodar, and Abdeshahi, (2012). On the contrary, the level of mechanisation was found to be statistically insignificant for Niger, Kaduna and Kano.

Furthermore, the study presents the results on the short-run dynamic impact of climate change, policies and adaptation technologies across AEZs based on the PMG (ARDL) estimates in the follow sub sections:

5.5.2.2 Short-run PMG Estimate for Climate Change Impact on Rice Productivity across AEZs

The short-run result of the four measures of climate change (carbon emission, temperature, average rainfall and flood intensity) across the selected state as highlighted in Table 5.8 is reported next.

The coefficient of the present carbon emission is found to be significant for Benue, Kano, Borno and Ebonyi and the coefficient were negative for Kano, Borno and

Ebonyi, while it is positive for Benue. The negative and significant effect implies increase in carbon emission result to decreases rice productivity in the particular states. While the positive and significant effect on rice productivity in Benue signifies carbon emission have resulted to an improved rice productivity in Benue. Overall, the short-run impact of current carbon emission indicates a negative influence of carbon emission on rice productivity in most states.

The positive effect in Benue is supported by the findings of earlier studies such as: Li et al., 2017; Reilly et al., 2007; IPCC, 2007; Wang et al., 2016; Hatfield, et al., 2011; and Kimball, 2006. While the negative effects in Kano, Borno and Ebonyi are also in agreement with studies like; Mulatu et al., (2016); Edoja et al., (2016) Li et al., (2017) that higher emission of carbon exerts negative impact on agriculture or rice productivity. To further explain this result, it is highlighted that the negative effect of carbon emission is possible in the event of combination of high temperature (as in the case of Kano and Borno) with high carbon emission (Islam, Tarique & Sohag, 2014; Daniel et al., 2009).

While on the contrary, the coefficients of carbon emission were insignificant in Niger and Kaduna, implying the non-existence of any statistical evidence on the impact of carbon on rice productivity in Niger and Kaduna region. These results further highlighted the variation or heterogeneity in the nature of the AEZs in the country. Furthermore, when the lag differences or previous value of carbon emission were examined, the outcome showed variation across the states. The previous value of carbon emission is found to be significant for Benue, Niger, Kaduna and Borno, while the coefficients were positive for Niger, Kaduna and Borno and negative for Benue. Contrarily, the short-run impact of the lag difference of carbon emission were not significant in Kano and Ebonyi states.

With respect to temperature, only the current temperature was assessed, the lag difference was not considered. In the current year temperature, the short-run estimate shows evidence on the significant effect of current year temperature in Benue, Kano, Borno and Ebonyi, while the coefficients were all negative (-0.19, -0.25, -0.067 and -0.11). This implies that an increase in current temperature leads to rice productivity decline in those AEZs. Thus increased temperature in the current season is not favourable to rice productivity across the four states. This is in accordance to a priori expectation and also find support from extant studies that indicate a negative impact of temperature such as: Krishnan, Ramakrishnan, Reddy & Reddy, (2011); Aggrawal et al., (2010), Basak et al., (2010), Misha & Sahu, (2014), Deressa & Hassan, (2009), Ayinde et al., (2011), dry season rice production in Ajetunmobi et al., (2010). On average these four states are considered to have high annual temperatures especially the cases of Kano and Borno. Although, there was no statistical evidence to support the significant impact of current temperature on rice productivity in Niger and Kaduna.

Another climate change variable considered is both values of the current and lagged differences of the average annual rainfall. The short-run estimate result of the current year rainfall indicates the existence of a significant impact on rice productivity in two (2) states; Benue and Ebonyi, the coefficients were also found to be negative (-0.0044 and -0.0004) in both. This implies, higher annual rainfall result to decline in rice productivity in these states. Although, a few other studies such as Aggrawal et al., (2010) and Deressa and Hassan, (2009) supported the negative impact of rainfall on rice productivity as it is with the findings in Benue and Ebonyi. This finding does not conform to a priori expectation and the findings of most studies that indicated positive impact of rainfall such as; Basak et al., (2010), Misha & Sahu, (2014), Benhin, (2008), Ayinde et al., (2011) and Idumah et al., (2016). The study has also shown that there is no evidence on the statistically significant impact of rainfall in other states (Niger, Kaduna, Kano and Borno). Although the negative effect of rainfall among the two states can be explained by the prevalence of the issues of flood, poor drainage systems especially in Kano state which leads to flooding and other undesired effect like leaching away of top soil and fertilizer nutrients.

Exploring further the lagged differences of the annual rainfall across the AEZs, the result showed a similar pattern, with significant impact in Benue, Borno and Ebonyi, and the coefficients remained all negative (-0.0051, -0.0033 and -0.00066). This implies increase in the average annual rainfall in the states will decrease the rice productivity for those states. As explained earlier, the study also found no statistical evidence to support the impact of previous average annual rainfall on rice productivity in the other states (Niger, Kaduna and Kano). The justification for this finding is similar to that of the current value of rainfall earlier presented.

The current and lagged difference of flood intensity is another variable measuring the impact of climate change on rice productivity. Result on the impact of the current year flood intensity shows a significant impact on rice productivity in Niger, Kano and

Ebonyi, also the coefficients were all positive (0.33, 0.25 and 0.63). Contrary to a priori expectations, the positive coefficients for the three (3) states implies higher flood intensity results to higher rice productivity. Although for other states (Benue, Kaduna and Borno), the results of the current year flood were not statistically significant.

The positive effect might be explained by the ability of rice to thrive in submerged or flooded environment or fields especially when it is not in the early growth stage of the rice plant (Asada & Matsumoto, 2009; Ikehashi, 2007; Brammer, 1990). Thus, as a result of prevalence of flood experienced by farmers in Niger, Kano and Ebonyi, the farmers have adjusted the planting time as a form of adaptation and are able to enjoy the beneficial effect of the excess water. Whereas most extant research (Idris, Siwar, Ghazali, & Alias, 2018; Aggrawal 2010; Nikas et al., 2019; Mishra & Sahu, 2014; Derbile & Kasei, 2012; Rosenzweig et al., 2002) have emphasized the negative impact of flood on rice productivity.

Extending further to examine the short-run impact of the lag difference of flood on rice productivity across the states, the results was found to be similar to the earlier findings. The result of the lagged difference of flood showed that Niger, Borno and Ebonyi were significantly impacted by flood. Similar to the earlier findings on the current value, the coefficients were also positive for Niger and Ebonyi, while the result is negative for Borno which was not significant earlier. The result of the lagged difference of flood was again not significant for other states (Benue, Kaduna and Kano).

5.5.2.3 Short-run PMG Estimate for Policies Impact on Rice Productivity across AEZs

Examining the dynamism of the impact of government policies on rice productivity across the AEZs in Nigeria is another concern of this study. This was achieved using three variables of trade policy, government stability and corruption perception index. From the PMG estimator which allows the short-run coefficients to vary across the states, the above stated objective is achieved. The variations in the impact of each policy factor across the AEZs is presented.

Trade policy measured as percentage of tariff on rice importation is considered to indicate the direction of government policy either trade openness or protectionist regime. Both results of the current value of trade policy and the lagged difference are as follows: The short-run effect of current trade policy was found to be significant in Kano, Borno and Ebonyi, the coefficients are negative for Kano and Borno, while it is positive in Ebonyi. Additionally, current trade policy was insignificant in the other three states (Benue, Niger and Kaduna).

Against the expected result, these negative findings in Kano and Benue indicates that higher import tariffs reduce their rice productivity. This is in line with the negative effect reported in some earlier studies such as: Adedeji et al., 2016; Kazungu, 2009; Rakotoarisoa, 2011 and Mitchell and Baffes, 2002. This category of studies argues that higher import tariffs do not encourage farmer's competitiveness. Especially if there is lack of investment in technologies to boost productivity. While, as expected, higher tariffs in Ebonyi increases rice productivity, this can be explained by the ability of higher tariffs to serve as import barrier, hence tends to encourage investment in domestic rice production and consequently improve rice productivity. This is also in line with a few studies that reported positive effects, these includes: Weibe et al., 2015; World Bank, 2001; Krishna and Mitra, 1998; Edward, 1997 and Harrison 1994. Similarly, the high tariff regimes could have a positive impact since they are normally associated with input subsidies and incentives to farmers which are expected to boost domestic productivity when properly utilised.

Furthermore, the short-run impact of the lag difference of trade policy is significant in Kano and Ebonyi, the signs of the coefficient were shown to be negative for both states of Kano and Ebonyi, which is against a priori expectation. While on the contrary, the result of lagged difference was insignificant in other four states (Benue, Niger, Kaduna and Borno). Overall, the negative impact of high tariffs has been indicated by most studies although variation exist from state to state.

Second policy variable examined relates to institutional factors, specifically government instability variable. Both the current and lagged value of government instability was examined in this study. From the short-run estimate of the current value of government stability, evidence showed that it is significantly related to rice productivity in three states of Benue, Kano and Borno. The sign of the coefficients were all negative, implying that an increased government instability reduces rice productivity. Also, the result of the coefficients were not statistically significant across the other states Niger, Kaduna and Ebonyi.

This negative and significant finding conforms to a priori expectation and also supported by earlier findings that includes: Rakotoarisoa, (2011); Abbas et al., (2018). Instability is expected to discourage long-term investment by farmers in this states. Also, this result on government instability is expected as most governments even within the same political party are fond of reversing or changing policies by previous government regardless of its effectiveness. The early reversal or changing of these government policies makes it impossible to gain any positive impact from the policies even in the short-run.

Extending further to examine the short-run impact of the lag difference of government instability on rice productivity across the states, the short-run results are found to be significant across Benue and Kano, the coefficients were contrarily positive for the two states. Whereas the result of the lagged difference of government instability was not statistically significant in other states (Niger, Kaduna, Borno and Ebonyi). This positive effect of the result on lag difference of government instability is expected as farmers get used to the instability, they tend to adapt to by making effort to absorb the shock mostly through diversification or decrease the acreage. This enables them to properly manage the smaller size farm size and thus better productivity.

The short-run impact of corruption perception index was examined, and the result indicates the existence of significant effect across Benue, Kano and Ebonyi. The coefficients are negative for Benue and positive for Kano and Ebonyi. This implies corruption is negatively associated with rice productivity in Benue and the result conforms to a priori expectation of a negative impact of corruption on productivity.

This is supported by earlier findings in the studies by; Shumetie, & Watabaji, 2019; Kimenyi, Adibe, Djiré, & Jirgi, 2014; Galinato & Galinato, 2011). Whereas the effect is positive or beneficial for the rice productivity in Kano and Ebonyi. The positive effect shows the ability of these states (Kano and Ebonyi) to exploit corruption in boycotting the beaucratic process and fast tract investment to boost rice productivity.

On the contrary, there is no evidence to support the impact of corruption perception index on rice productivity in the short-run for other states (Niger, Kaduna and Borno). That is, the results were statistically insignificant for these states. The differences in the findings of this study regarding the short-run impact of corruption perception index confirms the heterogenous nature of the selected states or AEZs.

The study explores further, the short-run estimate of the first lag difference of corruption perception index and the dynamism of its impact on rice productivity across the selected states. The result shows the lag of corruption to have a significant effect on rice productivity in Benue, Kaduna, Kano and Ebonyi. With the exception of Ebonyi, the coefficients are all negative, implying corruption has a negative implication on rice productivity in Benue, Kaduna and Kano. The result indicates an insignificant effect in other states (Niger and Borno).

5.5.2.4 Short-run PMG Estimate for Adaptation Technologies Impact on Rice Productivity Across AEZs

This study assessed the adaptation technologies employed to support rice productivity in each AEZs. For this purpose, two factors were examined, these are the irrigation capacity and the dummy of NASPA. The section therefore presents the outcome of the short-run coefficient for these variables in the PMG analysis.

The short-run estimates for irrigation capacity indicated that there is a significant effect of irrigation capacity on rice productivity for only two states which are Kaduna and Ebonyi, against apriori expectation the coefficients were negative, implying the higher the irrigation capacity the lower the rice productivity in the two states. This agrees with other studies that includes Salazar & Rand, 2016; Anik, Breustedt, and Bauer, (2011); Ajetomobi, Joshua, Abiodun, Ajiboye and Hassan, (2011); Seo *et al* 2005; Liu et al., 2004; García et al. (2020). Findings for the other four states (Benue, Niger, Kano and Borno) were insignificant, indicating that irrigation has no contribution to rice productivity in these states.

The adaptation capacity of the region was examined through NASPA. The findings of the short-run estimates indicated that NASPA has a significant effect on rice productivity in Benue, Kano and Ebonyi. As expected, the coefficients were also positive for Benue and Kano, while contrarily the effect is negative in Ebonyi. While the estimates for all the other states (Niger, Kaduna and Borno) where found to be statistically insignificant. From these findings, it is indicated that the impact of NASPA is considered weak across the AEZs in Nigeria. This also indicates the need for more robust strategies and plan for adapting the rice sector to climate change.

5.6 Interaction Effects among Variables

An interaction effect occurs when the relationship between one independent factor and the dependent factor is weakened or strengthened by the presence of another variable also called "moderator variable" (Andersson, Cuervo-Cazurra, & Nielsen, 2014.; Aiken & West, 1991). Thus, the moderator variable has the strength to alter the effect of another variable. Similarly, contrary to the expectations of this study, the findings based on the direct model had shown that fertilizer has a negative effect and corruption also indicated a positive effect on rice productivity. Consequently, as specified in equation 4.11, section 4.7 of the methodology chapter, the direct model was extended to examine the possibility of an interaction (indirect) effect between fertilizers and corruption. Furthermore, in view of the high correlation between labour usage and mechanisation (Cor = -0.64), these two variables were also interacted to examine their joint effect on rice productivity. In addition to the indirect effect, the partial direct effects of land area, fertilizer, labour, mechanization, CO_2, temperature, rain, flood, and corruption were included in the model.

In models with interaction terms, the coefficients are considered as partial effects. These coefficients include both direct and indirect (interaction) partial effects. Thus, the regression coefficients are said to reflect *conditional* relationships. This implies the effect of one variable is conditional to the value of the moderator variable in the model. The long and short-run result of the PMG estimates of the partial and interaction effects are presented in Table 5.10.

Table 5. 10

The PMG estimate of the Interaction Effect

Long-run result						
Productivity	**Coef.**	**Std. Error**	**z**	**P>z**	**[95% Conf. Interval]**	
Land Area	5.75 e-4	5.0 e-4	1.140	0.253	0.000	0.002
Fertilizer	-0.050***	0.008	-6.090	0.000	-0.066	-0.034
Labour	0.029***	0.010	2.800	0.005	0.009	0.049
Mechanization	-0.275***	0.101	-2.720	0.006	-0.473	-0.077
CO_2	3.47e-5***	4.18 e-6	8.300	0.000	0.000	0.000
Temperature	0.031	0.030	1.050	0.294	-0.027	0.090
Rain	-5.70 e-4***	1.50 e-4	-3.710	0.000	-0.001	0.000
Flood	-0.071	0.075	-0.950	0.342	-0.217	0.075
Corruption	-2.132***	0.360	-5.930	0.000	-2.837	-1.428
COR*FERT	0.036***	0.006	6.370	0.000	0.025	0.046
LAB*MECH	-0.002	0.002	-1.350	0.178	-0.006	0.001
Short-run result						
ECT	-0.4395*	0.2592	-1.7000	0.0900	-0.9476	0.0687
Land Area	-0.0014	0.0027	-0.5200	0.6020	-0.0066	0.0039
Fertilizer	0.0300**	0.0140	2.1400	0.0320	0.0026	0.0575
Labour	0.0811	0.0919	0.8800	0.3780	-0.0991	0.2613
Mechanization	0.1556	0.1602	0.9700	0.3310	-0.1583	0.4695
CO_2	-1.52 e-5*	8.7 e-6	-1.740	0.081	-3.23 e-5	1.9 e-6
Temperature	-0.0016	0.0297	-0.0600	0.9560	-0.0598	0.0565
Rain	7.6 e-5	1.55 e-4	0.490	0.624	-2.28 e-4	3.79 e-4
flood	0.1235**	0.0623	1.9800	0.0480	0.0013	0.2456
Corruption	0.7997**	0.4071	1.9600	0.0500	0.0017	1.5977
COR*FERT	-0.0179**	0.0083	-2.1700	0.0300	-0.0342	-0.0017
LAB*MECH	-0.0118	0.0160	-0.7400	0.4590	-0.0432	0.0195
Constant	1.6741	0.8819	1.9000	0.0580	-0.0545	3.4027

5.6.1 Long-Run Impact

As presented in Table 5.10, in the long-run the direct partial effects of fertilizer (-0.050), labour (0.029), mechanization (-0.275), CO_2 (3.47e-5), rain (-5.70 e-4), and corruption (-2.132) on rice productivity were statistically significant. While the indirect partial effect between corruption and fertilizer (COR*FERT) is statistically significant and positive. The interaction between labour and mechanisation (LAB*MECH) is negative but statistically insignificant. The full effect of fertilizer is thus explained by the partial indirect effect of fertilizer which is significantly positive (0.036) and its partial direct effect (−0.050). In the long-run, the full or net effect of fertilizer on rice productivity is conditional to the level of corruption and is expressed as (-0.050(FERT) +0.036(COR*FERT)). Ceteris paribus, the net effect of fertilizer is negative at low level of corruption since the negative coefficient outweighs the positive effect. Then as corruption increases, the size of the interaction effect (+0.036(COR*FERT)) increases positively. Thus, increase in corruption leads to a net positive effect of fertilizer in the long run, since the positive effect of the interaction effect will outweigh the negative direct effect.

This result is also consistent with the argument that the fertilizer subsidy policies encourage corruption. Through bribe payment some farmers with capacity to offer bribe can acquire adequate quantity of fertilizers and thus operate at higher efficiency (Anik, et al., 2017). Again, Kolstad and Wiig (2013) indicated that foreign investors prefer to invest in the most corrupt countries. While based on the argument on systemic corruption in collective action theory, acting corruptly is more beneficial than acting fairly in the presence of systemic corruption (Tacconi & Williams, 2020). Thus, more farmers could get involved in corruption practices in the long run.

5.6.2 Short-Run Impact

Based on short-run result, the indirect partial effect between corruption and fertilizer (COR*FERT) is statistically significant but negative. While the interaction between labour and mechanisation (LAB*MECH) is again statistically insignificant. The short-run coefficient of indirect partial effect of fertilizer (COR*FERT) on rice productivity is significantly negative (-0.0179) and relatively lower compared to its positive direct partial effect (0.030). The short-run full effect of fertilizer on rice productivity can thus be expressed as (0.030(FERT) -0.0176 (COR*FERT)). Again, keeping other factors constant, the effect of fertilizer strongly depends on the level of corruption. At the lower level of corruption, fertilizer indicates an overall positive effect on productivity since the positive effect 0.030(FERT) outweighs the negative effect (-0.0176(COR*FERT)).

While at higher level of corruption, fertilizer effect tends towards negative effect in the short-run. This negative effect in higher level of corruption in the short-run indicates early stage of corruption prior to becoming a systemic practice among farmers as explained by the collective action theory. This is also supported by extant studies such as Anik, Breustedt, and Bauer (2011); Anik, et al., (2017); Drebee, and Abdul-Razak, (2020). Also, Trabelsi and Hédi Trabelsi, (2019) indicated that beyond an optimal threshold, both high and low corruption levels can decrease economic growth. Further explanation on the relationship is also presented graphically in figure 5.1 below.

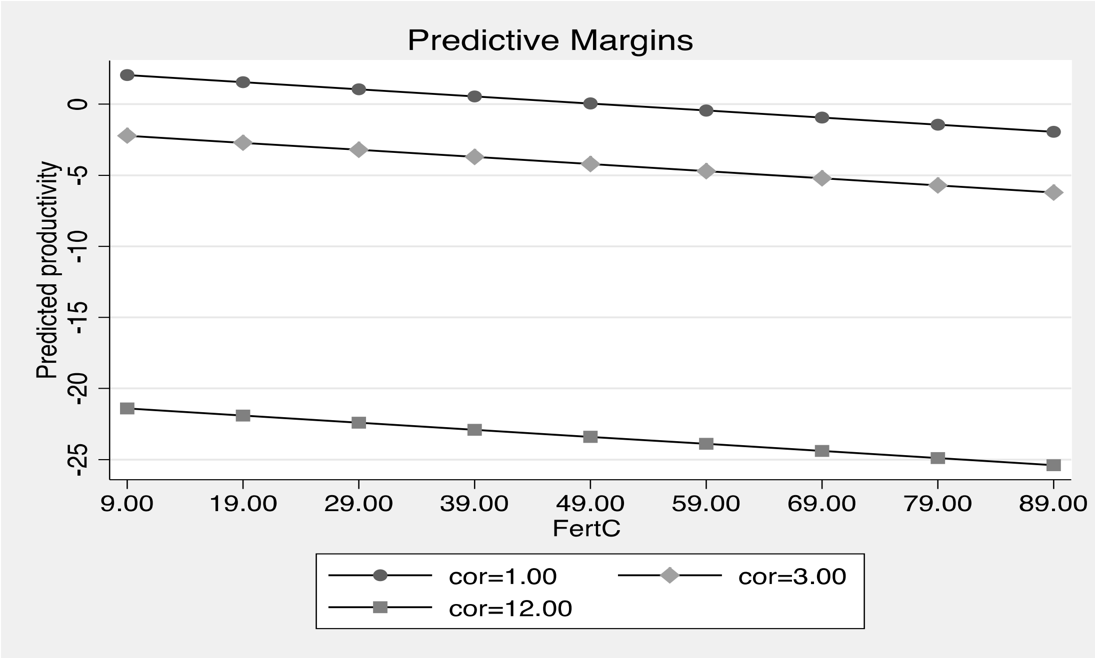

Figure 5. 1. Interaction effect of corruption and the predicted changes in rice productivity

Figure 5.1 was constructed by fixing three values for the level of corruption, that is low (1), medium (3) and high values (12). The graph indicates three different levels of corruption represented by each trend line. The upper line indicates the lowest level of corruption (1), the middle is the average level of corruption (3) and the lower line is the highest level of corruption (12). Each of the fixed level of corruption was interacted with various quantity of fertilizer (x-axis) and the corresponding percentage change in rice productivity is represented on the y-axis. At low level of corruption (upper line), the effect of fertilizer on rice productivity tends to be positive, and as the corruption level increases, the effect of fertilizer tends to shift towards the negative. This finding supports the assertion that when corruption increase, in the short-run, more farmers are restricted from retrieving adequate fertilizer input thus affecting their productivity

(Anik, et al., 2017). Also, based on the argument on systemic corruption in collective action theory, acting corruptly is more beneficial than acting fairly in the presence of systemic corruption (Tacconi & Williams, 2020). Thus, more farmers could get involved in corruption practices in the long run.

The findings justify the negative effect of fertilizer (-0.050) indicated by the partial direct coefficient. Evidently, corruption plays a role in this unexpected finding on the effect of fertilizer. Corrupt practices such as the over reporting of the quantity of fertilizer disbursed by government can occurs leading false claim in the quantity of fertilizer use, whereas in reality the fertilizers were not used on the farms. Another factor that might contribute to the negative effect is that the quality of the fertilizer supplied may be substandard. Another argument to support the role of corruption is that it leads to delay and untimely delivery of fertilizers inputs to users, thus considering that all farm operations are time bound, the negative effect could result from delayed or untimely application.

5.7 Chapter Summary

In this chapter, the growth in rice productivity in Nigeria has been examined using the Panel ARDL method (PMG). Panel data analysis is used because it contains more information than time-series data or cross-sectional data, so it provides more degrees of freedom and consequently more reliable estimates. Cointegration techniques are used to test the long-run equilibrium relationship between the variables in the model, followed by estimating the ECM. Compared with the MG estimator, the Hausman tests for homogeneity in long-run parameters suggested using the PMG estimator, as a more efficient and still consistent estimator in the context of the panel cointegration and ECM. Some robustness analyses were performed to provide reassurance of the estimates.

To summarize, the country-specific error correction modelling confirms the presence of heterogeneity across countries regarding the short-run dynamics between climate change, policies and adaptation technologies and rice productivity. This is recognizable from the sampled states representing the AEZs which are heterogeneous by nature. The sampled states constitute states that differs in climate type, vegetation and soil, similarly the agricultural potential of the states varies and similarly their level of vulnerability. The selection of PMG technique has also assisted in taking into account the heterogeneity across the states and as well stressed the variations in the impacts through the exploitation of short-run estimates.

CHAPTER SIX

CONCLUSIONS AND POLICY RECOMMENDATIONS

6.1 Introduction

This chapter concludes the findings of the study presented in Chapter 5. Section 6.2 provides an overview of objectives; section 6.3 discussed the long run findings of the study, also section 6.4 adduces the short-run results. Base on the discussed results, section 6.5 presents the contributions of the study while, section 6.6 forwarded relevant policy recommendations derived from the result of this study; limitations and several suggestions for future research are section 6.7.

6.2 Overview of Objectives

This study provides empirical evidence on the core objective of assessing the impact of climate change, policies and adaptation technologies on rice productivity across the AEZs in Nigeria. The first specific objective is to describe the climate factors, policies and adaptation technologies influencing rice productivity across AEZs in Nigeria. This involves the use of descriptive approaches such as mean, standard deviations, minimum and maximum to describe the determinants factors across the individual AEZs. The second objective which involves assessment of climate change impact on rice productivity was achieved using four variables (temperature, rainfall, carbon emission and flood intensity). The third objective examines government policies on rice productivity is achieved using three categories of variables (trade policy, government instability and corruption perception index). While fourth objective involve assessing adaptation technology impact on rice productivity using two measures (the irrigation capacity and the Nigeria Adaptation Strategy and Plan for Action (NASPA)). Finally, the fifth objective assessed the variation in the impact of these factors (climate change, policies and adaptation technologies) across the different states representing the AEZs.

Concerning the methodology, the study is based on panel data of six states each representing an AEZ in Nigeria and the data span covers from 1980 to 2018. The time-series properties of the data are established by using IPS, LLC unit root tests. Hence, it was found that some of the variables are stationary at levels and others at first difference form. The analytical technique used to achieve this broad objective is the ARDL (PMG) model. This model presents a long run error correction model (ECM) which shows that the variables cointegrated in the long run to affect rice productivity in Nigeria. The PMG model presents both long run and short-run estimates of the rice productivity model. The long run impacts are the same across the AEZs, while the short-run varies across AEZs. Thus, considering these properties of PMG the sets of specific objectives outlined for this study were achieved. Thus, the discussions and implications of both the long run and short-run estimates are presented next.

6.3 Summary of Findings on Long Run Impact of Factors on Rice Productivity in Nigeria

The study set out to achieve the broad objective of assessing the impacts of climate change, policies and adaptation technologies on rice productivity across AEZs in Nigeria. While specific objectives two to four were achieved from the long run coefficients of the ARDL (PMG) estimates. The long run estimates show how each factor impact rice productivity in the long run. Thus, the following section discusses the long run impact of each factor on rice productivity.

6.3.1 Summary of Findings on Long Run Impact of Climate Change, on Rice Productivity in Nigeria

For the second objective, the study found that climate change factors related to carbon emission, temperature, rainfall and flood impacts rice productivity in Nigeria in different manners. That is, in the long run, carbon emission exerts a positive and significant impact on rice productivity growth in Nigeria. That is an increase in carbon will lead to increase in rice productivity. This is expected when other conditions remain constant considering that carbon is also required for the food production process of rice plants, thus the beneficial effect of more carbon. While temperature was similarly found to be positive and significantly correlated with rice productivity growth in Nigeria. The implication is that increase in temperature will equally increase the rice productivity in the long run, this is because sunlight is needed at certain stage of rice growth for photosynthesis. Thus, as an essential component of the food production process, if the threshold of temperature required for the optimal growth of the rice plant is not exceeded then the beneficial effect of temperature can be observed.

Another factor examined is rainfall, findings indicates that it impacts significantly on rice productivity growth in the positive direction in the long run. This also indicates that increase in rainfall is beneficial to rice productivity, this further shows the high water requirement by rice plant to support its growth and nutrient movement within the plant. This is expected since rice thrive well in submerged or flooded area. While on the contrary flood intensity have an insignificant effect on rice productivity in the long run. Overall, result indicates that three climate variables employed in this study have a significant and positive effect on rice productivity growth in the long run. That is, higher temperature, rainfall and carbon emission all favours rice productivity in Nigeria. This is expected since the three factors are necessary conditions for the process of food production in plants. These results reveal that climate change has overall beneficial effect on rice productivity growth in Nigeria except for flood prone regions which requires intervention.

6.3.2 Summary of Findings on Long Run Impact of Policies on Rice Productivity in Nigeria

The third objective concerns the examination of the impact of government policies on rice productivity growth in Nigeria. Based on the findings, trade policies measured as the percentage of tariff on rice import was shown to have a positive and significant impact on rice productivity growth in Nigeria. Hence, it is concluded that higher tariffs which were aimed at protecting domestic rice production in Nigeria has a favourable impact on productivity. This could imply that higher tariff on rice import discourages importation and encourage the diversion of capital asset towards boosting domestic rice productivity. Conclusively, the result has shown that a trade protectionism policy favours domestic rice productivity growth in Nigeria in the long run. Thus, the investment in machineries, optimal input usage during high import tariffs is evident in this study to have positive implications on rice productivity.

Also, the result of Government instability shows an insignificant impact in the long run. This result on government instability is expected as most governments even within the same political party are fond of reversing or changing policies by previous government regardless of its effectiveness. The early reversal or changing of these government policies makes it impossible to gain any significant impact of the earlier policy. Again, contrary to the widely acknowledged challenges of corruption in Nigeria, the result has indicated a positive impact of corruption on rice productivity growth in Nigeria, which is also statistically significant. Thus corruption continues to pose a beneficial effect on rice productivity in the long run. The possible explanation for this result is that the practice of corruption has become part of the bureaucratic processes for farmers to obtain subsidies and incentive support from government representatives. That is, corruption enhances the ability of farmers to access more inputs or production incentives, while increased use of inputs such as hybrid seeds and fertilizer acquired through corrupt practices result to increased rice productivity. This is especially applicable to the large farms owned by the rich or political classes.

6.3.3 Summary of Findings on Long Run Impact of Adaptation Technologies on Rice Productivity in Nigeria

Regarding the fourth objective of assessing the impact of adaptation technologies on rice productivity growth in Nigeria; the study has expectedly shown that irrigation capacity has a positive and statistically significant impact on rice productivity growth in Nigeria. The possible reason adduced for such findings relates to the fact that several irrigation practices such as tube well, direct use of water pumps to divert steams or river waters are deployed for irrigation by farmers. This is to support the mostly dilapidated government irrigation schemes which are poorly constructed and mis-managed, hence mostly non-functional. The “National Adaptation Strategy and Plan of Action” on climate change (NASPA) stipulates a consolidation of number of strategies on climate change adaptation in Nigeria. Thus, by employing the dummy of this factor to assess the impact of its introduction on rice productivity, the results of this study shows that NASPA is insignificant in impacting rice productivity growth in the long run. That is, the periods after and prior to the implementation of NASPA are not different with respect to rice productivity. Hence the NASPA have not successfully contributed to improving rice productivity growth in Nigeria.

6.3.4 Summary of Interaction Effects

Corruption is a generally considered an immoral practice, wrong and economically harmful behaviour. It characterises inadequate systems with economic, political insecurity and weak rule of law. However, no economy is corruption-free but its preponderance in transitional economies such as Nigeria is high. Specifically, the low-income level and poverty among farmers makes them highly vulnerable to this challenge. Again, the debate on the effects of corruption on performance of various economic sectors remains polarised. While some studies have claimed that corruption stifles economic growth and development, others have contended that under certain situations corruption could be economically desirable as it provides a channel to overcome series of inefficient regulations and bureaucratic challenges.

The findings have interestingly affirmed the role of corruption in moderating the relationship between important inputs such as fertilizer and rice productivity in Nigeria.

Especially considering that Nigeria's agriculture is largely dominated by smallholder farmers who are mostly marginalised, resource poor, with huge capital deficit and voiceless in the national policies (Anik & Bauer, 2017). Thus, it is widely affirmed that the misappropriation of subsidy, incentive funds, and assets by corrupt officials and middlemen have a major implication on their productivity. As it is widely acknowledged that corruption contributes to the slow growth of the various economic sectors such as agricultural sector in Nigeria.

6.4 Summary of Findings on the Short Run Impact of Climate Change, Policies and Adaptation Technologies on Rice Productivity across AEZs in Nigeria.

Finally, the third objective also aims to assess the dynamism in the impact of climate change, policies and adaptation technologies across the different AEZs represented by the selected states. This objective is achieved based on the outcome of the short run estimates of the ARDL (PMG) technique and unlike the long run impacts, the short run results are different for all the six states. Thus, this section discusses the implication of the results base on individual state.

6.4.1 Summary of Short run impact for Climate Change, Policies and Adaptation Technologies on Rice Productivity in Benue, Nigeria

In the assessment of climate impact on rice productivity in Benue, the results of the four measures of climate change that includes carbon, temperature, rainfall and flood intensity (both current values and their lags) are as follows:

The current value of carbon emission indicates a significant and positive impact on rice productivity in Benue. Contrarily, the lag or previous year's value of carbon emission is also significant but has a negative effect rice productivity in Benue. This implies carbon has an important effect on rice productivity however, the direction of the impact differs or is influenced by other factors. As indicated by some experimental studies that higher carbon in the presence of higher temperature can negatively impact rice productivity. Whereas, when temperature is within certain threshold, carbon is beneficial to rice productivity. The result has also shown that temperature has a negatively significant effect in rice productivity in Benue. As earlier explained, most of the essential production factors including temperature interact with other factors to yield either positive or negative effect.

Furthermore, both current and previous year rainfall indicated a significant and negative impact on rice productivity in Benue. Implying that higher rainfall at early stage of rice growth will negatively impact its growth and consequently the productivity. Although, rice can withstand larger volume of water at the later stage of growth. For flood intensity, both previous year and current values of flood intensity shows an insignificant effect on rice productivity in Benue and the signs of the coefficients were negative. This could possibly be attributed to the ability of the state in adapting to flood challenges through practices of early planting and harvesting prior to the unset of excess rain.

The dynamism in the effect of policies on rice productivity in Benue state as indicated by the short run result of trade policies, government policies, and corruption perception index are presented thus. Trade policy was found to exert an insignificant impact on rice productivity in Benue and the coefficient for the current trade policy and that of previous year's trade policy indicated a positive and negative effects respectively. This outcome is most likely due to the higher competition between local rice and the imported variant. Similarly, the expected technology transfer or investments to help boost productivity in the period of high tariffs is not achieved, thus no difference in productivity between periods of lower tariffs and higher tariffs.

Government instability is found to significantly influence Benue's rice productivity. Whereas, the lag difference or previous year's instability exhibit a negative impact. On the other hand, the current instability shows a positive impact. The instability or changes in previous policies can pose shock to the farmers hence the inability to adjust or invest in optimal inputs usage could negatively affect rice productivity in the short run. While, it is expected that current changes in policies will follow the introduction of new policies which will lead to higher input usage and hence the productivity increment. The impact of corruption was found to be significant and negative. Implying corruption negatively affects Benue's rice productivity. The result of the negative coefficients is expected, it indicates corruption has a detrimental effect on rice productivity in the short run.

Next the result of the measures of adaptation technologies is presented. First, the irrigation capacities coefficient indicated an insignificant and negative effect on Benue state rice productivity. The second measure of adaptation involves NASPA and the results shows a significant and positive effect on rice productivity in Benue indicating that NASPA has effectively enhanced adaptation and consequently rice productivity even in the short run. Hence, to increase rice productivity efficient adaptation strategies such as NASPA are preferred in Benue. Summarily, in Benue state the findings have shown that among the factors in the model, three climate factors (carbon, temperature and rain), two policies (government stability and corruption) and one adaptation technology (NASPA) were found as significant in influencing rice productivity.

6.4.2 Summary of Short run impact for Climate Change, Policies and Adaptation Technologies on Rice Productivity in Niger State

In Niger state, the assessment of climate impact on rice productivity involves four measures of climate change (carbon, temperature, rainfall and flood intensity). Only the previous year's value of carbon emission has a significant effect on rice productivity in Niger. Contrarily, the current value of carbon emission was insignificant although, both have a positive impact on rice productivity in Niger. Overall carbon has a significant and positive short run impact on rice productivity. The result has also shown that temperature has a negative but insignificant effect in rice productivity in Niger. Furthermore, both current and previous year rainfall indicated an insignificant and negative impact on rice productivity in Niger.

In the case of flood intensity, both previous year and current values have been shown to have a significant effect on rice productivity in Niger. The signs of the coefficients were also both positive. Niger state is surrounded by the river Niger and most farmers are located around the bank of river Niger, thus a flood prone region. Also, the ability to harness the excess water from flood results into the beneficial effect. That is, developing adaptation mechanism to flood challenges through practices such as; water harvesting, redistribution or rechannelling, early planting and harvesting prior to the unset of excess rain.

The dynamism in the effect of policies on rice productivity in Niger state as indicated by the short run result of trade policies, government policies, and corruption perception index are presented thus. Trade policy was found to exert an insignificant impact on rice productivity in Niger and the coefficient for the current trade policy and that of previous year's trade policy indicated a positive and negative effects respectively. Government instability is found to insignificantly influence Benue's rice productivity. Whereas, both the lag difference and current year's instability exhibit a negative impact. The impact of corruption was also found to be insignificant. While, the lag difference and current year's corruption exhibit a positive and negative impact respectively. Although, it is expected that the coefficients should be negative indicating corruption has a negative effect on rice productivity in the short run.

Subsequently the finding of the measures of adaptation technologies is presented. First, the irrigation capacities coefficient indicated an insignificant and negative effect on Niger state rice productivity. The second measure of adaptation involves NASPA and the results shows an insignificant and negative effect on rice productivity in Niger indicating that NASPA is effective in enhancing the adaptative capacity in Niger unlike Benue. Consequently, rice productivity increase requires alternative efficient adaptation strategies.

Summarily, in Niger state the findings have shown that among the factors in the model, two climate factors (carbon and flood intensity) were significant. Contrarily, no policy factors and no adaptation technologies were found to be significant in influencing rice productivity in Niger state.

6.4.3 Summary of Short run impact for Climate Change, Policies and Adaptation Technologies on Rice Productivity in Kaduna.

The assessment of climate impact on rice productivity in Kaduna, the results of the four measures of climate change (carbon, temperature, rainfall and flood intensity) are as follows: Similar to Niger state, only the previous year's value of carbon emission has a significant effect on rice productivity in Kaduna. Also, the current value of carbon emission was insignificant although, both previous and current values have a positive impact on rice productivity in Kaduna. The results have also shown that temperature has a positive but insignificant effect in rice productivity in Kaduna.

Furthermore, both current and previous year's rainfall indicated an insignificant and negative impact on rice productivity in Kaduna. In the case of flood intensity, both previous year and current year's values is shown to be insignificant to influence rice productivity in Kaduna and the signs of the coefficients were positive and negative for previous year and current year's values respectively. This could possibly be attributed to the ability of the state in adapting to flood challenges using practices including early planting and harvesting prior to the unset of excess rain.

The dynamism in the effect of policies on rice productivity in Kaduna state as indicated by the short run result of trade policies, government policies, and corruption perception index are presented thus. Both lag and current value of trade policy was found to exert an insignificant impact on rice productivity in Kaduna and the coefficient for both the current trade policy and that of previous year's trade policy indicated a positive effect. Government instability is found to be insignificant in influencing Kaduna's rice productivity. Whereas, the lag difference or previous year's instability exhibit a negative impact. On the other hand, the current instability shows a positive impact. Furthermore, the impact of corruption was found to be significant only in the current year. The coefficient was also negative for the current year value. Implying corruption negatively affects Kaduna's rice productivity in the current season, whereas, previous corruption value is insignificant. It is expected that the coefficients should be negative indicating corruption has a negative effect on rice productivity in the short run.

Again, the result of the measures of adaptation technologies is presented. First, the irrigation capacities coefficient indicated a significant but negative effect on Kaduna state rice productivity. The second measure of adaptation involves NASPA and the results shows an insignificantly negative effect on rice productivity in Kaduna indicating that NASPA is not effective in enhancing the adaptative capacity in Kaduna unlike Benue. Consequently, rice productivity increase requires alternative efficient adaptation strategies.

Summarily, in Kaduna state the findings have shown that among the factors in the model, one climate factors (carbon), one policy factor (corruption) and one adaptation technology factor (irrigation technology) were found as significant in influencing rice productivity. All other factors were insignificant.

6.4.4 Summary of Climate Short run impact for Change, Policies and Adaptation Technologies on Rice Productivity in Kano Nigeria.

The results of the assessment of climate impact on rice productivity in Kano base on the four measures of climate change (carbon, temperature, rainfall and flood intensity) are as follows: The estimated result shows that only the current value of carbon emission was significant and shows a negative impact on rice productivity in Kano. Contrarily, the previous year's value of carbon emission has a positive impact although insignificant. The result have also shown that temperature has a negatively significant effect in rice productivity in Kano, this is similar to result of Benue. Furthermore, both current and previous years rainfall indicated an insignificant and negative impact on rice productivity in Kano, this result is similar to that of Niger and Kaduna. In the case of flood intensity. Only current year values show a significant with positive effect on rice productivity in Kano**.** The previous year's flood intensity is insignificant.

The impact of policies on rice productivity in Kano state as indicated by the short run result of trade policies, government policies, and corruption perception index are presented thus. Both current and previous values of trade policies were found to exert a significant impact on rice productivity in Kano and the coefficient for both current and previous year's trade policy indicated a negative effect. This outcome indicates that higher tariffs decrease rice productivity. The technology transfer as a result of the lower tariffs or open economy has not helped to boost productivity in Kano as evidenced by this study. Furthermore, Government instability is found to significantly influence Kano's rice productivity. Whereas, the lag difference or previous year's instability exhibit a negative impact. On the other hand, the current instability shows a positive impact.

The impact of both current and previous year's corruption was found to be significant. The previous year corruption value is positive while current year is negative. Implying higher corruption in the current season decreases Kano's rice productivity. Apriori expectation is that the coefficients should be negative indicating corruption has a negative effect on rice productivity in the short run. Next the result of the measures of adaptation technologies is presented. First, the irrigation capacities coefficient indicated an insignificant and negative effect on Kano state rice productivity. The second measure of adaptation involves NASPA and the results shows a significant and positive effect on rice productivity in Kano for both current and previous year. This indicates that NASPA has effectively enhanced adaptation and consequently rice productivity even in the short run. Hence, to increase rice productivity efficient adaptation strategies are preferred.

Summarily, in Kano state the findings have shown that among the factors in the model, three climate factors (carbon, temperature, and flood intensity), all three policy factors (trade policies, government instability and corruption) and one adaptation technology factor (NASPA) were found as significant in influencing rice productivity. All other factors were insignificant.

6.4.5 Summary of Short run impact for Climate Change, Policies and Adaptation Technologies on Rice Productivity in Borno Nigeria

The results of the four measures of climate change (carbon, temperature, rainfall and flood intensity) impact on rice productivity in Borno, are as follows: The previous and current values of carbon emission significantly impact on rice productivity in Borno. While the coefficient of the current value is negative and positive for previous value of carbon emission. Also, the result has shown that temperature has a negatively significant effect on rice productivity in Borno, this is similar to the result of Benue. Furthermore, only the previous year's rainfall indicated a significant and negative impact on rice productivity in Borno. In the case of flood intensity, only the previous year values significantly influence rice productivity in Borno**.**

The dynamism in the effect of policies on rice productivity in Borno state as indicated by the short run result of trade policies, government policies, and corruption perception index are presented thus. Only the current trade policy was found to exert a significant impact on rice productivity in Borno and the coefficient was negative. For the previous year's trade policy, result indicated a positive but insignificant effect on rice productivity. The outcome of government instability indicates that only the previous year's instability is found to significant but negatively influence Borno's rice productivity. Whereas, the lag difference or previous year's instability exhibit a negative but insignificant impact on rice productivity. The impact of corruption was found to be insignificant and positive. Implying corruption does not have any significant effect on Borno's rice productivity.

Finally, the result of the measures of adaptation technologies is presented. First, the coefficient of irrigation capacities indicated an insignificant and positive effect on Borno state's rice productivity. The second measure of adaptation which is NASPA and the results was found to be insignificant for both current and previous values. This indicates that NASPA has not effectively enhanced adaptation and consequently rice productivity in Borno.

Summarily, in Borno state the findings have shown that among the factors in the model, all four climate factors (carbon, temperature, rain and flood intensity), two policy factors (trade policies and government instability) and no adaptation technology factor (NASPA) were found as significant in influencing rice productivity.

6.4.6 Summary of Short run impact for Climate Change, Policies and Adaptation Technologies on Rice Productivity in Ebonyi Nigeria

The findings on climate impact on rice productivity in Ebonyi reveals as follows; Only the current year's value of carbon emission has a significant and negative effect on rice productivity in Ebonyi. While the current value of carbon emission was insignificant and negative. The result has also shown that temperature has a negative but significant effect on rice productivity in Ebonyi. Similar to result in Benue state, both current and previous year's rainfall indicated a significant and negative impact on rice productivity in Ebonyi. In the case of flood intensity, both previous year and current year's values is shown to have a positive and significant influence on rice productivity in Ebonyi. This could possibly be attributed to the ability of the state in adapting to flood challenges using practices that includes different water harvesting techniques, early planting and harvesting prior to the unset of excess rain.

The variability in the effect of policies on rice productivity in Ebonyi state as indicated by the short run PMG estimate result of trade policies, government policies, and corruption perception index are presented thus. Both lag and current value of trade policy was found to exert a significant impact on rice productivity in Ebonyi. Whereas the coefficient for both the previous and that of current year's trade policy indicated a positive and negative effects respectively. Government instability is found to be insignificant in influencing Ebonyi's rice productivity. Whereas, the previous and current year's instability exhibit a negative and positive impact. Furthermore, the impact of corruption was found to be significant for both previous and the current year. Both the coefficients were also to be positive. Implying corruption positively affects Ebonyi's rice productivity. Although, it is expected that the coefficients should have a negative effect on rice productivity.

Lastly, the result of the measures of adaptation technologies is presented. First, the irrigation capacity's coefficient indicated a significant but negative effect on rice productivity in Ebonyi state. The second measure of adaptation involves NASPA and result also indicates that only its current value has a significantly negative effect on rice productivity in Ebonyi. Indicating that NASPA is effective in enhancing the adaptative capacity as in Ebonyi.

Summarily, in Ebonyi state the findings have shown that among the factors in the model, all four climate factors (carbon, temperature, rain and flood intensity), two policy factors (trade policies, and corruption) and the two-adaptation technology factor (irrigation capacity and NASPA) were found as significant in influencing rice productivity. While all other factors were insignificant. Base on the discussions above, it is imperative that the study presents recommendations on policy dimensions that are relevant the national goal of improving rice productivity and achieving food sovereignty in Nigeria.

6.5 Policy Recommendations of the Study

The current section offers relevant recommendation to inform policy direction aimed at the improvement of rice productivity growth in Nigeria. In the light of the outcome of the examined factors and for the future of food security particularly relating to rice, the study recommends successive agricultural policies that can lead to achievement of higher levels of self- sufficiency of rice and narrowing the gap between production and consumption to reduce imports. This policy recommendations relate to increasing rice productivity that will result to decreased imports dependence and thus, the decrease in costs of rice imports, which could save the extra governmental expenditures. These policies are forwarded to help reduce losses from farms by supporting optimization and utilization of natural, alongside human and financial resources. This involves improved land management practices, supporting climate change mitigation, with stronger adaptive capacity using innovative technologies suitable to the local context.

These recommendations are based on the empirical findings reported in chapter five of the current study. It is established that the continuous dependence on rice importation exposes the over 70% of Nigeria's population that rely on rice as food or source of income to imminent threat from climate change. Also, without appropriate policies, the national effort of diversification of Nigeria's economy towards agriculture might become futile. Some consequences will include the threat of food insecurity, higher poverty as a result of further neglect of the domestic productivity challenges. Loss of foreign exchange earnings, conflicts and volatility to global fluctuations in prices and supply of rice. This will as well harm the Nigeria's economy particularly in the face of dwindling oil revenue occasioned by volatile prices of crude oil at the global market.

A number of recommendations are suggested to remedy the problems of low productivity and excessive rice import in Nigeria. The recommendations are split into two which are long-term and short run recommendations. The long-term policy recommendation are based on the long run results and are focused on the entire nations. While using the short run result, short term recommendations proffered for the AEZs as represented by individual state.

6.5.1 Long Run Policy Recommendation

Base on the long run PMG estimates, which are the same for all the AEZs, a long run policy recommendation is proffered to revamp the rice productivity in Nigeria. The study had examined how climate change factors (carbon, temperature, rainfall and flood) have impact Nigeria's rice productivity. The findings have shown three climate factors (carbon, temperature, and rainfall) to be of positive and significant impact on rice productivity, while flood was found to be insignificant. Relating these findings on climate change particularly carbon emission impact, the government should provide agri-environmental payments in order to inspire rice producers to adopt sustainable production practices that will enhance the climate change mitigation and environmental protection.

These practices are also expected to affect productivity and preservation of land resource and hence, impacting on land productivity (Hasan & Kristkova, (2017). These practices include the development of improved seed varieties such as climate tolerant seed varieties (C4 rice plant varieties), early warning systems, rain water harvesting. Additionally, these practices can further enhance the positive effect of climate change by helping to sustain the temperature threshold, rainfall volume which remain beneficial to rice productivity and also ensure efficient utilization of rainwater.

Furthermore, to attain improved rice productivity and self-sufficiency in Nigeria, there is need for investments in the area of appropriate climate change adaptation technologies such as the early warning systems. The development of Nigeria's irrigation capacity as an adaptation technology was found to be positive and significant on rice productivity. Thus, it is recommended that more investment to be directed to improving the irrigation facilities across Nigeria. Enhanced management and conservation of water to increase water use efficiency and productivity (rainwater harvesting, water storage and conservation techniques). This will not only have the tendency to control flood, augment drought effect, it will further improve the rice productivity as evident by the findings of this study.

Aligning the findings of this study pertaining to the impact of irrigation capacity with the existing mismanagement challenge of most irrigation schemes, the recommendations by Oriola and Alabi (2014) on the privatization of the nation's river basins to ensure effective irrigation systems across the country is also adopted. Therefore, the alternative of complete implementation of public private partnership arrangements in relation to the large irrigation projects across the country is recommended. This will serve to curb the lingering challenges of inadequate maintenance. Considering low technology use in general and adaptation technology in particular, the study also recommends the development of an organised and large rice farm settlements that engage global best practices in rice production and adaptation to climate change.

While furthermore, the issues of policies particularly trade policies, government stability and corruption issues, the study established the positive and significant impact of both trade policies and corruption on the rice productivity. Unfortunately, there has been inconsistency in the tariff regimes by different government. First, there has to be consistency of policies in order to encourage farmer and investors to fund technologies and adopt practices that can boost rice productivity. Concerning trade policy, it is evident that higher tariffs serve a beneficial effect on rice productivity.

Thus, in line with this result the introduction of higher import tariff is highly recommended. This will serve to discourage import and refocus investment in domestic rice productivity especially since in the long run this protectionist policy of higher import tariff in Nigeria can be beneficial to the countries productivity. Therefore, this study recommends the implementation of policies that will protect and improve the productivity of volatile domestic rice industry. This is given Nigeria's comparative advantage in terms of land area for rice production and the effect on both employment creation and food security of the nation.

Similarly, corruption was found to exert a positive and significant influence on rice productivity. Although corruption impact is positive, it definitely increases the unit cost of production in the system. This finding aligns with the hypothesis that corruption is inevitably part of the growth process among developing countries. This school of thought attributed this to high bureaucratic process and the manual or low technology adoption in the system. Thus, electronic channels and ICT adoption in the procurement processes is highly recommended. This has the potential of reducing the physical contact during exchange of good and services and curtail corruption.

Finally, two factors should be considered in the implementation of policies in Nigeria: first, the heterogeneous nature of the various AEZs in the country. Second, the dynamic nature of climate change. From the outcome of this research, it is proven that policies at the federal government level are designated without the due recognition of the dynamism in each region. Therefore, it is the recommendation of this study that policies should consider this heterogeneous nature of regions in its National plan by:

Involving state or regional government in the planning stage of any project, maintenance policies and evaluation of projects at various levels. These could be achieved through Public Private Partnership. Especially, since the study has provided empirical evidence on the inefficiency of past policies in mitigating the challenges of rice productivity growth in the country.

6.5.2 Short Run Policy Recommendation for Different AEZs in Nigeria

A key approach to the short run policy recommendation is to first identify immediate and imminent risks to rice productivity and consequently the livelihoods (income) and food security at the different AEZs. Particularly those potential or imminent threats that could further lead to degeneration (negative impact) of the low rice productivity in the region requires short term policy measures to be timely undertaken. These priority areas are identified from the short run result of the PMG for all AEZs. Therefore, in order to build resilience to climate change and improve rice productivity, government and relevant ministries or agencies could prioritise the significant climate factor for the particular AEZ, rather than developing the same adaptation technologies to use across the entire AEZs. The following sections will discuss some indicators to assess:

6.5.2.1 Policy Recommendations for Benue (Derived Savanna AEZ)

The findings base on the assessment of climate change, policies and adaptation technology as determinants of rice productivity in derived savanna (DS) AEZ (Benue) indicates that; among the factors in the model, three climate factors (carbon, temperature and rain), two policies (government stability and corruption) and one adaptation technology (NASPA) were found as significant in influencing rice productivity. According to the coefficients of the carbon emission, the current value of carbon was found to be positive implying that carbon was beneficial to rice productivity contrarily the lag difference of the carbon emission showed a negative coefficient. This mix result could be accounted for by the interaction effect of carbon and temperature.

Generally, carbon is expected to have a positive impact on rice productivity. Although, negative impact can result when temperature go higher than the required threshold. Then the higher temperature interacts with high carbon level to result into a negative. Similarly, temperature was found to have a significant but negative effect. It is thus recommended that measures to avoid the simultaneous occurrence of high carbon emission and higher temperature should be discouraged in DS. This can involve the development of high temperature tolerant varieties and also to develop varieties with more carbon efficiency such as the C4 photosynthetic rice varieties. Furthermore, both current and lag difference of rainfall was evident to have a negative and significant effect on rice productivity in the DS AEZ. Thus, it is recommended that irrigation facilities such as dams and reservoirs for irrigation and water harvesting respectively should be developed.

This recommendation on irrigation development can also support the insignificant effect of irrigation capacity in the DS AEZ. In addition, these facilities can also support the findings regarding the positive and significant effect of NASPA. As regards policies, it is critical to discourage the prevalence of corruption owing to the negative and significant impact of this factor. This can be achieved through the strengthening of institutions and deployment of ICT in the operations between farmers and government. As this will reduce physical contact that that encourages corruption since the transaction cannot be traced electronically. Government instability is proven to have a significant effect on rice productivity although the coefficient was negative for the lag difference and positive for the current value. To improve rice productivity, it is therefore recommended that policy stability should be a priority.

6.5.2.2 Policy Recommendations for Niger (Southern Guinea Savanna AEZ)

In Southern Guinea Savanna (SGS) AEZ represented by Niger state, the findings base on the assessment of climate change, policies and adaptation technology as determinants of rice productivity indicates that; among the factors in the model, two climate factors (carbon and flood intensity) were significant. Contrarily, no policy factors and no adaptation technologies were found to be significant in influencing rice productivity in Niger state.

As climate change is the only significant factor, the recommendations therefore focus on the nature of impact from this factor. The coefficient of the lag difference of carbon emission was found to be positive implying that carbon was beneficial to rice productivity. Generally, carbon is expected to have a positive impact on rice productivity. It is thus recommended that measures to maximise current carbon emission should be followed. This can involve the development of varieties with more carbon efficiency such as the C4 photosynthetic rice varieties. Furthermore, both current and lag difference of flood intensity was evident to have a positive and significant effect on rice productivity in the SGS AEZ. Niger state is dominated by rice farms around the river Niger areas, thus prone to flood. Thus, considering the positive effects it is recommended that irrigation facilities such as dams and reservoirs for water harvesting should be developed.

6.5.2.3 Policy Recommendations for Kaduna (Northern Guinea Savanna AEZ)

In Northern Guinea Savanna (NGS) AEZ represented by Kaduna state, the findings base on the assessment of climate change, policies and adaptation technology as determinants of rice productivity indicates that; among the factors in the model, one climate factors (carbon emission), one policy factor (corruption) and one adaptation technology factor (irrigation technology) were found as significant in influencing rice productivity. All other factors were insignificant.

According to the coefficients of the carbon emission, the lag difference of carbon was found to be positive implying that carbon was beneficial to rice productivity in the short-run in areas of NGS AEZ, contrarily the current value of carbon emission showed to be insignificant. This mix result could be accounted for by the interaction effect of carbon and other factors like temperature. Thus, carbon is considered to have overall beneficial effect if other factors such as temperature and rainfall remain constant. As such, it is recommended that agricultural measures or practices to regulate carbon emission and sustain the beneficial effect should be undertaken in NGS. In addition, the development of high temperature tolerant varieties and varieties with greater carbon use efficiency such as the C4 photosynthetic rice varieties is encouraged. All other climate factors lack the statistical evidence to show any significant effect on rice productivity in NGS AEZ.

It is further recommended that irrigation capacities of this AEZ be properly developed, as the current capacity shows an unexpected negative effect. This signifies that most irrigation scheme functions below capacity as a result of the dilapidated state and weak maintenance. The rice productivity improvement effort can further be supported by discouraging the prevalence of corruption practice inherent the transactions between government and rice farmers. This can be achieved through the strengthening of institutions and deployment of ICT in the operations between farmers and government. Through this approach physical contact is reduced and corruption can be decreased since electronic transactions are easier to be tracked or traced. Other policy factors (trade policies and government stability) were insignificant based on the statistical evidence.

6.5.2.4 Policy Recommendations for Kano (Sudan Savana AEZ)

In the Sudan Savana (SS) AEZ as represented by Kano state, the findings base on the rice productivity model indicates that; among the factors in the model, three climate factors (carbon, temperature, and flood intensity), all three policy factors (trade policies, government instability and corruption) and one adaptation technology factor (NASPA) were found as significant in influencing rice productivity. All other factors were insignificant.

According to the coefficients of the carbon emission, the lag difference of carbon was found to be positive implying that carbon was beneficial to rice productivity in the short run in areas of SS AEZ. Similarly, the current value of carbon emission showed to be significant but negative. This mix result could be accounted for by the interaction effect of carbon and other factors like temperature. Thus, carbon is considered to have overall beneficial effect if other factors such as temperature and rainfall remain constant. It is therefore recommended that agricultural measures or practices to regulate carbon emission and sustain the beneficial effect should be undertaken in SS. In addition, temperature was found to have a significant and negative effect, hence the study recommends the development of high temperature tolerant varieties along with varieties having better carbon use efficiency such as the C4 photosynthetic plant. In SS AEZ, flood was found to be of positive and significant effect, therefore, to further sustain the positive effect, construction of dams, alongside the design and adoption of water harvesting technologies that are suitable to this AEZ is highly recommended.

The rice productivity improvement effort can further be supported by discouraging the prevalence of corruption practice inherent in the transactions between government and rice farmers. This can be achieved through the strengthening of institutions and deployment of ICT in the operations between farmers and government. Through this approach physical contact is reduced and corruption can be decreased since electronic transactions are easier to be tracked or traced. To improve rice productivity, it is also recommended that policy stability should be a priority. At the same time, higher import tariff rates have not been totally effective in raising the rice productivity. As an evident by the negative and significant effect of higher tariffs, therefore, lower tariff policy is considered a better instrument for developing domestic rice productivity in the short run in the SS AEZ.

6.5.2.5 Policy Recommendations for Borno (Sahel Savanna AEZ)

In the Sudan Savana (SUS) AEZ as represented by Borno state, the findings base on the rice productivity model of this study indicates that; among the factors in the model, all four climate factors (carbon, temperature, rain and flood intensity), two policy factors (trade policies and government instability) and no adaptation technology factor (NASPA) were found as significant in influencing rice productivity.

According to the coefficients of the carbon emission, the lag difference of carbon was found to be positive implying that carbon was beneficial to rice productivity in the short run in areas of SUS AEZ. Similarly, the current value of carbon emission showed to be significant but negative. This mix result could be accounted for by the interaction effect of carbon and other factors like temperature. Thus, carbon is considered to have overall beneficial effect if other factors such as temperature and rainfall remain constant. It is therefore recommended that agricultural measures or practices to regulate carbon emission and sustain the beneficial effect should be undertaken in SUS. In addition, temperature was found to have a significant and negative effect, hence the study recommends the development of high temperature tolerant varieties along with varieties having better carbon use efficiency such as the C4 photosynthetic plant. In SUS AEZ, flood was found to be of negative and significant effect, therefore measures to control the negative effect of flood such as construction of dams, alongside the design and adoption of water harvesting technologies that are suitable to this AEZ is highly recommended.

Although corruption was found to be beneficial to rice productivity, the practice of corruption is still undesired as it has the capacity to increase the production cost. Thus, it is recommended that the prevalence of corruption practice inherent in the transactions between government and rice farmers should be minimised. This can be achieved through the strengthening of institutions and deployment of ICT in the operations between farmers and government. Through this approach physical contact is reduced and corruption can be decreased since electronic transactions are easier to be tracked or traced. To improve rice productivity, it is also recommended that policy stability should be a priority. At the same time, higher import tariffs rates have not been totally effective in raising the rice productivity. As a consequence of the negative and significant effect of tariffs, lower tariff policy is considered a better instrument to enhance productivity and competitiveness of domestic rice. All the adaptation technology factors were statistically insignificant to influence rice productivity.

6.5.2.6 Policy Recommendations for Ebonyi (Humid Forest AEZ)

In the Humid Forest (HF) AEZ as represented by Ebonyi state, the findings from the rice productivity model indicates that; all four climate factors (carbon, temperature, rain and flood intensity), two policy factors (trade policies, and corruption) and the two adaptation technology factors (irrigation capacity and NASPA) were found as significant in influencing rice productivity.

According to the coefficients of the carbon emission, the lag difference of carbon was found to be negative implying that carbon was harmful to rice productivity in the short run in the HF AEZ. Similarly, the current value of carbon emission showed to be significant but negative. Thus, carbon is considered to have overall harmful effect on rice productivity in the HF AEZ if other factors such as temperature and rainfall remain constant. It is therefore recommended that agricultural measures or practices to regulate carbon emission and mitigate the negative effect of higher carbon emission should be undertaken in HF. In addition, temperature was found to have a significant and negative effect, hence the study recommends the development of high temperature tolerant varieties along with varieties having better carbon use efficiency such as the C4 photosynthetic plant. In HF AEZ, flood was found to be of positive effect and strongly significant therefore, to further sustain the positive effect, it is recommended to construct drainage canals, dams, alongside the design and adoption of water harvesting technologies that are suitable to this HF AEZ.

Although corruption was found to be beneficial to rice productivity, the practice of corruption is still undesired as it has the capacity to increase the production cost. Thus, it is recommended that the prevalence of corruption practice inherent in the transactions between government and rice farmers should be minimised. This can be achieved through the strengthening of institutions and deployment of ICT in the operations between farmers and government. Through this approach physical contact is reduced and corruption can be decreased since electronic transactions are easier to be tracked or traced. At the same time, higher import tariffs rates have not been totally effective in raising the rice productivity. As a consequence of the positive and significant effect of higher tariffs, trade policies should focus on discouraging import through high import. This will in addition to discouraging import result to investment in innovative technologies that can support the domestic rice productivity for the HF AEZ in the short run.

6.5.3 Policy Recommendation on Interaction Effect

The fertilizer subsidy policies are designed to support farmers accessing enough inputs to improve productivity. The subsidy process is dominantly considered to encourage corruption, where bribe paying farmers can acquire more fertilizers and thus operate at higher efficiency compared to other farmers with no capacity to offer bribe. Thus, most farmers are restricted from retrieving adequate inputs. As suggested by the short run result, prior to becoming a systemic practice, at low corruption level, this study found a positive effect of fertilizer since a greater number of farmers access fertilizer during low corruption level. As corruption grow stronger, either a smaller number of eligible farmers are able to assess the fertilizer, or the quality of fertilizer are substandard, hence the negative effect in the long run. In the long run period, the findings suggest that corruption has become a systemic problem practiced by all categories of farmers. This potentially enables assess to more inputs, although these inputs come at a higher cost and could also be substandard thus the negative effect on productivity or further decline in net income among majority of small-scale farmers.

Considering the long run negative effect and the significant role of corruption on the effectiveness of this vital production input, there is need to deter corruption in the system. Thus, this particular recommendation is focused on ameliorating the deficiencies in the system that triggers corruption. Generally, as a result of corruption, the fertilizers supplied might be substandard. Also, subsidy funds are usually diverted by corrupt officials, the middlemen and politicians. Therefore, in order to ensure effectiveness of the fertilizer use, the government must develop institutions to control corruption through strong monitoring and accountability.

Particularly, there is need to consider that it is difficult for small-scale farmers to compete with larger farms due to lower access to government input supports compared to bigger farmers with capacity to offer bribe and influence policies of government thus small farmers who are the majority produces at relatively lower productivity and higher marginal costs. This study suggests more policy efforts at enforcing rule of law and accountability while reducing corruption through judicial reforms, political and economic reforms. An emphasis is laid on the need to exploit the advancement in information technology towards enhancing transparency, awareness, accountability, adoption of preventive mechanisms such as system automation to reduce human interference can do a great deal in minimising high level of corruption. Introduce farmers database. Also, the digitalization of farmers census and registration is recommended. This approach has successfully controlled leakages in agricultural sector of countries like The Philippines.

Corruption is a generally considered an immoral practice, wrong and economically harmful behaviour. It characterises inadequate systems with economic, political insecurity and weak rule of law. However, no economy is corruption-free but its preponderance in transitional economies such as Nigeria is high. Specifically, the low-income level and poverty among farmers makes them highly vulnerable to this challenge. Again, the debate on the effects of corruption on performance of various economic sectors remains polarised. While some studies have claimed that corruption stifles economic growth and development, others have contended that under certain situations corruption could be economically desirable as it provides a channel to overcome series of inefficient regulations and bureaucratic challenges.

6.6 Contributions of the Study

The goal of food sovereignty or achievement of sufficient food supply and at the same time, curtailing the environmental damages as a consequence of climate change and several agricultural practices is a major concern for most food deficit nations. Improving productivity of food crops have been considered a sustainable practice and an environmentally option compared to land expansion. In view of the challenges or threats to productivity improvement current study endeavoured to assess the determinants of productivity using a model that encompass factors posing imminent threat to the sector including climate change, policies and adaptation technologies. A detailed analysis of the productivity model revealed significant factors that impacts rice productivity in Nigeria. Thus, offering a number of contributions in form theory, methodology and practice as follows:

6.6.1 Practical Contributions of the Study

Nigeria has the potential to increase its domestic productivity and consequently its share of the rice market globally. This will practically contribute to the goal of economic diversification, meeting domestic consumption, enhancing food security and contribution to GDP. Thus, this study endeavoured to make practical contribution through establishment of the most relevant challenges to the rice productivity growth in Nigeria. The findings serve as a policy guide to stakeholders like government and most importantly rice producers. Government and relevant ministries working towards the growth of the agricultural sector particularly rice productivity can rely on the lessons from this study to design or determine future direction of effort. It is evident that different factors (climate, policies and adaptation technology factors) in the rice productivity model are highly significant in determining rice productivity in Nigeria. Furthermore, it especially noteworthy to consider the differences in the impacts of the relevant factors across the different AEZs in Nigeria.

Climate is the predominant threat impacting the agricultural sector in general. In order to build resilience to climate change and improve rice productivity, government and relevant ministries or agencies could design adaptation technologies that prioritises the significant climate factor for each particular AEZ, rather than developing the same adaptation technologies to use across the entire AEZs. Several training could also be organised through extension programs. This is to enlighten farmers on the critical factors influencing their rice productivity and the peculiar adaptation strategies or adaptation technology that is suitable to individual AEZs. In addition, government is encouraged to develop evidence-based policies through enhancing R&D on the key technologies to enhance adaptation base on local context rather than the current top-down approach to designing adaptation technologies. Government policies should also be friendly enough to attract and facilitate investment in domestic rice productivity consequently resulting in sectoral growth and achievement of import substitution. For example, in cases with evidence of positive effect of tariffs, this should be encouraged and the revenue diverted to productivity boasting investments.

6.6.2 Methodological Contributions of the Study

The study also make effort towards some methodological contributions in its endeavour to analyse rice productivity growth and determinants in Nigeria. One of the methodological contributions of this study is the assessment of the role of government stability and corruption on the rice productivity sector in Nigeria especially considering that these factors are mostly focused on other economic sectors, while it is widely acknowledged that there is existing challenge of the inconsistencies in government policies (political instability) as well as massive corruption in the agricultural sector in general and rice sub sector in Nigeria.

Also, the methodological improvement over the extant studies is observed by the application of dynamic methodological approach to analyse rice productivity growth and determinants in Nigeria. The dominant methodologies of extant literature in the agricultural sector of most developing countries particularly in Nigeria include, the crop simulation models, traditional field experimentation and other cross-sectional techniques like the Ricardian model. These methods normally disregard the variability of factors across space and time, and hence is less robust compared to panel data approach. Thus, the recommendations and policy decisions to improve productivity of the rice sector arising based on the earlier methodologies are limited to the specific site of the experiment or the particular cross section covered. Against the background of the limitation of these econometric methods used in extant studies, the current study involves a panel data approach specifically the Panel ARDL (PARDL) technique including the MG, DFE and PMG. Additionally, several tests such as Hausman cointegration tests for long run and short effects in addition to comparing the alternative ARDL techniques (MG and DFE) were deployed in the current study to estimates the specified models.

Also, regional or sub national differences exists regarding the climate type, socio economics and adaptive capacity hence variation in the degree of vulnerability across space. Against most existing studies, this points to the need to examine impact by focusing data collection at the sub regional level. Similarly, studies on rice productivity growth and determinants in Nigeria have mostly focused on the entire agricultural sector, this could lead to biased estimation as crops reacts differently to climate change. However, this study adopted a unique pattern from that of previous studies by collecting data at the level of AEZs and using the data to examine impact on specific and important crop (rice), hence avoiding the bias of generalising the whole farm sector or aggregated impact. That is, in terms of the nature of data, this study employs data at the level of AEZs rather than the usual national averages used by most existing studies. While findings have also affirmed the wide difference in the impact at the AEZs level at least in the short run period.

While, extant studies are again limited in the number of factors examined, the model for the current study covers several new factors in the rice productivity model in Nigeria such as the adaptation capacities, trade policies, corruption, government stability and the AEZs in addition to several climate factors. Thus, the study has contributed to the methodology sphere by closing the knowledge gap as regards these variables by factoring in and jointly assessing the impact of these important determinants of rice productivity in Nigeria.

6.6.3 Theoretical Contributions of the Study

Among the novel contributions of the current study is in the theoretical sphere whereby, the study first attempted the integration of the production theory, AGW and EKC theories to form the theoretical basis for the current study. Although, other existing studies mostly employed the theory to examine the conventional inputs and socio-economic factors. Present study contributed to production theory by including other factors in addition to the conventional inputs in the production theory (seed, capital, labour, and technology). These factors include non-conventional inputs such as environmental factors (Carbon, flood, temperature and rainfall), institutional factors (corruption and government instability) as exogenous factors in the model. Furthermore, the current study also extends the theoretical literature by examining the relative effect of the spatial differences among regions using the AEZs which shows the demarcation of areas base on climate, soil and vegetation type.

Although existing studies (Lim & McAleer, 2001; Cobb & Douglas, 1928; Kumar, 2014) have examined the conventional inputs using the production theory. However, based on evidence from reviewed literature, no attention was given by extant studies to assess the productivity of the farm sector by specifically combining other critical factors as determinants in a model. Thus, dearth exists regarding the extension of this theory to include policies, climate and institutional factors. However, establishing a valid relationship between the production theory, inputs alongside the climate and institutional factors have several policy relevance especially in considering the imminent threats on the food sector of most developing countries.

Furthermore, using the different variables (rainfall, flood, temperature, carbon and rice productivity), the study relates that the argument of AGW on the nexus between relative contribution of the agriculture sector to climate change and in turn the negative consequence on the productivity of the agricultural sector were tested using the climatic variables and productivity measure. Though, so many empirical tests of this theory were conducted by previous studies in different domains such as environmental and health (Dinda, 2004; Usenata, 2018). Additionally, as a support the argument of the EKC theory on the income and environmental pollution have mostly been focused on specific population, other sectors of the economy or different economies of the world. While the little attention was given the agriculture sector regarding the EKC hypothesis, despite the link between farm practices (land expansion, chemical usage, energy use and technology adoption) and environmental degradation.

6.6.4 Contributions to the Current State of Knowledge

The current study researched on the implications of the differences in AEZs on the impact of climate change, adaptation technologies and policies on rice productivity. The current state of knowledge in the domain of agricultural productivity and climate impact indicates several diversities at regional, national and even sub national levels. The most abundant literature has ignored vital factors across studies. Thus, this study contributes significantly to the less explored realm in sub national research by considering diversity across AEZs, introduction of corruption and stability of government as critical determinant of rice productivity growth. The author also argues on the interaction effects of corruption on the effectiveness of vital inputs such as fertilizers and the stability of government policies.

6.7 Recommendation for Future Study

Although this study made effort towards contributing to existing state of knowledge especially pertaining climate change, rice productivity, the study suffers some limitations. Thus base on the limitations, recommendations are made for the consideration in future studies: Firstly, as a consequence of the scarcity of data and its disaggregated nature in Nigeria, the current study only covered the major or key rice producing states across the different AEZs of the country, thus future studies can expand the current scope to cover more states. Secondly, another limitation of the study is that owing to the data limitation and the secondary data, the proxies for some factors such as irrigation capacities only measured availability and not actual use. Thus, it is recommended that data on actual use reflects the situation of this variable and can better measure the impact. Also, some relevant variables such as drought intensity and subsidies were dropped as a result of data limitation in the regions, future effort can be directed towards acquisition and inclusion of these variables in the rice productivity model.

Furthermore, although the ARDL PMG is consistent, it is possible to show less reliability among small time-series alongside larger number of explanatory variables. This is due to the need to constrain the maximum lag number in specified ARDL model.

Consequently, the dynamic characteristics of the modelled variables might not be entirely discerned (Bussière et al., 2010). This study was also challenged by the large number of variables thus, the limitation of the lag length to only one.

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Appendix A

Summary of Relevant Literature

The tables below present the summary of literature on the studies of the impact of climate change on agriculture, grouped base on the methodologies used:

Table A1

Summary Literature Review (Crop Simulation Approach)

S/N	Author	Period/Country	Dependent Variables	Independent Variables	Results
1	Aggarwal et. al. -2010	11 districts of the Upper Ganga Basin, India 1969-1990	Growth and yield of rice and wheat crops	Solar radiation, temperatures, rainfall, wind speed and vapour pressure.	In the simulation analysis using infoCropWheat and InfoCrop-Rice models found that rice and wheat crops will be affected by climate change.
2	Basak, Ali, Islam, Rashid (2010)	Bangladesh	Crop yields.	Weather variables (rainfall, daily minimum and maximum temperatures)	DSSAT model and PRECIS: With modeled climate change: 20% and 50% reduction in yield of Boro (BR3 and BR14) rice by 2050 and 2070 respectively. Increases in daily minimum and maximum temperatures are mainly responsible.
3	Reilly, et al., (2007)	Global	crop productivity	climate variables, CO_2 and ozone via	Using the MIT IGSM, TEM and EPPA updated models: Effects of climate and CO_2 are generally positive. Ozone damage could offset these benefits. Intra- and

					inter-country resource allocation can strongly affect the estimated economic effect on agriculture.
4	Southworth et al. (2000)	Mid-western Great Lakes Region 1987-1990	Maize yields	Temperatures, rainfall	CERES maize model was created for the period 2050-2059. It was found that high temperatures during the tasseling of maize lead to significant decreases in productivity.
5	van Oort and Zwart (2017	Africa	Rice production	RCP climate change scenarios, Adaptation,	ORYZA2000, to simulate rice yield reported that; for irrigated rice yields: In East Africa, will rise (+25%) resulting from favorable temperatures and CO_2 fertilization. For West Africa, under wet season irrigated rice the yields were projected to change by -21% or +7% (without/with adaptation). In the dry season yields would decrease by -45% and -15% with adaptation (without/with adaptation).

Table A 2

Summary Literature Review (Ricardian/Cross Sectional Approach)

1	Mishra and Sahu -2014	Odisha (for all the nine coastal districts) 1979-2009	Farm-level net revenue.	Rainfall, Temperature	July rainfall was useful for the farm activity in Odisha. Also increase in temperature for all seasons had adverse effects on the agricultural sector of coastal Odisha.
2	Benhin (2008)	South Africa	Crop revenue.	Temperature, precipitation	1 percent temperature increase will increase net crop revenue by US$ 80.00. 1 mm/month fall in precipitation leads to US$ 2.00 fall in crop revenue. Significant spatial differences exist in the impacts of climate change. Revenue is expected to fall by 90% by 2100.
3	Deressa and Hassan (2009)	Ethiopia 2050 and 2100	Net crop revenue	Rainfall and temperature, household, and soil variables	Temperature and precipitation affected slightly net crop income. In addition, it has also been observed that small changes in temperature during the summer and winter period negatively affect net crop revenue.
4	Kabubo-Mariara and Karanja (2006)	Kenya 1988-2003	Net crop revenue	Rainfall and temperature	Global warming has an important influence on net crop revenue in Kenya. However, the result is that temperature is much more important than rainfall.

5	Gbetibouo and Hassan (2005)	South Africa (300 districts) 1970-2000	Net revenue per hectare	Rainfall, temperature, soil types, labor, population, irrigated land and geographical coordinates	Production of field crops is sensitive to marginal changes in temperature compared to variations in rainfall. The increase in temperature affects the net income positively, while the effect of the decrease in rainfall is negative.
6	Schlenker, Hanemann, and Fisher (2005; 2006; 2007)	US non-urban counties.	Crop land revenue	Irrigation value, temperature and rainfall	Under all models, agriculture is predicted to suffer from the benchmark climate change scenario associated with a doubling of greenhouse gas concentrations. The estimated loss in annual profit comes to about $5 to $5.3 billion
7	Kurukulasuriya and Ajwad (2007)	Sri Lanka (2007)	Farm net revenue	Temperature, precipitation and non climate variables	Non-climate variables accounts for almost half variation in net revenues. reductions in precipitation leads to a change in net revenues between −23% and+22%.
8	Liu, Xiubinli, Fischer and Sun (2004)	China counties	Agricultural net revenue	temperature and precipitation	impacts vary seasonally and regionally, projection of the 5 climate scenarios by year 2050 showed that East, Central part, South, northern part of Northeast, and Plateau would benefit from climate change, but the Southwest, the Northwest and the southern part of the

					Northeast may be negatively affected.
9	Seo et al., 2005	Sri Lanka	Net revenue per hectare (rice, coconut, rubber and tea)	temperature and precipitation	Rainfall increases are predicted to be beneficial in all five AOGCM scenarios, but temperature increases are predicted to be harmful. Impacts vary from −20% to +72 % (loss of 11 billion to gain of 39 billion rupees) depending on the climate scenarios.
10	Kumar and Parikh (2007)	India	farm-level net-revenue	annual temperature and crop prices	Loss of farm revenue ranging from 9 to 25%. With further temperature increase of 2^0C to 3.5^0C the loss is projected to range between 30 – 35% equivalent of USD 3 to 4 billion
11	Deressa *et al* -2005	South Africa (11 regions) 1977-1998	Sugar cane production	Rainfall, temperature height and latitude	Sugar cane production is highly sensitive to climate change.
12	Maddisson (2000)	England and Wales	Farm land value	Elevation, frost days, wind speed, temperature, humidity.	Frost days, wind speed, temperature, humidity all have positive and significant impact on farm value. While elevation have an negative and significant effect on farm value.
13	Polsky (2004)	US Great plains (1969–1992)	Farm land values	Monthly mean precipitation and number of growing days	Climate change impact varies significantly with the scale, location, and time of analysis. Under a hypothetical climate change, at the county scale,

					land values would decline (by up to one third in the western counties, but increases by up to one-half in the eastern counties.
14	Reinborough (2003)	Canada	Farm revenue	Temperature and rainfall	There is a marginal benefit from climate change ranging between USD 897, 000 to USD 1.48 million
15	Mendelsohn and Dinar (2003)	USA 1997	Farmland value	Rainfall and temperature	The paper shows that the value of irrigated cropland is not sensitive to precipitation and increases in value with temperature.
16	Mendelsohn *et al*, 1994; 1996; 1999	USA	Land value per acre; Aggregate value per acre; land value per acre respectively	1994 and 1996: (Mean temperature, precipitation), 1999: (inter annual precipitation and Temperature, diurnal temperature)	For 1994; result indicated a loss of USD 5.8 billion or gain of USD 36.6 billion. For 1996: in addition to the above impact, it will also affect the possibility of cultivating a land. While the case of 1999, revealed that the effect of inter annual variation in precipitation was found to be less significant compared to temperature.

Appendix B

Diagnostics Tests

1.0 Multicollinearity Test

Examining the correlation matrix among the variables in the model, result reveals non-existence of high correlation between variables (see Table 5.8); therefore this model is not prone to the problem of multicollinearity. Moreover, a further test for VIF was performed and confirmed the non-existence of this problem (see Table 5.9). To solve this problem, we dropped the affected variables from the model which are subsidy and mechanisation. This treatment reduced the multicollinearity issue in the model as illustrated in the correlation matrix in Table 5.8. Consequently, the correlation matrix of all the variables as shown in Table 5.8. In addition, the VIF test proved the non-existence of high collinearity between the variables in the model (see Table 5.9).

Table B 1

Variance Inflation Factor (VIF) Result

Variable	VIF	1/VIF
Carbon	8.51	0.118
NASPA	3.33	0.300
Irrigation Cap	3.07	0.325
Temperature	2.84	0.352
Gov. Stability	2.71	0.369
Trade Policy	2.66	0.376
Corruption	2.63	0.380
Rainfall	2.6	0.384
Fertilizer	2.02	0.496
Labour	1.58	0.633
Mechanisation	1.33	0.750
Land area	1.29	0.773
Flood intensity	1.08	0.922

Mean VIF	2.74