ECONOMIC IMPACT OF CLIMATE CHANGE ON SMALLHOLDER CROP FARMS IN NIGERIA

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DEDICATION

I dedicate this thesis to God Almighty, the Beginning and the End.

ABSTRACT

The negative effect of Climate Change (CC) on agriculture across Africa has been well established. This underscores its global policy interest. In Nigeria, crop farming is climate dependent and farmholders often employ measures that are sub-optimal against climate risk. This raises the vulnerability of farming to CC uncertainty. For a long time, knowledge of CC perception by farmholders dominated the existing literature. However, information on economic estimates of damages and responses at the farm level is relatively scanty. Economic impact of CC on smallholder crop farms was therefore investigated.

General household survey data on smallholder farms collected by the National Bureau of Statistics (NBS) in 2010 was used together with baseline climate observations from 1950-2000 and projections (2000-2050) of the World Climate Data Base (WCDB). Complementary data on population, soil and altitude for 774 Local Government Areas (LGA) were sourced from National Population Commission (NPC) and Food and Agriculture Organisation (FAO). Variables from NBS were farm value, farm revenue, crops cultivated, land size, area planted, household size and age. Variables from WCDB were Mean Temperature (MT) and Mean Precipitation (MP) for wet and dry seasons. Data was analysed using descriptive statistics, multivariate probit and Ricardian models at $\propto_{0.05}$

Farm value and annual farm revenue were 156293.3 (10714.3-1619433.0) ₦/ha and 47837.1 (3966.2-2159244.3) ₦/ha respectively. Land size was 2.7±1.9 ha while area planted, household size and age were 2.3±18.2 ha, 5.2±1.6 and 51.3±15.3 years respectively. Baseline MT and MP were 26.3±2.9 ℃and 179.2±75.1 mm/month respectively for wet season and 25.9±3.0 ℃ and 22.3±24.7 mm/month for the dry season. Projected MT and MP were 27.61±3.0 ℃ and 192.3±61.6 mm/month for wet season and 27.5±3.0 ℃ and 25.6±29.3 mm/month for dry season respectively. Baseline MP increased the probability of cultivating sorghum (0.5%), cowpea (0.2%), and yam (0.1%) while it reduced the probability of cultivating millet (0.8%), rice (0.1%), cassava (0.1%) and maize (0.5%). Baseline MT increased the probability of cultivating millet (5.8%), rice (2.4%) and maize (51.5%) and reduced the probability of cultivating sorghum (0.7%), cowpea (2.1%), cassava (0.7%) and yam (36.7%). Projected MT reduced the probability of cultivating all crops with the highest probability on sorghum (10.5%). While the effect of projected MP on the probability of cultivation was mixed across crops, the highest probability of reduced cultivation was observed for rice (25.9%) and the least for maize (1.8%). Controlling for non-climate factors, climate change reduced farm value by 62.8% for the whole country and across agricultural zones by 8.2%, 41.9%, 7.2% and 41.0% for North central, North east, North west, and South west respectively except for South east that increased marginally by 3.4%.

Climate change affected revenue and crop cultivation of smallholders and could affect food security in the near future. Impact was huge for the whole country and varies across agricultural zones. Use of stress tolerant technologies (irrigation, and drought tolerant seeds) and institutional support would enhance coping capacity against climate change risk.

Keywords: Climate change, smallholder, economic impact, baseline mean temperature
Word Count: 483

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CERTIFICATION

I certify that this research was carried out by Mr. John ChiwuzulumOdozi in the Department of Agricultural Economics, University of Ibadan, Ibadan, Nigeria.

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TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMNS

AAP	African Adaptation Programme
ACCRA	Africa Climate Change Resilience Alliance
ADPs	Agricultural development programme
AMCEN	African Ministerial Conference on the Environment
ARDA	African Radio Drama Association Nigeria;
ATBU	AbubakarTafawaBalewa University Bauchi State
BHC	The British High Commission,
BNRCC	Building Nigeria's Response to Climate Change
C4C	Coalitions for Change
CA	Christian Aid,
CAHOSCC	The Committee of African Heads of State on Climate Change
CARUDEP	Catholic Archdiocesan Rural and Urban Development
CBA	Cost benefit analysis
CBOs	Community-based Organisations
CCFWR	Centre for Climate Change and Fresh Water Resources, Federal University of Technology, Minna;
CCN	Climate Change Network Nigeria,
CELDEV	Centre for Education and Leadership Development
CERD	Centre for Energy, Research and Development, ObafemiAwolowo University Ile-Ife.
COLIN	Coastal live in Nigeria, cross river state
DNA	Designated National Authority for the Clean Development Mechanism
EC	Energy Commission,
ECOWAS	the Economic Community of West African States
FD	Fertilizer department
FEPA	Federal Environmental Protection Agency
FEWSNET	Famine Early Warning System Network
FMAWR	Federal Ministry of Agriculture and Water Resources,
FMEnv	Federal Ministry of Environment

FMFA	Federal Ministry of Foreign Affairs,
FNC	First National Communication
GCM	General Circulation models
GHS	General Household Survey
GMP	guaranteed Minimum Price
ICCC	Inter-Ministerial Committee on Climate Change
IPCC	Inter-governmental panel on climate change
NAERLS	National Agricultural Extension Research and Liaison services
NAIS	Nigerian Agricultural Insurance Scheme
NAMA	Nationally Appropriate Mitigation Action
NAP	New Agricultural Policy Thrust
NASPA-CCN	National Adaptation Strategy and Plan of Action on Climate Change for Nigeria
NBS	National Bureau of Statistics
NCF	Nigeria Conservation Foundation
NEST	the Nigerian Environmental Study Action Team
NFRA	National Food Reserve Agency
NFSP	National Food Security Programme
NigeriaCAN	Nigeria Climate Action Network
NigMUNS	Nigeria Model United Nations Society
NIMET	Nigerian Meteorological Agency,
NIOMR	The Nigerian Institute for Oceanography and Marine Research
NNPC	Nigeria National Petroleum Corporation,
NPC	National Planning Commission
PCU	Project coordinating Unit
SCCU	Special Climate Change Unit of the Federal Ministry of Environment
SGR	Strategic Grains Reserve
SRES	Special Report on emission scenarios
UNDP	United National Development programme
UNFCCC	United Nations Framework Convention on Climate Change
UNICEF	United Nations International Children's Emergency Fund

UNIDO	United Nations industrial development organization
UNIMAID	University of Maiduguri
WEP	Women Environment Programme
WFP	World Food Program,
WMO	World meteorological organisation
WOFAN	Women Farmers Advancement Network, Kano Nigeria
YOCC	Youth Organization for Climate Change,

CHAPTER ONE
INTRODUCTION

1.1.Background to the Study

1.1.1. Nature of Crop Farming in Nigeria

Crop farming is the most practiced agricultural activity and accounts for 90% of total growth in the agricultural sector (NBS, 2010). Except for livestock which is mostly on free range, land is often allocated to one or more crops as a strategy for food self-sufficiency and security at the household level. There are more than seventeen million (17,010,754) small crop farm holders in Nigeria.Large corporate crop farmers exist, but are few and made up of private limited company, cooperative and governmentfarms (NBS/CBN, CCC, 2012). Smallholder crop farm as the name implies is a production system operated at a small scale of less than 2 hectares and of rain fed technology. Ownership consists of an individual member of the household, two or more members of the same household and members of different households.

Table 1.1.**Cropping pattern across agricultural zonesin Nigeria**

Crop mixtures	AGRICULTURAL ZONES				
	North West(NW)	North East(NE)	North Central(NC)	South West(SW)	South East(SE)
Yam/ Cassava/Maize			X	X	X
Cassava/Yam/Maize/Vegetable					X
Cocoyam/Cassava/Maize/Vegetable					X
Cassava/ Maize			X	X	X
Cassava/Sorghum			X		
Cassava/Vegetable/Melon					X
Yam/ Cassava			X	X	X
Yam/Okro				X	X
Cassava/Cocoyam/Maize					X
Cassava/Cocoyam/Maize					X
Cassava/Maize/Sweet potatoes			X		X
Cassava/ Pepper/Maize					X
Yam/Maize/Pepper					
Cassava/Sweet Potatoes/G. Nut			X		X
Cassava/Maize/Cowpea				X	X
Cassava/Cocoyam				X	X
Yam/Vegetable/ Cocoyam					X
Cassava/Potatoes/Cowpea				X	X
Yam/Maize			X		
Yam/Cassava			X		
Maize/Sorghum	X				
Millet/Sorghum		X			
Maize/Millet/Sorghum	X	X	X		
Millet/Sorghum/Cowpea	X	X	X		
Millet/Cowpea	X	X	X		
Maize/Sorghum/Cowpea	X	X	X		
Maize/Groundnut	X	X	X		
Millet/Sorghum/Beniseed	X	X			
Sorghum/Millet/Groundnut	X	X	X		
Millet/Sorghum/Cowpea	X	X	X		
Rice/Maize	X	X			
Rice/Sorghum	X	X			
Maize/Cotton	X	X			
Maize/Soyabean	X		X		
Maize/Cotton/Cowpea	X	X			
Maize/Groundnut	X	X	X		
Maize/Melon			X		
Sorghum/Maize/Yam	X		X		

Source: NFRA/NAERLS, 2009

Table 1.1 presents the cropping pattern across agricultural zones in Nigeria. The pattern in most cases is mixed consisting of cereal/legume systems in the northern part and mixed root/cereal cropping systems in southern Nigeria. Crops most often cultivated are yam, cassava, sorghum, millet, rice, maize, cowpeas, groundnuts, cocoyam, melon and cotton. Others are plantain, banana, sweet potatoes, vegetables, fruits and pulses. Tree crops are also cultivated and include cocoa, rubber, oil palm, gum Arabic, cashew, mango, citrus, palm, rubber, coffee, tea, cashew and cocoa(NFRA/NAERLS, 2009).

Table 1.2 presents the distribution of land areacultivated in hectares for selected food crops in Nigeria across years.The percentage distribution is presented in Table 1.3. From Table 1.2, over 1995 – 1998 to 2007 – 2010, area of land cultivated increased from 25,954,000 to 29,846, 000 hectares. The table also suggests that 20.67% of cropped land was devoted to millet production during the period 1995 -1998, but declined to 13.13% over the period 2007 – 2010. Sorghum declined slightly from 19.99% in the second half of the 1990s to 17.35% over the period 2007 – 2010. Maize crop shows an increasing trend from 11.80% during the 1995 -1999 period to 16.77% over the period 2007 – 2010. Cassava, yam and cocoyam have remained consistent in terms of acreage cultivated over the 15 years period with only slight increases for cassava. From Table 1.3, land area under cotton, maize and cassava in the period 2007-2010 almost doubled relative to the period 1995- 1998. Reflecting expansion in land area cultivated for most of the crops, mostly for rice, maize, cassava and cotton.

Table 1.2.**Land area cultivatedin hectares for selected crops from 1995-2010 in Nigeria**

CROPS	1995 – 1998 Ha '000	1999- 2002 Ha '000	2003 – 2006 Ha '000	2007 – 2010 Ha '000
MILLET	5365.35	3673.91	3847.535	3917.433
SORGHUM	5188.255	4301.143	4018.905	5178.883
GROUND NUT	2281.655	2023.988	2185.273	2308.703
COW PEA	3023.238	2456.02	2206.508	3122.72
YAM	2165.168	2102.828	2086.13	2981.53
COTTON	309.05	303.29	265.17	591.0767
MAIZE	3063.573	3126.66	3291.478	5005.81
CASSAVA	2299.605	2415.203	2587.965	3706.383
RICE	1482.918	1552.535	1443.038	1986.523
MELON	489.4375	410.0975	510.615	612.85
COCOYAM	286.195	266.9275	304.73	434.7067
Area planted	**25954.44**	**22632.6**	**22747.35**	**29846.62**

Source: NFRA/NAERLS, 2009

Table1.3.Landarea cultivated index for selected crops from 1995 – 2010 in Nigeria

Crops	1995-1998 Base (%)	1999-2002 Index %	2003-2006 Index%	2007-2010 Index%
MILLET	100	68.47	71.71	73.01
SORGHUM	100	82.90	77.46	99.82
GROUND NUT	100	88.71	95.78	101.19
COW PEA	100	81.24	72.98	103.29
YAM	100	97.12	96.35	137.70
COTTON	100	98.14	85.80	191.26
MAIZE	100	102.06	107.44	163.40
CASSAVA	100	105.03	112.54	161.17
RICE	100	104.69	97.31	133.96
MELON	100	83.79	104.33	125.22
COCOYAM	100	93.27	106.48	151.89
CEREALS	100	83.80	83.45	106.55
ROOTS/TUBERS	100	100.71	104.80	149.92
LEGUMES	100	84.45	82.79	102.39
MELON/COTTON	100	89.34	97.16	150.78
AVERAGE	100	87.20	87.64	115.00

Source: NFRA/NAERLS, 2009

Table 1.4. Production output of selected crops from 1995- 2010 in Nigeria

CROPS	1995 – 1998 Tonnes '000	1999- 2002 Tonnes '000	2003 – 2006 Tonnes '000	2007 – 2010 Tonnes '000
MILLET	5322.238	4324.943	4244.698	2822.603
SORGHUM	5768.303	5240.038	4830.065	6331.447
GROUND NUT	2761.705	2409.858	2546.77	2853.33
COW PEA	1927.678	1612.388	1522.26	1565.22
YAM	24420.27	25616.02	24978.71	35839.26
COTTON	422.205	406.93	395.11	371.7033
MAIZE	4798.54	5481.338	5527.09	8558.75
CASSAVA	26578.27	29016.35	32172.59	49085.93
RICE	2694.638	3089.288	3020.395	3850.277
MELON	266.8175	260.695	339.2425	347.4833
COCOYAM	1703.198	1702.033	2008.783	3289.81
PRODUCTION INDEX IN %				
MILLET	100	81.26	79.75	53.03
SORGHUM	100	90.84	83.73	109.76
GROUND NUT	100	87.26	92.22	103.32
COW PEA	100	83.64	78.97	81.20
YAM	100	104.90	102.29	146.76
COTTON	100	96.38	93.58	88.04
MAIZE	100	114.23	115.18	178.36
CASSAVA	100	109.17	121.05	184.68
RICE	100	114.65	112.09	142.89
MELON	100	97.71	127.14	130.23
COCOYAM	100	99.93	117.94	193.15

Source: NFRA/NAERLS, 2009

Table 1.5 Average yield per hectare land for selected crops from 1995 – 2010 in Nigeria.

CROPS	1995-1998	1999-2002	2003-2006	2007-2010
MILLET	0.99	1.18	1.10	0.72
SORGHUM	1.11	1.22	1.20	1.22
GROUND NUT	1.21	1.19	1.17	1.24
COW PEA	0.64	0.66	0.69	0.50
YAM	11.28	12.18	11.97	12.02
COTTON	1.37	1.34	1.49	0.63
MAIZE	1.57	1.75	1.68	1.71
CASSAVA	11.56	12.01	12.43	13.24
RICE	1.82	1.99	2.09	1.94
MELON	0.55	0.64	0.66	0.57
COCOYAM	5.95	6.38	6.59	7.57

Source: NFRA/NAERLS, 2009

1.1.2. Nature of climate changeand impact on crop yield in Sub-Saharan Africa

Climate is projected to change strongly in sub-Saharan Africa, with annual average temperature change between 1.8 and 4.8°C and annual changes in regional precipitation ranging between –12 and +25 % by 2100. Although different authors have stated conflicting projections on Africa`s future climate; the general consensus is that Africa's climate will generally become more variable. Increasing temperature, changed precipitation patterns and more frequent droughts may lead to substantial decrease in crop yields. Figure 1.1shows a decline in cereal production potential for sub-Saharan Africa in the range of 12 % by the end of the twenty first century.

Areas shaded in green are expected to experience improved conditions for cereal production by 2080; in areas shaded in brownish colours, cereal yields are expected to decline. Although the effect of climate change is both beneficial and detrimental, there is the challenge of how to reduce damage and optimize benefit. An entry point is to determine the extent of impact on agriculture currently and the project change in the future. This is also includes understanding the current level of farm adaptive capacity for future resilience.

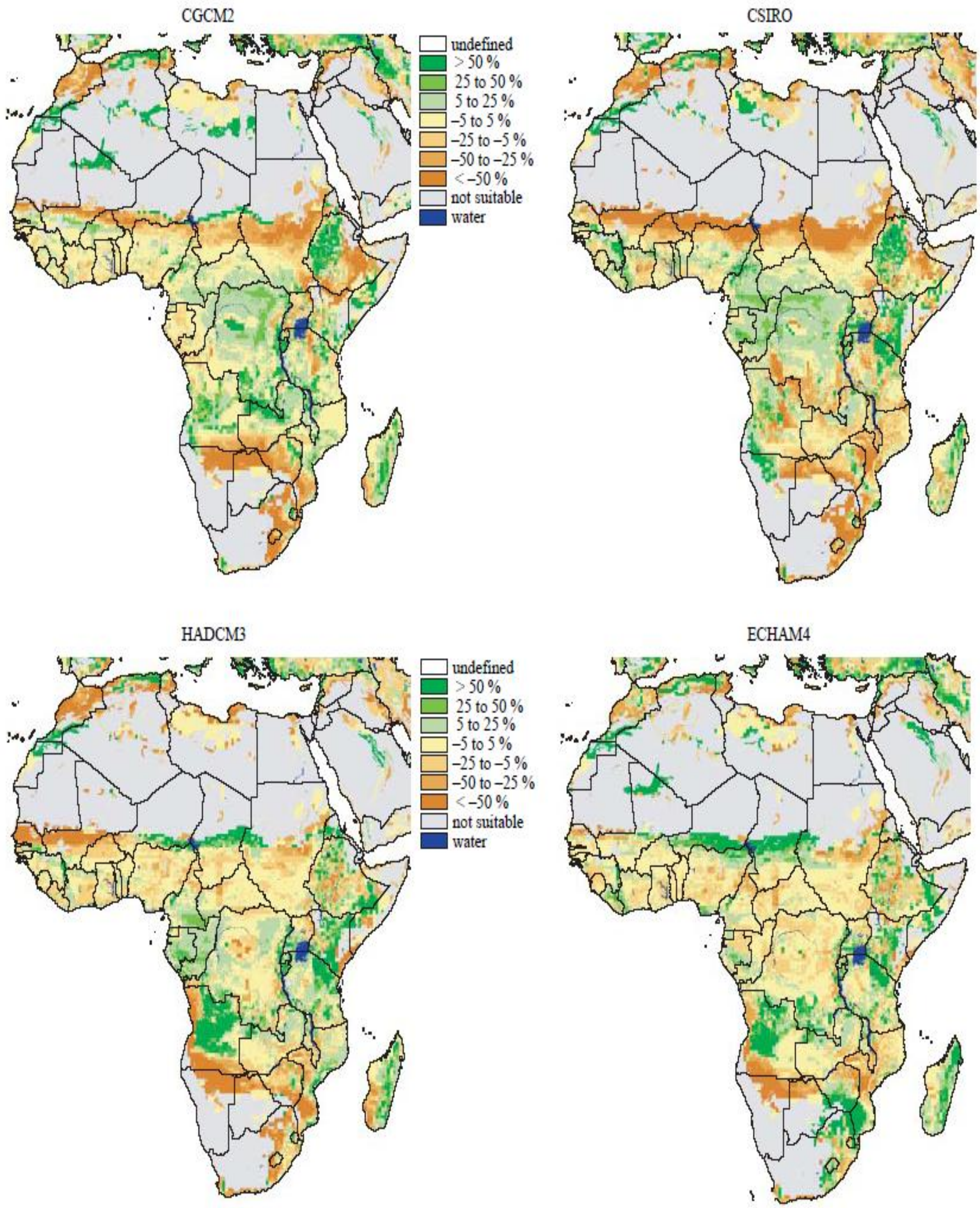

Figure1.1. Map of Africa showing crop yield impact distribution
Source: Fischer et al., 2005

1.1.3. Nature of Climate change Impact in Nigeria

Using the available data from the Tyndall Centre for Climate Change Research, DFID (2009)study concludes that average precipitation and temperature would rise in Nigeria between 2010-2050. The effect would vary across different zones in Nigeria with some areas becoming increasingly desertified, while others will likely suffer increased precipitation. Using climate data collected from meteorological stations in the twentieth century Nigeria, Olaniran (2002) finds a shift in the rainfall belt of the Sahel zone southward by 60km with a reduced annual rainfall by 100-150mm and expansion of desert conditions; southern zone eastward towards the coast by about 160km and with less equable seasonal rainfall distribution and a widespread flooding and erosion mainly in August and September. The Sudan savannah zone southward by about 230km.Furthermore, it has been observed that in most of the 20th Century, from 1922-1985, there was a general trend towards aridity in Nigeria and aridity was more pronounced in the Sudan and Guinean ecological zones than in the Forest zones and Sahel zones; however, there was a contrasting evidence using data from 1961-2000 as the arid zone moved towards a wetter climate (Adejuwon, 2006). This suggests that climate change is a phenomenon that is uncertain and therefore an important determinant of farmers' future profitability.

There are different scales at which the food system will be impacted. There is the local scale, an example being the small farmer who produces,processes and consumes food on farm. There are more complicated scales at national, regional and global food exchange. Whatever the scale, food crop production is affected when exposed and perturbed by climate change and other global stressors in the absence of protection. Other food stressors are civil conflict, national policy instability, international trade agreements and disease shocks. Exposure to climate change results in changes in the welfare level that includes reductions in food availability, loss of or diminished access to food, fluctuation of income streams, chronic illness, poor nutrition, inability to access public services, and increased indebtedness. This study is limited by the inability to isolate other stressors of crop production at the farm level, besides climate change.

1.2. Statement of the Problem

Recent studies have implicated agriculture as one of the sectors that will be most impacted by climate change in Nigeria (Odjugo, 2010; Anuforom, 2010; Olaniran, 2002; Adejuwon, 2006and Obioha, 2009). This is plausible because agriculture and climate are intrinsically tied particularly in rain fed agriculture of most developing countries like Nigeria. In other words, farmers are already exposed to climate change. NIMET(2010) documents that rainfall reduction in August 2010 in Northern states of Borno and Yobe resulted in a drop in millet, sorghum and cowpea production by 10%. Similarly rice production reduced by 50% due to excessive flooding that same year in Sokoto, Kebbi and Jigawa states.Accordingly, optimal climate condition is a key determinant for smallholder farms to sustain continual output of crops for local and regional markets.

Repeated exposure to adverse climatic condition imposes cost on farms and therefore on farm revenue. Thus there is a growing research interest on the economic impact of climate change on agriculture and how to estimate it for adaptation programming at the farm level (Rosenzweig and Parry, 1994; Kumar and Parikh, 2001;Seo et al., 2005; Kurukulasuriya et al., 2006; Seo and Mendelsohn, 2008). Nonetheless, farmers' adaptation is a process and depends on the institutional support they can get. Thus there is also a growing interest on the social, economic and political aspects of farmers' vulnerability (Wehbe*et al*., 2005; Gbetibouo et al., 2010).

The aim of this study is to generate information to support adaptation programming at the farm level. Although mitigation and adaptation are major policy issues in Nigeria, there is limited information on this issue for agriculture and how is to be implemented in the sector.Information on economic damages of climate change is crucialto shed light on how much to compensate the sector. The following research questions were addressed:

1. To what extent has current climate condition influence the decision of farmers on the type of crops to cultivate?
2. To what extent has current climate condition been beneficial or detrimental to farm production?

3. What is the climate change impact on farm production?
4. What is the nature of farmers' adaptive capacity across agro ecological zones?

1.2.1. **Objectives**

1.2.2. **Broad Objective:**

- **To**assess the economic impact of climate change on smallholder crop farms in Nigeria

1.2.3. Specific Objectives

1. To estimate the impact of current climate condition on the type of crops cultivated by farmholders.
2. To estimate the impact of current climate conditions on farm production
3. To simulate the climate change impact on farm production
4. To examine the nature of farmers adaptive capacity across agro ecological zones.

1.3. justification of the Study

With the challenge of climate change[1] globally, the issue of what happens to the profitability of smallholder farming in sub-Saharan Africa has aroused increased public interest and outcry. Climate change is likely to impose additional cost on crop farming as land use for cultivation purposes may no longer be productive over the next century. This would require farmers to substitute crops, increased intensification or complete switch from agriculture. All these would further implicate the productivity of farm land..Thus issues of climate justice, compensation, and government responsibility for reducing vulnerabilities are central in policy debates (Nelson et al., 2007).

Economic impact analysis serves as a tool for policy makers to measure the phenomenon from an economic perspective, as well as to derive information about the opportunity to act in order to reduce the negative impacts and to take advantage of positive ones(Gambarelli and Goria, 2004).While the Ricardian approach to estimating economic

[1]The process of global warming is posited to cause climate change (CC) in the form of shift in rainfall pattern and extreme weather conditions such as drought and flood.

impact at the farm level has been used extensively in countries like south-Africa, Ethiopia, Kenya India, Brazil, and the United states, only two studies to the best of my knowledge have emerged so far in Nigeria's literature using this approach. The first is that of Ajetomobi et al., (2010) and the second is that of Fonta et al., (2011).

Thesestudies used a cross sectional data on rice and cocoa farmers respectively to regress farm revenue against climate variables. There are gaps that this study attempts to address. First in both studies farmer's crop substitution possibility was assumed and not explicitly considered. Secondly farm revenue was used as the endogenous variable relating with climate. In contrast, this study used farm value since it connotes long run equilibrium value of the farm and therefore able to relate with long term change in climate. Thirdly, the study made use of a rich farm survey data collected by Nigeria's government in collaboration with the World Bank that has not been explored by any climate change researcher in Nigeria.

While primary data collected by authors themselves are good, they are often devoid of external verification and knowledge build up. Thirdly in multi-cropping farming systems, single crop analysis might exaggerate the impact of climate on crop farms. Also empirical studies of how much farmers are likely to switch crops in response to climate change are rare in the literature (Seo and Mendelsohn, 2008). The few exceptions that exist often use models that assume that farmers' crop choices are independent. In a mixed cropping system the interdependence of input choices are well known in developing countries. Thus unlike previous studies done in Nigeria, the study estimated the implicit farmers cropping decision using a multivariate probit methodology that captures the mixed interdependent crop choices in Nigeria. Thirdly the Ricardian model was used to simulate the impact of climate change in the near future using a physically consistent downscaling approach rather than arbitrary addition

1.3.1. Plan of Study

The paper is structured into six chapters. Chapter 1 presents the introduction comprising of background information on crop production and the factors determining the outcome. Others include the problem statement, objectives, and analysis of the objectives, justification and plan of study. Chapter two presents the institutional and policy framework of climate change adaptation and mitigation while chapter three presents an extensive literature review of what climate change means in agriculture, reviews on adaptive capacity, adaptation modelling and climate models. Others include review of economic impact modelling in agriculture and empirical studies. Chapter four presents the methodology while chapter five presents the results and discussion.Chapter six presents summary of findings, recommendation and conclusion.

CHAPTER TWO
LITERATURE REVIEW

2.1. Concepts and definition

2.1.1. Climate change

The Intergovernmental Panel on Climate Change (IPCC) definesclimate change as changes in the mean and /or the variability of its elements that persists for an extended period typically decades or longer (IPCC, 2007). Climate is caused by the process of global warming that comes in the form of shift in rainfall and temperature pattern and extreme weather events such as flooding, drought and river rise. Stern (2008) presents a simplified summary of the scientific process. First, people, through their consumption and production decisions, emit Green House Gases (GHGs) such as carbon dioxide, methane, nitrous oxide, and hydrofluorocarbons (HFCs). Second, these flows accumulate as stocks of GHGs in the atmosphere. Third the stock of GHGs in the atmosphere traps heat and results in global warming. Fourth, the process of global warming results in climate change. Fifth, climate change affects people, species, and plants in a variety of complex ways.

Conceptually meteorological observations of temperature, precipitation, solar radiation, and relative humidity over time are used to describe current climate and change in climate of a particular location. Climate change in agriculture is conceptualized as change in average climate, year to year annual variability and frequency of extreme events such as drought and flood.

2.1.2. Concept of Climate Change Impact

Impact or sensitivity is the degree to which a system is affected, either adversely or beneficially by climate or other non-climatic factors. It consists of damages and adaptation responses of the system exposed to climate stimuli. It is the observed or potential outcome of an exposed system. Attempts to provide monetary estimate of climate change impact started in the 1990s. The use of monetary measures remains controversial. The first argument against the use of monetary estimate is the uncertainty regarding the process of global warming and the consequential effect on human and natural systems. Second is the large temporal lag between causes and impacts. Nonetheless, impact can be quantified in physical and in economic terms. Physical impacts can be measured in terms of total production, productivity (e.g., crop yields or total factor productivity). In economic terms, impacts can be measured in many ways, such as the gross value of production, cost of production, net value of production, and farm income (Antle, 2009).

2.1.3. Concept of Adaptation

The most popular definition of adaptation is that given by the Inter-governmental panel on climate change (IPCC). It is the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities (IPCC, 2007: p750 chap18). While ecologists often focus on how organisms or species adjust to their environment in response to a change in climate, social scientists view adaptation from the perspective of adjustments by individuals and the collective behaviour of socioeconomic systems (Smit et al., 2000).

A simple way to understand adaptation is to view it in light of the following questions: “adaptation to what”, “who adapts” and “how does it happen and the effectiveness” (Smit and Pilifosova, 2001). “Adaptation to what” captures the type of stimuli farmers are adapting or adjusting or responding to. In agriculture climate stimuli can be climate change, variability or just climate and other change such as policy or market stimuli or opportunities. It is often difficult to separate climate from non-climate stimuliin practice.

Hence both stimuli correlate to determine farmers' decisions. "Who or what adapts" refers to the targeted system such as people, social and economic sectors and activities, managed or unmanaged natural or ecological systems, practices, processes or structure of systems. "How adaptation happens" reflects the mechanism or process of adaptation. The mechanism of adaptation is described by the scale (time and spatial), the type of adaptation, and the form of adaptation and the effectiveness or performance. The type of adaptation defines whether adaptation is autonomous (farmers action not supported by external aid, e.g government) or whether adaptation is planned (i.e. government or non-government support programmes). Adaptation can also be defined by whether it is anticipatory (ex ante). That is programmed in anticipation of climate risk or reactive (ex post) programmed after the occurrence of particular hazard. Adaptation can be shorter-term or longer-term processes. The scale defines the spatial unit to which the adaptation takes place. This could be adaptation for some specific crops on farms. Adaptation can also be described in terms of the various forms in which it can be pursued. For example adaptation forms can be typified as technological developments, (2) government programs and insurance, (3) farm production practices, and (4) farm financial management.

2.1.4. Conceptof Adaptive Capacity

Associated with "who or what adapts" is the underlying nature of the system that is exposed. Thus various concepts have emerged to characterise human and natural systems such as adaptive capacity, vulnerability, viability, resilience, sensitivity, susceptibility, and flexibility.

2.1.5. Vulnerability, Risk and Adaptive Capacity

The glossary of the Third Assessment Report (TAR)(IPCC, 2001, p. 995) defines vulnerability as ''the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity.'' Smit et al. (2001)in the IPCC TAR, citing Smit et al. (1999) describes vulnerabilityas the ''degree to which a system is susceptible to injury, damage, or harm (one part—the problematic or detrimental part—of sensitivity)''. Sensitivity in turn is described as the ''degree to which a system is affected by or responsive to climate stimuli'' (IPCC, 2001, p. 894). In this definition, vulnerability is viewed as essentially a state variable, determined by the internal properties of a system. From this view point, Blaikie et al (1994) define vulnerability as "the characteristics of a person or group in terms of their capacity to anticipate, cope with, resist, and recover from the impacts of a natural hazard".Thus the notion of social vulnerability for social systems.(Brooks, 2003; Adger, 1999; Adger and Kelly, 1999; Kelly and Adger, 2000).Abson et al., 2012 conceptualize vulnerability as a function of exposure, sensitivity and adaptive capacity. Where exposure is defined as the degree to which a system experiences internal or external system perturbations. Sensitivity is defined as the degree to which a system is affected by those system perturbations. Adaptive capacity is defined as the ability of a system to adjust its behaviour and characteristics in order to enhance its ability to cope with external stress.

The concept of vulnerability is related to the concept of risk. Definitions of risk are commonly probabilistic in nature, relating either to (i) the probability of occurrence of a hazard that acts to trigger a disaster or series of events with an undesirable outcome, or (ii) the probability of a disaster or outcome, combining the probability of the hazard event with a consideration of the likely consequences of the hazard (Smith, 1996; Brooks, 2003.). In other words, risk can be viewed as a product of probability and consequence (Smith, 1996; Brooks, 2003), a definition similar to risk as a function of hazard and vulnerability (UNDHA, 1992).

There are various perspectives of vulnerability in the literature with implication on the analysis and the policy prescription. From climate change literature, there is the end point perspective of vulnerability. It is the more traditional interpretation of vulnerability in climate change research whereby "assessment of vulnerability is the end point of a sequence of analyses beginning with projections of future emission trends, moving on to the development of climate scenarios, thence to biophysical impact studies and the identification of adaptive options". Any residual consequences that remain after adaptation has taken place define the levels of vulnerability. Vulnerability here summarizes the net impact of the climate problem, and can be represented quantitatively as a monetary cost or as a change in yield or flow, human mortality, ecosystem damage or qualitatively as a description of relative or comparative change. The second interpretation considers vulnerability as a starting point for analysis. Vulnerability is interpreted as a present inability to cope with external pressures or changes, in this case changing climate conditions. Here, vulnerability is considered a characteristic of social and ecological systems that is generated by multiple factors and processes. One purpose of vulnerability assessments using this interpretation is to identify policies or measures that reduce vulnerability, increase adaptive capacity, or illuminate adaptation options and constraints. Understanding the biophysical, social, political and cultural factors that contribute to climate vulnerability is seen as a critical prerequisite for taking actions to reduce this vulnerability.

Adaptive capacity is defined in the glossary of the IPCC (2001, p. 982) TAR as ''The ability of a system to adjust to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.'' Like vulnerability, adaptive capacity is a concept that has come to have multiple interpretations and nuances in the climate change literature. In general terms, adaptive capacity is defined in the climate change literature as "the potential or ability of a system, region, or community to adapt to the effects or impacts of climate change" (Smit and Pilifosova, 2001, p. 881).

2.1.6. Concept of Smallholder Farm

The farm can be viewed as aproduction system for the cultivation of crops or rearing of animals or both. Farms in Nigeria are family-based co-residential unit that takes care of resource management both on the farm and the household. It consists of individuals that do not necessarily live together in the same house but share the majority of the household resources and farm activities. The farm employs labour, land, equipment, knowledge and capital resources to produce goods–which are consumed or marketed or both. Farming activities include not only on farm but off farm. Management of the farm can take place over short period of time or long period of time.

2.2 Review of Institutional Context of Climate Change Mitigation and Adaptation

As far back as 1992, more than 150 governments attending the Rio Earth summit signed the United Nations Framework Convention on Global Climate Change (UNFCCC). The main objective is to achieve stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent further warming of the earth surface. In particular, the UNFCCC calls on industrialized countries, known as Annex I Parties, to take the lead in climate action because of their historic responsibility for the majority of GHGs emissions, as well as their greater financial and institutional capacity to address the problem. As a follow up, the Conference of the Parties to the UNFCCC in Kyoto in 1997 agreed to what is known as the Kyoto Protocol. The UNFCCC and its Kyoto Protocol constitute the basic framework and legal basis for international cooperation to address climate change. Jointly, these instruments embody the consensus of the international community and serve as the foundation governing the implementation of decisions agreed at various annual meetings of the Conference of Parties (COP).

The Kyoto Protocol sets legally binding GHG emission targets for the developed nations on the average to reduce GHG emissions 5% below 1990 levels over the first commitment period, which lasts from 2008 to 2012. As of July 2009, 183 countries and 1 regional economic integration organization (the European Economic Community) had ratified the Protocol. The Kyoto agreement also includes several mechanisms designed to give the industrialized nations flexibility in meeting their targets. For example, the Clean Development Mechanism (CDM) instituted by Article 17 of the Kyoto Protocol and Article 6 for Joint Implementation (JI) allow nations to fund and receive emission reductions credit for actions taken in countries with less expensive mitigation options.

The Bali Action Plan (BAP) agreement followed in 2007 and it is based upon “a shared vision for Long-term Cooperative Action (LCA), including a long-term global goal for emission reductions. BAP creates provisions for developing countries to take “Nationally Appropriate Mitigation Actions” (NAMAs). These are actions on climate change that would be based in countries’ local circumstances, supported financially by developed countries, and crafted to allow developing countries to meet sustainable development objectives. In December 2009 the Copenhagen Conference culminated to the formulation of a global legally non-binding Climate Change Accord known as the Copenhagen Accord. While mitigation remains a major issue for all countries, SSA countries including Nigeria are compelled to pursue planned adaptation action and how to take advantage of climate change damage compensation and international aids. Thus Nigeria is classified as a Non-Annex 1 nation by the UNFCCC and not required to make firm international commitments.

Regionally, the Nairobi Declaration adopted by the African Ministerial Conference on the Environment (AMCEN) in May 2009 outlines a detailed agenda for regional cooperation and national commitments to mainstream adaptation steps in national and regional development policies. The Committee of African Heads of State on Climate Change (CAHOSCC), created in July 2009, is comprised of eight states including Nigeria and has played an active role in developing common positions among African states on climate change. In 2010, the Economic Community of West African States (ECOWAS) adopted the Framework of Strategic Guidelines on the Reduction of Vulnerability and Adaptability to Climate Change in West Africa; this agreement seeks to build scientific and technical capacity to reduce climate change vulnerability in member states, integrate climate change in national and regional development policies, and implement national and regional climate change adaptation programs (Moran et al., 2011)

In Nigeria, climate change is an environmental issue and as contained in Nigeria's constitution, it is the responsibility of the state at all levels to protect and improve the environment and safeguard the water, air and land, forest and wildlife of the country (Constitution, Chapter 2, Article 28)".(Oladipo, 2010). The constitution allocates certain legislative competencies to each of the three tiers of government (Federal, State and Local). The responsibility for applying the legislation falls to the judiciary, and the constitution recognizes the specific competencies of the National Assembly, the State Assemblies and the Local Government Councils (Oladipo, 2010).

The Federal Ministry of Environment is the most influential governmental actor in climate change policy-making and management. The Federal Environmental Protection Agency

(FEPA) was the earliest institutional actor operating within a wide scope of environment related matters. In 1999, the agency metamorphosed into the Federal Ministry of Environment (FMEnv) with a focus on environmental protection (Oladipo, 2010). Within this umbrella are various committees and agencies being coordinated by the Ministry.

The Inter-Ministerial Committee on Climate Change (ICCC) was established in 1993 as a technical and advisory network to the federal governmenton climate change related issues. It has representation from the following ministries: Finance, National Planning Commission, Agriculture and Water Resources, Energy Commission, Nigeria National Petroleum Corporation, Federal Ministry of Foreign Affairs, Nigerian Meteorological Agency, NGOs: the Nigerian Environmental Study Action Team, Academia: the Centre for Climate Change and Fresh Water Resources, the Federal University of Technology, Minna; the Centre for Energy, Research and Development, ObafemiAwolowo University Ile-Ife.

The Special Climate Change Unit (SCCU)is a department under FMEnvand established as a coordinating unit for all climate change related matters. The Unit's broad mandate is the development of a short to long term national plan to enable Nigeria to respond to its obligations as specified by the UNFCCC and the Kyoto Protocol. SCCU drives the national response to climate change at the national and international levels. SCCU is also Nigeria's Designated National Authority (DNA) for the Clean Development Mechanism. It works with the Inter-Ministerial Council on Climate Change. SCCU coordinates the role of Nigeria's Inter-Ministerial Committee. The National Adaptation Strategy and Plan of Action on Climate Change for Nigeria (NASPA-CCN) is formulated and implemented through the SCCU.

The Federal Ministry of Agriculture and Water Resources (FMAWR)is part of theInter-Ministerial Committee on Climate Change and therefore acts as a technical and advisory agency in respect to climate change policy in Nigeria. Although it is not yet clear how climate change adaptation is being mainstreamed in the sectoral plan, there are existing responses in the sector. The National Food Reserve Agency (NFRA) is a Parastatal of the

Federal Ministry of Agriculture & Water Resources (FMAWR). It emanated from the merger of the former departments of FMAWR namely, the Project coordinating Unit (PCU), Strategic Grains Reserve (SGR),Fertilizer department (FD), Cooperatives department, andmechanization and post-Harvest Technology. The agency addresses issues of agricultural production, processing, storage and marketing. The operations are decentralised with Regional Offices in each geo-political zone and linkage with the states, Local Governments and farmers. Of the six departments[2] making up the agency, the functions of the Food Reserve and Storage(FRS) department are to operate the strategic food reserve stock, establishment, operation and maintenance of storage facilities, operate the guaranteed Minimum Price (GMP) mechanism, and management and distribution of food commodities(NFRA/NAERLS, 2009).

There are also key institutions at the Federal and State levels involved in agricultural development and protection.The Nigerian Agricultural Insurance Scheme (NAIS) provides hedge against the several risks that farmers face. For example, the crop insurance product provides stability in farmer‘s income by underwriting the risks of crop farmers. The agency was established under the Nigerian Agricultural Insurance Corporation (NAIC) Act Cap 89 (LFN) 1993. The scheme is however limited by small coverage of farmers and funding (ICEED, 2012)

The National Emergency Management agencyprovides relief materials for victims of flooding at the national and collaborates with the National food reserve agency. It was originally called the National Emergency Relief Agency (NERA) in 1976 established by the Federal Government of Nigeria to coordinate disaster response activities. The Agency was purely a relief organisation focusing only on reactive disaster management. The increase in deaths from natural and man-made disasters resulted in the idea of proactive responses. Thus in 1999, the National Emergency Management Agency (NEMA) was established to replace NERA and to manage disasters in Nigeria with the following mandate amongst other things: formulate policy on all activities relating to disaster

[2]The departments are the Food Reserve & Storage (FRS); Agro-Processing & Marketing (APM); International Collaboration & Partnership (ICP);Agricultural Production & Inputs Services (APIS); Cooperatives Development; Finance & Accounts; and Administration.

management in Nigeria and co-ordinate the plans and programmes for efficient and effective response to disaster at national level; Co-ordinate and promote research activities relating to disaster management at the national level; Monitor the state of preparedness of all organisations or agencies which may contribute to disaster management in Nigeria; Collate data from relevant agencies so as to enhance forecasting, planning and field operation of disaster management; Educate and inform the public on disaster prevention and control measures; Co-ordinate and facilitate the provision of necessary resources for search and rescue and other types of disaster curtailment activities in response to distress call.

The Nigerian Meteorological Agency (NIMET) has the statutory responsibility of observing weather, making forecasts and advising Government and the general public on all aspects of meteorology. Provides weather data to all stake holders (aviation, military, environment, agriculture etc.) in Nigeria. The agency is linked to the World Meteorological Organisation (WMO) and other international agencies on global issues concerning climate and climate change. NIMET in its operational capabilities has the following:

- 1 Central Forecast Office and 4 Independent Forecast Offices
- 54 Synoptic Stations, 20 Agrometeorological Stations
- 1 Agrometeorological Experimental Farm
- 50 Rainfall Stations, 2 Upper Air Stations
- 2 Ozone Stations and
- 40 Automatic Weather Observing Stations (AWOs)

The WMO requires that the gap between two weather stations does not exceed 50 km. NIMET is yet to attain this level in the station network density (ICEED, 2012)

There are also non-government institutional actors involved in climate change mitigation and adaptation**.** Development partners have made a number of interventions to support climate adaptation initiatives in Nigeria. Examples are UNDP, UNIDO and UNICEF, the British High Commission, Christian Aid, CIDA, William J. Clinton Climate Change initiative etc. Nigeria remains the top recipient of international development aid in Africa.

Non-governmental organizations have great potential to play a larger role in Nigeria‘s adaptation response to climate change. Few active ones are Nigeria Climate Action Network (NigeriaCAN) stands out very well as perhaps the most active, particularly in the area of advocacy. Another active NGO climate actor in Nigeria, particularly in the area of knowledge and research, is the Nigerian Environmental Study Action Team (NEST). Others include Climate Change Network (CCN) Nigeria, Youth Organization for Climate Change, Nigeria Conservation Foundation (NCF); Women Farmers Advancement Network, Kano Nigeria (WOFAN); Women Environment Programme (WEP); African Radio Drama Association (ARDA) Nigeria; Coalitions for Change (C4C); Centre for Education and Leadership Development (CELDEV): and Nigeria Model United Nations Society (NigMUNS).

Public-private partnership has been more in climate change mitigation, particularly as it relates to the Clean Development Mechanism (CDM). Community-based Organisations (CBOs), including Fadama User Associations formed under Fadama I were promoted by the ADPs to facilitate the delivery of extension messages and agricultural inputs.

2.3. Framework for Adaptation Programming at the Farm Level

There are various ways adaptation can be programmed. Table 2.1 presents various typologies of adaptation that can be programmed for farmers.

Table 2.1. Adaptation Programming Framework

TECHNOLOGICAL DEVELOPMENTS **Crop development** • Develop new crop varieties, including hybrids, to increase the tolerance and suitability of plants to temperature, moisture and other relevant climatic conditions. **Weather and climate information systems** • Develop early warning systems that provide daily weather predictions and seasonal forecasts. **Resource management innovations** • Develop water management innovations, including irrigation, to address the risk of moisture deficiencies and increasing frequency of droughts. • Develop farm-level resource management innovations to address the risk associated with changing temperature, moisture and other relevant climatic conditions.
GOVERNMENT PROGRAMS AND INSURANCE Modify crop insurance programs to influence farm-level risk management strategies with respect to climate-related loss of crop yields. • Change investment in established income stabilization programs to influence farm-level risk management strategies with respect to climate-related income loss. • Modify subsidy, support and incentive programs to influence farm-level production practices and financial management. • Change *ad hoc* compensation and assistance programs to share publicly the risk of farm level income loss associated with disasters and extreme events.

Source: Smit and Skinner (2002)

Table 2.1. Adaptation Programming Framework(Cont)

Agricultural subsidy and support programs **Private insurance** • Develop private insurance to reduce climate-related risks to farm-level production, infrastructure and income. **Resource management programs** • Develop and implement policies and programs to influence farm-level land and water resource use and management practices in light of changing climate conditions.
FARM PRODUCTION PRACTICES **Farm production** • Diversify crop types and varieties, including crop substitution, to address the environmental variations and economic risks associated with climate change. • Diversify livestock types and varieties to address the environmental variations and economic risks associated with climate change. • Change the intensification of production to address the environmental variations and economic risks associated with climate change.
Land Use • Change the location of crop and livestock production to address the environmental variations and economic risks associated with climate change. • Use alternative fallow and tillage practices to address climate change-related moisture and nutrient deficiencies. **Land topography** • Change land topography to address the moisture deficiencies associated with climate change and reduce the risk of farm land degradation. **Irrigation** • Implement irrigation practices to address the moisture deficiencies associated with climate change and reduce the risk of income loss due to recurring drought. **Timing of operations** • Change timing of farm operations to address the changing duration of growing seasons and associated changes in temperature and moisture.

Source: Smit and Skinner (2002)

Table 2.1. Adaptation Programming Framework (Cont)

FARM FINANCIAL MANAGEMENT
Crop insurance
• Purchase crop insurance to reduce the risks of climate-related income loss.
Crop shares and futures
• Invest in crop shares and futures to reduce the risks of climate-related income loss.
Income stabilization programs
• Participate in income stabilization programs to reduce the risk of income loss due to changing climate conditions and variability.
Household income
• Diversify source of household income

Source: Smit and Skinner (2002)

2.4. ModellingClimate Change Impact on Farms

Farm production is a continually evolving outcome of interactions between climate and human environment. The climate environment consists of such factors as rainfall, temperature, relative humidity, hydrology, soil and altitude and generally referred to as the biophysical space. The human environment includes government policies; population pressure, technology advancement and farmers' characteristics and generally referred to as the socio economic space. Farm production depends on the biophysical environment of the farm and the managerial characteristic of the farmer. Socioeconomic factors such as farmers characteristic, population pressure and government polices influence the pattern of agriculture and yield and changes in the biophysical environment.

Temperature variations affect many functions of the plant, such as respiration, transpiration, and photosynthesis. Increasing temperature leads to increasing respiration intensity, which requires a higher intake of carbohydrates and, consequently, a loss of biomass. Inthe tropics precipitation is the most important influence of plant growth and this is determined by the amount of rainfall and distribution. Crop plants are sensitive to the moisture situation both during their growth, development and especially as they reach maturity. Thus climate through its elements not only aid plant growth but also influence biotic and abiotic conditions within which plants grow and therefore influences what adaptation options farmers would use and the cost of production. Biotic stresses are associated with living organisms such as pests and diseases while abiotic stresses are associated with physical factors like excessive moisture and poor soil quality.Odjugo, (2010) findsfarmers shifting from long duration crops to short duration in North east due to drought.

Precipitation in Nigeria is influenced by the movement of the Inter Tropical convergence zone (ITCZ) responsible for wet and dry seasons in Nigeria.Other factors influencing the variability of precipitation include the Tropical Easterly Jet (TEJ), Tropical Atlantic Sea Surface Temperature Anomaly (SSTA), Bio geophysical feedback Mechanism (BFM) and El Nino Southern Oscillation (ENSO) (Olaniran, 2002).Coastal flooding occurs in low-lying land along the coast. River flooding occurs in the flood plains of the larger rivers, and rivers in the inland areas. Floods are also influenced by the River Niger flow which exhibits a seasonal flood regime responsible for the annual flood characterises of the river in Nigeria and the time pattern.Beyond temperature and precipitation, hydrology plays important role in determining crop farming in Nigeria. However the majority of water that discharges from the basin outlet originates from precipitation. Water resources potential of the country comprises surface water and groundwater. Surface water, especially rivers and lakes, reflect higher fluctuations than groundwater. The drainage system feeds the Niger and Benue rivers and provides water as moisture for agriculture and widespread fadama and flood plains in Nigeria.Soil is another important limiting factor in agriculture and varies in texture, colour, chemical composition, PH (acidity and alkalinity), depth and suitability.

Human factors such as government policy, population and individual characteristics are important factors determining crop production.Government institutional framework directs the agricultural development pattern of any country. Various policy regimes have influenced the nature of Nigeria's agriculture. It is argued that institutions exert significant effect on the choices individuals, households, as well as smallholder farmers make. The use of desirable crop variety or low cost irrigation technology for poor farmers would depend on how effective government and private organisations make them available to farmers.Institutional deficiencies such as lack of support mechanisms, poor functioning markets and poor or inadequate infrastructure frustrate farmers' efforts to cope with climate variability. For example, resource limitations and poor infrastructure limit the ability of most rural farmers to take up adaptation measures in response to changes in climatic condition.

Another important factor influencing crop farming is change in population. The role of population pressure is well established from the time of Malthus. Studies in support of Malthus views population pressure as leading to land degradation. There are also studies that support the view that population growth leads to intensification of agricultural systems. Population pressure stimulates changes in land use cropping patterns, traditional modes of farming such as shifting cultivation, and the extent of land use for agriculture.

Farmers' behaviour also shape to what extent action is taken to reduce the impact of climate change on their farms. Farmers' characteristics such as age, gender, education, marital status, off-farm job, household sizeand the presence of assets (e.g., machinery, animals) also affect the extent to which farms take advantage of the opportunities of climate change impact.

2.5. Review of Theoretical Models of Climate Change Impact in Agriculture.

Many models have evolved since the 1990sfor estimating the economic impact of climate change on agriculture. Mendelsohn et al., (1994) classified these models into agronomic, and Ricardian land use econometric models. Agronomic models can be static or dynamic and are used to estimate changes in crop yield. An example is the dynamic growth simulation model or agronomic yield simulator model. The model relies on coefficients drawn from crop experiments. The model simulates the effect of weather and soil conditions on biological processes such as evapotranspiration, respiration, and photosynthesis and the implied effect on crop yield(Kaufmann and Snell, 1997). Accordingly the model is physiologically oriented with functions that calculate the rates of photosynthesis, translocation, respiration and other crop processes under different climatic conditions of temperature, precipitation, solar radiation, soil characteristics and CO_2 regimes.This approach to modeling the impact of climate change on agriculture is experimental that requires substantial resources and time to estimate variation in yield.

The agro-economic model is an advancement of the agronomic model that is a hybrid of yield simulator model and economic model. It is also called bio economic model. The yield simulator is used to capture the biophysical aspect while the economic model captures the optimization process of the farmer or farms. The programmes are preloaded *with soil, climatic and cultivar data for specific regions of the world. The production coefficients generated from the yield simulator are fed into the economic model and used to predict the impact on yield and indicators reflecting welfare such as food security or income. Examples of such models are: SOYGRO used for soy bean, EPIC model used for maize, millet, rice, cassava, sorghum, DSSAT used for wheat, corn, potato, soybean, sorghum, rice and tomato and CENTURY used for hay and grassland crops including cane. Agronomic-economic models offer the advantages of being widely calibrated and validated. They are useful for testing different types of adaptation techniques and can be used to test mitigation and adaptation techniques simultaneously (Iglesias et al., 2011). The following techniques are used linear programming, non-linear, mixed integer optimisation nested optimisation and stochastic MP. In some studies crop yield statistical regression function such as Cobb Douglas yield production function has been used. Agronomic-economic models have several weaknesses that limit their use to study the impact of climate change. The model do not account for constraints affecting actual farm-level adaptation decisions, which could lead to biases of overestimating damages or underestimating potential benefits of climate change. Secondly, it is costly and questions the robustness of generalizing inferences based on results from few experimental sites to large areas and diverse agricultural production systems (Adam, 1999; Mendelsohn, 1994). The model requires detailed weather and farm management data, and omits the effects of crop pests and diseases. The models are calibrated to experimental field data which often have yields higher than those currently typical under farming conditions and as such the effects of climate change on yields in farmers' fields may be different than simulated.

The Ricardianmodel is a land use spatial econometric model pioneered in Mendelsohn et al., (1994). The technique is named the Ricardian method because it draws heavily on an observation by Ricardo that land values would reflect land productivity at a site (under competition).The underlying idea is that agricultural practices and land values are correlated with climate and that knowing their distribution across today's climatically variable landscape provides us with information about how farmers are likely to immediately respond to global climatic change and what such immediate responses mean for land values.(Darwin, 1999). The equation below represents the essence of the Ricardian model and postulates that if producing an output, Q is the best use for the land given exogenous factors, the observed rent on the land is equal to the annual net profits from producing Q and that farm value is the present value of future land rents.

$$V_{LF} = \int_0^{\infty} P_{LF^{-rt}} \, dt = \int_0^{\infty} \frac{[P_i Q_i - C_i(Q,P,F)]e^{-rt}}{L_i(F)} dt \quad 2.1$$

Ricardian climate sensitivity estimate depends on some assumptions. It is assumed that land value capitalizes long term climate and other drivers of land use and that farmers have already adjusted by choosing the best use of land that gives the largest profit. Thus a major assumption in the model is the implicit adaptation behaviour of farmers to changes in climate. This assumption appears restrictive because at least in the short run there may be constraints that prevent the farmer from responding to changes in climate.Secondly it assumes CO2 levels are generally the same across locations. Thirdly it assumes prices of inputs and outputs remain constant. This is a strict constraint – one not likely to hold under global climatic change. If biases associated with price changes are relatively small and somewhat predictable, then changes in Ricardian rents may, perhaps with a little adjustment, approximate annual values of agriculturally related climatic change (Darwin, 1999). Specifically, changes in Ricardian rents do not provide information about the welfare implications of climatic change for specific agents. (Darwin, 1999).It does not account for changes in climate variation or extreme events. The approach does not measure transition cost. For example, if a farmer has crop failures for a year or two as the farmer learns how to grow a new crop, this transition cost is not reflected in the analysis. Similarly, if the farmers make the decision to move to a new crop suddenly, the model would not capture the cost of decommissioning capital equipment prematurely.

There are also economy wide models beyond sector wide models. Economy wide models look at the interaction across all sectors of the economy. The computable general equilibrium(CGE) is an example of an economy wide model. An example is the FARM, the eight-region CGE model of theworld agricultural economy by the U.S. Department of Agriculture. Although a CGE model takes intersectorallinkages into account, these come at the cost of quite drasticaggregation, in which spatially and economically diversesectors are characterized by a representative farm or firm.CGE models are only appropriate to highly aggregated sectors of the economy (Schlenker et al., (2006).While the use of economy-wide models is growing there are limitations that include difficulties with model selection, parameter specification and functional forms, data consistency or calibration problems, the absence of statistical tests for the model specification, the complexity of the CGE models and the high skills needed to develop and use them.

Impact prediction might be bias since many producers and consumers will be responding to changes in shadow prices rather than to market prices. For example, in many developing countries, a large part of agricultural production, and frequently also other primary production, such as fishing, is subsistence or near-subsistence activity, carried out by households that are not part of the formal economy. In practice, this means that less comprehensive methods for estimating the economic impacts of climate change are necessary (Stage, 2010).

The integrated assessment models (IAMs) approach is also economy wide and account for the many interactions and feedback effects of various elements of a system in measuring the total or net effect of changes in climate. However despite their wide application, IAMs models are based on aggregation of effects on selected subsets of sectors and impact mechanisms separately measured under a host of strong assumptions (Stern, 2008). Of note in all economy wide models is the use of observed annual variations in temperature and precipitation and thus measures short-term responses and do not properly measure long-run responses to climate change.

2.6. Review of Measurement Issues

Analysis of the economic impact of climate change on agriculture is made difficult by a number of measurement issues. First, climate change is a long-term phenomenon that normally would require long time series data on both climatic variables and relevant human economic decision variables to isolate impact. This is made difficult by the paucity of data covering decades on production and consumption decisions in response to climate change. Second climate itself is a non-market good and therefore the challenge of how to value it. Thirdly climatic elements such as temperature and precipitation observed at weather stations are often incomplete particularly in developing countries such as Nigeria with low weather station density network (ICEED, 2012).

Monthly climate normal is often used from 20 years upwards because climate change concerns longer-term trends rather than annual variations. Degree days measurement of climate has also been suggested rather than monthly average climate measure. Schlenker et al., (2006) argued that plant growth depends on exposure to moisture and heat throughout the growing season and therefore inclusion of weather variables for April and July, but not May, June, August, or September, can produce a distorted representation of how crops respond to ambient weather conditions. The methodological issue in the use of [3]climate models prediction for climate change impact assessment is the miss-match between the global scale of climate predictions and the local scale of current climate as observed in weather stations. For these reasons, GCMs results must be considered as representative of physically plausible future climates, rather than exact predictions.

CGCM2, CSIRO2, HadCM3 and PCM are some examples of climate models developed in climate modelling institutions. The commonest approach for relating GCM projections with specific area climate impact is through downscaling of GCM models to the closest finest geographic resolution. Several approaches exist in the literature for downscaling global climate predictions. A simplified way is to define a uniform scenarios (for instance +10% in rainfall, +2.5*C in temperature and to add these changes to the observed climate data of a present time. The few studies donefor Nigeria have followed this approach such as Ajetomobi et al (2010) and Fonta et al (2011). The limitation of the uniform approach is that it has no real physical basis and does not preserve consistency among climate variables (Roudier et al., 2011). It has been severely criticized by climatologists, since it tends to reduce variances (and thus alter uncertainties) and to cause a wrong sensation of more accuracy, when actually it only provides a smoothed surface of future climates. Dynamical downscaling is a computationally and technically expensive approach. There is also the stochastic weather generators approach which uses observed weather local data to simulate synthetic time-series of daily weather that are statistically similar to observed weather in the desired local site.Another issue concerning the use of these models is the time span for scenario analysis. Based on relevance the time span can be seen as near term 2050 and long term 2100 and above.

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[3]Climate models used to generate climate change projections are commonly referred to as Global Circulation models (GCMs). The models are large-scale representations of the atmosphere and its processes and are designed to predict physically consistent sets of climate variables under various anthropogenic forcing. In the past, the IPCC coordinated the process of developing scenarios for climate change projections. The process of scenario development is currently coordinated by the research community and group scenario development as representative pathway emission.

2.7. Review of Empirical Studies on Climate Change Impact

While the literature on the economic impact of climate change has advanced globally, the literature in Nigeria is still in its infancy. The first strand of literature uses time series data to .examine the relationship between weather variables and crop yield. Akintola (2000) used 25 years times series data to relate meteorological variables on crop yield of selected crops in Ibadan area of Oyo state using regression analysis and Parvin's and Minzer-Zarnovitz methods. The result shows that agro climatic variables have significant and varying effects on crop yield. Ajetomobi and Abiodun (2010) estimated the response of annual cowpea yield to some selected climatic parameters namely temperature and precipitation for the period 1961 – 2006 for 20 major cowpea producing states in Nigeria. Responses varied across states while in 6 states, five of which are in North, there was negative and significant relationship between cowpea yield and temperature. Response to precipitation was similar to those of temperature in the northern states, except Sokoto. There was a negative correlation between rainfall and cowpea yield in Adamawa, Bauchi, Kaduna, Katsina, Kwara, Niger, Plateau and Yobe. A similar study is that of Ayindeet al., (2010) who examined the trend in climatic parameters and agricultural production as well as the relationship between climatic parameters and agricultural production. Time series data sourced from Central Bank of Nigeria and National Bureau of Statistics. Descriptive statistics and granger causality test analysis were used as tools of analysis. The Granger causality approach revealed that changes in rainfall (climatic parameter) positively affects agricultural production in Nigeria.

While these studies are important in understanding current conditions of climate and annual production, the studies stop at the level of establishing relationship between weather variables such as temperature, precipitation, sunshine hours and crop yield or output. Quantification of the value of climate change impact is difficult to estimate using the methodologies that the studies have employed. Secondly, the studies considered aggregated agricultural output which masks the heterogeneous response of various agricultural commodities to climate variables at community or farm level. Thirdly the studies used weather variables that are collected annually rather than climate that connotes the average weather conditions for several years.

The second strand of literature consists of studies that have applied the Ricardian model for valuing the economic impact of climate change on agriculture. While a lot of studies have applied this approach and its advancement outside Nigeria, only few studies have applied the approach for Nigeria's agriculture. Kurukulasuriya and Mendelsohn, 2006 used the Ricardian model to assess the economic impact of climate change in Africa. They employed three time periods of Canadian Global Coupled Model (CGCM2) and Parallel Climate Model (PCM) projections for 2020, 2060 and 2100. Findings indicate warming results in losses for dryland systems, a gain for irrigated cropland, and losses for all African cropland. Precipitation reduction results in reduction for both dry land and irrigated lands but have a much more negative effect on the wetter parts of Africa, namely the central humid band. A continental wide estimation of climate change impact would fail to reflect country specific effects and therefore estimates would be too general.

In contrast to a continental wide modelling, Ajetomobi et al., (2010), used the Ricardian approach for Nigeria's rice economy. Net revenue was the key response variable whose impact was examined. Canada Climate Change (CCC) and the Parallel Climate Model (PCM) climate predictions for 2050 and 2100 under the IPCC emission scenario were used. Dry land rice net revenue per hectare fell at an average of N18, 155.60 per 1℃ increase in temperature whereas irrigated rice net revenue fell at an average of N4864.63 per 1℃. A unit change in precipitation on dry land rice reduce the net-revenue by N52421.50 per annum but increase it by N2657.03 per annum on irrigated rice farm.Similarly, Fonta et al., (2011) used the Ricardian model to analyse the impact of climate change on Nigeria's cocoa plantation. Used net revenue as the key impact variable regressed on climate and soil variables. Used CGM2, HaDCM3 and PCM climate models predictions for 2020, 2060 and 2100 under the Special Report on emission scenarios (SRES) to simulate impact. Findings show reduced net revenue by NG5771.94 while increase in precipitation decreased net revenue by NG86731.3. Net revenue impact to the combined effect of temperature and precipitation reduced by NG92503.3. The CGM2 model simulates a net revenue reduction by 41,187.5(8.98%) for the year 2020.

Similar study using the Ricardian approach has also been done for specific countries of Africa such as Kenya. For example Kabubo-Mariara (2008) used the Ricardian on net income and livestock value. Used HADCM and Parallel climate model (PCM) under A2 emission scenarios to simulate impact.Monthly mean temperatures were estimated from 14 years data (1988-2004) and the mean monthly precipitation was estimated for (1960-1990). Other variables included are household characteristics (farm size, electricity, household size, age and education. A 1% increase in rainfall caused between 153% and 1.19% fall in net value of livestock while temperature caused between 0.42% and 0.85% decline in revenue. A 1 unit rise in temperature, results in 5% increase in net revenue. Used uniform addition of +2.5°C and +5°C temp, and -7%, +7% and +14% changes in precipitation. The Kenya study contrasts with the Nigerian studies by looking at the farm rather than on specific crops.

In multi-cropping farming systems as practiced in many developing countries like Nigeria, single crop analysis might exaggerate the impact of climate on crop farms.Another limitation of the three studies using the Ricardian model is the use of annual net revenue as the response variable. Annual revenue is often influenced by year-by-year variation in weather and prices. Since climate impact is the interest, and not weather impacts, land value measure is more relevant. Land value measure captures farmer's expectations about other things that might change in the future.Mendelsohn et al.,(1994) pioneered the Ricardian model and used the farm value of farms in the US as the response variable. County variables such as social, demographic, and economic data were included. Estimated county-average climate on precipitation and temperature for each month from 1951 through 1980 using spatial statistical analysis. The study used four months in order to capture seasonal effects of each variable. The means have been removed from the independent variables in the regression. The quadratic climate variables are consequently easier to interpret. The linear term reflects the marginal value of climate evaluated at the U.S. mean, while the quadratic term shows how that marginal effect will change as one moves away from the mean. Three models were run. In the first model, only climate variables were included. In the second model both climate and non-climate variables were included. For the climate variables linear and quadratic terms are included to reflect the nonlinearities that are apparent from field studies. To reflect possible differences and heterogeneity across space, two weights were applied. The first uses the cropland weights, in which observations are weighted by the percentage of each county in cropland. The second uses crop-revenue weights; that is, observations are weighted by the aggregate value of crop revenue in each county. Predicted climate by the Intergovernmental Panel on Climate Change was applied uniformly by season and region to generate project impacts. The results suggest a highly non-linear effect on agricultural rents that vary dramatically across seasons.

Wang et al., (2009) used the Ricardian on China agriculture measured by net crop revenues of 8,405 farm households across 28 provinces. Four climate seasons specification was employed namely winter, spring, summer and fall. Three major soil specifications namely clay, sand, and loam soils was used. The unit of analysis was at the county level to relatively match climate data with the socioeconomic data of each farmer. The results suggest that higher annual temperatures slightly reduce net revenues per hectare in China (−10 USD/◦C). Parallel Climate Model (PCM), Hadley CM3 (Hadley), and the Canadian Climate Centre (CCC) were used to simulate impact.

In much of these empirical studies reviewed, climate parameter is specified as calendar months from January to December or quarterly using such terms as winter, spring and summer. In contrast to calendar month climate specification, Schlenker et al., (2006) specifies climate as degree days and argued that it more appropriately captures a nonlinear transformation of the climatic variables. The study decomposed error term into two components, attributable to the location of farm and the error attributable to the specific use of the land. The dependent variable is the county average value of land and buildings per acre as reported in the 1982, 1987, 1992, and 1997 Censuses of Agriculture. Used monthly average temperature and precipitation for the 30 years to specify the degree day agronomic conceptualization. HadCM3 model was used. Specifically, used the model’s predicted changes in minimum and maximum average monthly temperatures and precipitation for four standard emissions scenarios identified in the IPCC Special Report on Emission Scenarios (SRES). The study used the 1960–1989 climate history as the baseline and calculated average predicted degree days and precipitation for the years 2020–2049 and 2070–2099.

Seo et al.,(2009) useda combination of net revenue from livestock and crops on climate, soil, and socio-economic variable with and without country fixed effects. Compared Ricardian regressions with and without country dummies: OLS and fixed effect models. The OLS model predicts that increased rainfall would increase net revenues whereas the fixed effect model predicts that increasing rainfall is harmful, but the rainfall effects vary by Farmers in different AEZs employ different farm practices. The estimated coefficients from both models were then used to predict climate change impacts for 2100 across a range of climate scenarios. The OLS model predicts that the PCM scenario leads to a 12% increase in net revenue, but the CCC scenario leads to a 27% reduction in net revenue for Africa at large. The fixed effects model predicts that net revenue will rise by 19% with the PCM scenario, but will fall by 2% with the CCC scenario.

Seo and Mendelsohn (2008a) used the structural Ricardain model to estimate the behavioural and physical responses of livestock farms. The methodology is a two-stage model in which in the first stage, the probability of choices is modeled and in the second stage, the conditional optimal number species and the net revenue per animal were estimated. Thus total impact on welfare was disaggregated into probability of the species choice, conditional profit per animal and conditional number of animals. The unit of analysis was the household. The study used the Canadian Climate Center (CCC), Center for Climate System Research (CCSR) and Parallel Climate Model (PCM). The impact time scales or frame used are 2020, 2060 and 2100. Uniform addition was used. For all the scenarios, the expected incomefrom livestock farms is expected to drop substantially by 2020, by between 15 and 20%. In the CCC scenario, the loss from livestock sector declines to 10% by 2060 and turns into a large gain by 2100. With the CCSR scenario, the damages increase to 25% in 2060 with more precipitation but then shrink again by 2100.With the PCM scenario, there is a 15% loss of income by 2020, but this loss is offset completely by 2060, and turnsinto a gain by 2100.

Mendelsohn et al.,(2009) used the Ricardian to model the impact of climate on agricultural production in Mexico. Meteorological data included monthly climate normal (30 year averages) from each weather station in Mexico. Used HADCM3 and the Parallel Climate Model (PCM) to simulate impact.Used uniform addition of the model predictions. The PCM scenario is relatively mild, predicting a 2.3◦C warming in Mexico and a reduction of 1.7 mm/mo in annual precipitation. The MIMR scenario predicts an average increase of 5.1◦C and a precipitation reduction of 3.6 mm/mo. The HADCM3 scenario predicts a temperature increase of 5.1◦C with a small increase of 0.4 mm/mo of precipitation. We calculate the change in farmland value per hectare for each climate scenario in each municipio in Mexico. We then average the change in farmland values across all of Mexico to get a total impact for the country.

The third strand of literature consists of studies that have applied the agronomic model in estimating the impact of climate change. Not much has been done for Nigeria. What is common is studies that used econometric method to regress yield on climate and socio economic variables using Cob Douglas production function. The second and third strands of literature are described as end point vulnerability models or adaptation models.

2.8. Review of Literature on Adaptation Modelling in Agriculture

From the perspective of vulnerability, climate change impact modelling can be viewed as end point analysis. In which case gives an estimate of climate change stimuli consisting of systems exposure, sensitivity and adaptive capacity. However, starting point vulnerability analysis looks at the process leading to the end point. Thus climate change impact modeling or adaptation modeling means the same thing as end point and starting point vulnerability modeling. In light of this, there are various strands of empirical literature that have examined a system’s response in the form of adaptation or adaptive capacity or vulnerability generally. Perspectives of starting point vulnerability analysis include natural hazards; agrarian political economy; innovation adoption; agricultural systems and farm decision-making; risk management; and agricultural vulnerability (Smit and Skinner, 2002).

In Nigeria, there are various strands of this literature. There is the strand of literature that looks at the perception of climate change impact and the determinants of adaptation. There is also the literature that employs the profit choice model to model decision making in relation to climate change.Seo and Mendelsohn (2008a) used the profit choice model to examine primary livestock choices of African farmers using the Multinomial probit model specification. In the multinomial logit (MNL) specification model, the errors are independent and identically distributed according to the type 1 extreme value distribution (Greene 2003). The implication of MNL error term assumption is the assumption of the independence of irrelevant alternatives (IIA). That is the probability of an outcome to the probability of some other outcome is independent of every other alternative.

Another profit choice model specification that has been used is the multivariate (MVP). In the MVP model, the errors are not independent and are distributed as multivariate normal (Greene 2003). MVP relaxes the IIA assumption and captures substitutions between alternatives and therefore often taken as a better alternative to MNL. While the MNL scores well on computation, MVP is more flexible (Tse, 1989). Kabubo-Mariara (2008) examined the choice decision of farmers regarding livestock activities in Kenya using a system of equations. Choices are viewed as dependent of each other and a multivariate probit analysis was used. The multivariate probit achieve both flexibility and computational practicability". It has been argued that the multivariate probit is practically appropriate in farming systems in developing countries where farmers are resource constraints and diversify livelihoods to minimize risks. This is also true for Nigeria where for much of the land scape, farmers practice mix cropping and mix farming systems. In multivariate probit analysis, a common practical practice in literature is to approximate it using bivariate approach because of the computational difficulty in estimating three or more equations jointly using the maximum likelihood (Fezzi and Bateman (2011) Kabubo-Mariara (2008) Chang and Mishra (2008)). While algorithms exist that provide accurate calculations for univariate and bivariate normal pdfs, incorporated in many software packages, the evaluation of trivariate and higher-dimensional normal distributions do not exist in these packages. Researchers have turned instead to simulation-based methods that have much better properties (Cappellari and Jenkins, 2003)

Arriagada (2005) modelled a crop response function that links climate and farmers cropping decisions using a mixed logit technique. The technique relaxes the assumption of independence of choices. The study regressed the share of land dedicated to each crop in each county as a function of farm and crop characteristics. One problem in modelling profit choice is the importance of crop prices or input prices in the determination of farmers' land use decisions and profit, the operationalization differ across studies. In some studies the effect of prices on profit is captured by set of fixed effect and in others it is estimated (Seo and Mendelsohn (2008b)

2.9. Review of Literature on Adaptive Capacity Modelling.

Itis increasingly accepted that the vulnerability of agricultural populations to climatic conditions cannot be solely understood through the quantification of biophysical impacts (Wehbe et al., 2005). Social, economic and political factors mediating vulnerability to climate risk have taken important weight in climate change debate. Researchers are moving toward a framework to analyze components of a given system that might either aid or hinder adaptation to climate change (Engle, 2007). Adaptive capacity refers to the magnitude of the potential to cope in relation to exposure and sensitivity components of climate change (Yohe and Tol, 2002) and therefore a component part of the overarching concept of vulnerability. Also captures the agrarian political economy perspective of adaptation to climate change

There is no agreement about the determinants of adaptive capacity at national, community or household levels. (Jones et al., 2010). At the national level, the Intergovernmental Panel on Climate Change (IPCC) identifies economic wealth, technology, information and skills, infrastructure, institutions and equity as the principal determinants of adaptive capacity (IPCC, 2001). Yohe and Tol (2002) listed the indicators of a countries adaptive capacity to includethe range of available technological options for adaptation, the availability of resources and their distribution, the structure of critical institutions, the stocks of human and social capital, access to risk spreading mechanisms, the ability of decision makers to manage risks and information and the public perceived attribution of the source of the stress and the significance of exposure to its local manifestations. Africa Climate Change Resilience Alliance (ACCRA) ACCRA's consultative process identifies five distinct yet interrelated characterisationof adaptive capacity. These are: the asset base, institutions and entitlements, knowledge and information, innovation, and flexible forward-looking decision-making.

Two approaches have emerged to select indicators for vulnerability or adaptive capacity calibration. There is the data driven approach whereby data availability is the central criterion for selection (Neimeijer, 2002). There is the theory-driven approach of selecting the best possible indicators from a theoretical point of view and data availability.Babulo et al., (2008) used the sustainable livelihood framework to identify nine asset-based adaptive capacity indicators. Aulong et al., 2011, Babulo et al., (2008) and Reddy et al., (2004) identified adaptive capacity indicators based on asset base paradigm. Federica and Conforti (2010) pointed out the importance of selecting principal indicators since variables of minor importance hide fundamental aspects of the survey behind a wealth of details. In essence a mix of theory and data availability as well as the policy relevance of the indicators will make a good quality selection.

Another strand of literature discusses the relevant weighting approach and aggregation techniques for the indicators selected. The commonest is the indexing approach. It is used to summarise selected indicators into a single value. Indices have the ability to isolate key aspects from an otherwise overwhelming amount of information and help policymakers to see the larger patterns of what is happening and help them to determine appropriate action (Neimeijer, 2002). Within this approach is another strand of literature that dwells on the various techniques of attaching weights to indicators known as weighting approaches. Filmer and Pritchett (1998)observed four possible approaches:subjectivejudgment, (2) use of common factor such as market or shadow prices applied to all the indicators. (3) Multivariate regression with all the indicators as unconstrained variables and (4) principal component analysis approach. The merit and demerit of each of the weighting techniques have been extensively reviewed in Decancq and Lugo (2010)

The subjective approach might be hampered by the multitude of factors that often define a systems vulnerability or adaptive capacity and as such becomes difficult to find a common factor which could meaningfully be applied to all the factors. Use of market price is difficult in countries where markets are imperfect. The multivariate approach is unsatisfactory because the indicators selected are often correlated and therefore can produce bias weights (Langyintuo and Mungoma, 2008).The use of principal component analysis is often motivated by a concern for the so-called problem of double counting because of the high correlation among indicators selected. There are, however, some drawbacks to the use of PCA. First, is the problem of interpreting the obtained factor loadings or linear combinations of the indicators. Second is the problem of selecting the relevant combinations. Third PCA will assign lower weights to indicators that are poorly correlated. Fourthly weights can be counter-intuitive. For instance, negative weights are can be assigned to valuable indicators. (World Economic Forum 2001)

2.10. Summary of Literature Review

To circumvent the inherent methodological problem of analysing the economic impact of climate change in agriculture several approaches have evolved. A very common approach is the Ricardian partial equilibrium model. From the literature reviewed, there are various indicators upon which the impact of climate change is investigated. These are gross domestic product (GDP), gross and net revenue of agricultural production; and the value of land. In all the empirical studies, temperature and precipitation climate variables were used and were operationalized as average monthly seasonal observation over 30 years period. Future climate is generated through statistical process or arbitrary process. Also to model explicitly farmers' decision making, studies have used profit choice models using limited dependent variable specification such as multinomial and multivariate probit models. Also the political economy of adaptation referred to as adaptive capacity has also been studied using the sustainable livelihood asset framework.

2.11. Conceptual Framework

The process of global warming results in climate changes in the form of changes in precipitation, and temperature; extreme weather events and sea/rive rise. Climate change (CC) refers to changes in the mean and /or the variability of its elements that persists for an extended period typically decades or longer (IPCC, 2007). CC is attributed majorly to anthropogenic causes including agricultural activities. The impact of CC on crop farms is however pursued in this study.

The farm is an agricultural production system over space and time and consists of one or more activities upon which resources are combined to maximize output and profit. Farmholdersare the principal decision makers. They continually make short-term and long-term decisions in response to changes in climate and other global risks in other to maintain or increase returns on their farms[4]. Optimization decisions of holders are linked to the biophysical environment because of the important role of local climatic and physiographic characteristics of the farm on crop selection and growth. Specifically temperature and precipitation are key climatic variables determining agricultural output as well as the choices farmers make in terms of crop and livestock activity choices. Climate affects crop farms directly through the timing, intensity and distribution of temperature and precipitation and also indirectly through diseases, excessive weeds and flooding.

Holders' optimization process can be viewed in relation to long term changes in climate, year to year weather variability, seasonal variability or the frequency of extreme events or all changes put together. This study models farmers' optimization process to long term changes in average climate. It has been posited that even with no change in variability, a change in average climate will affect year to year variability or seasonal fluctuations and the frequency of extreme events (Mearns et al., 1984; Wigley, 1985, Smith et al., (2000)).

[4]Estimates of economic impacts rely either on the link between climate and agricultural production (agricultural process models), between climate and land values (Ricardian approach), or between climate and agricultural profits (profit function approach). These three schools of thought have provided insight on a number of phenomena, the most important of which is that profit maximizing farmers will change crop and farming practices to adapt to any changes in climate, implying that farmer's decisions are, in fact, relevant for estimating the economic impact of climate change(Arriagada, 2005)

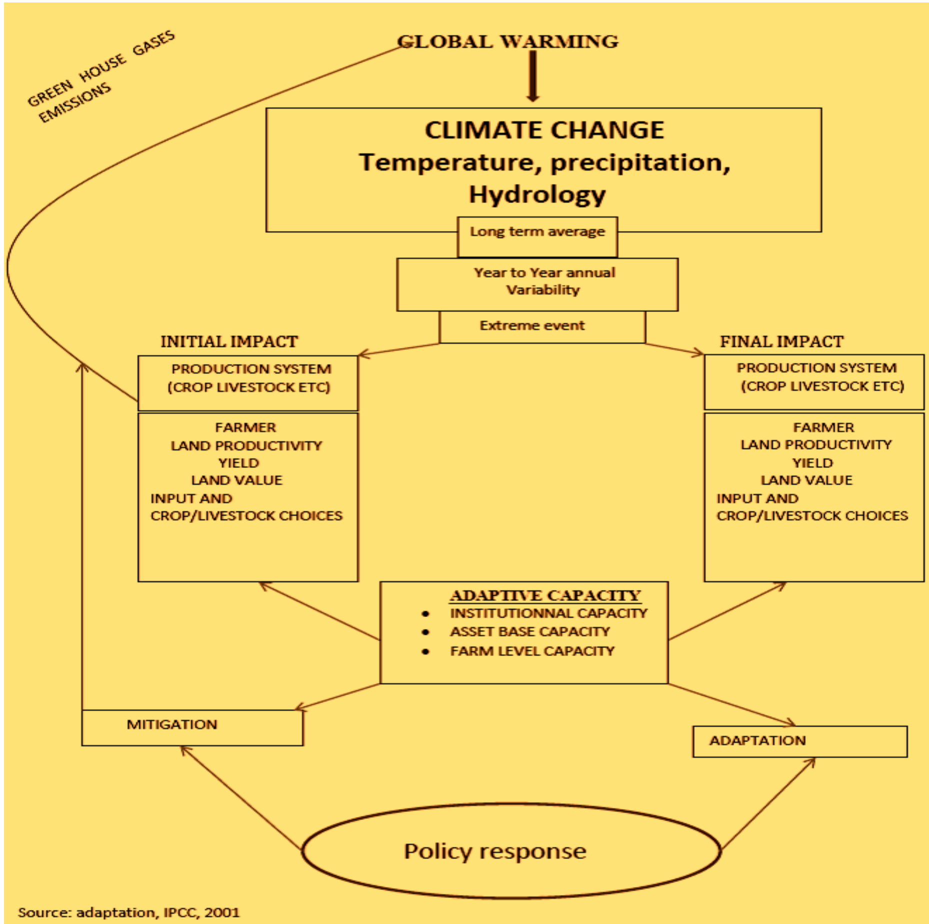
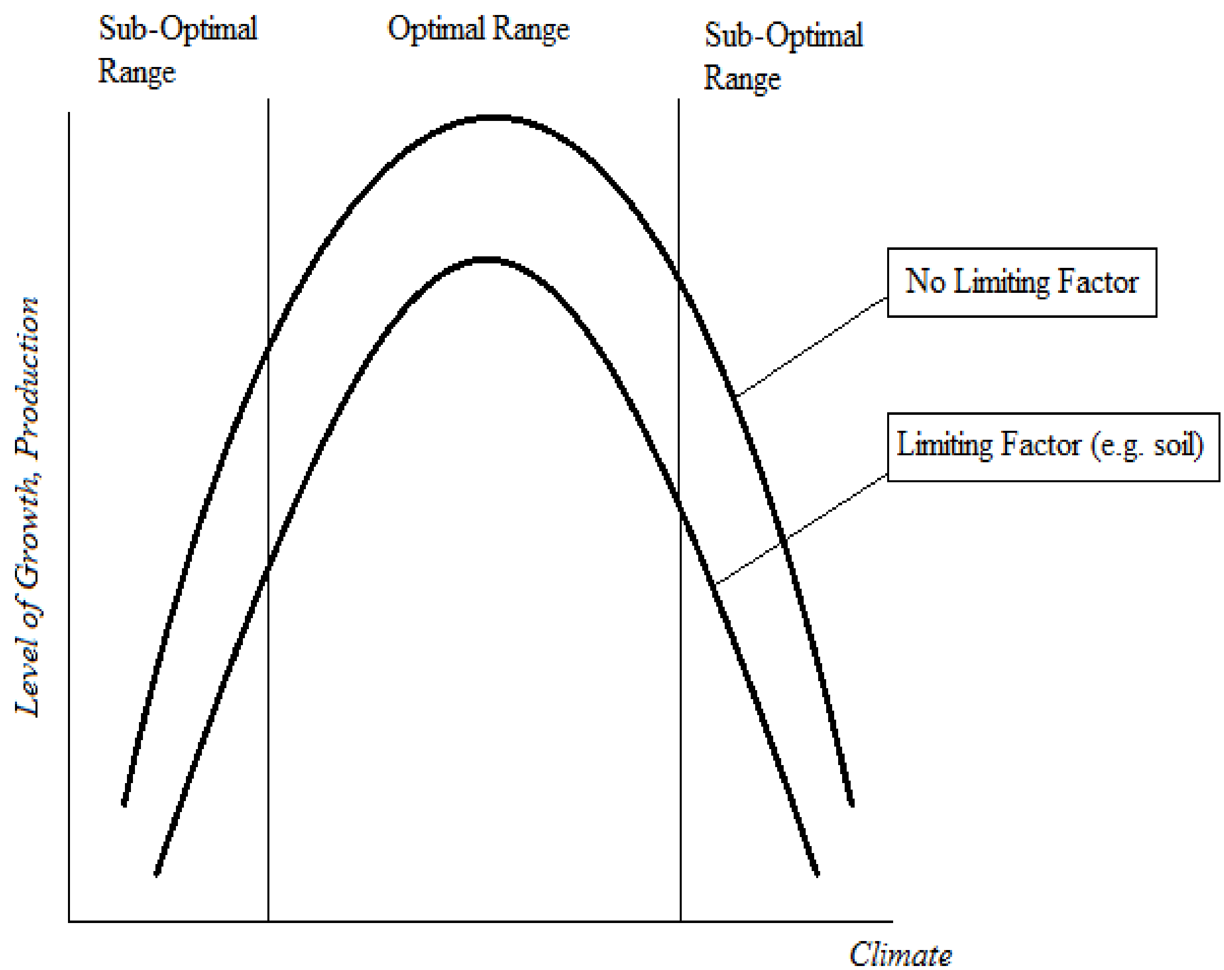


Figure 2.1. Conceptual framework



Source: Mendelsohn and Dinar, 2009

Figure 2.2. Crop development and climate relationship

Agronomic studies suggest a non-linear relationship between agricultural production and climate as presented in the figure below. Non-linearity suggests a maximum and minimum amount of climate beyond or below which revenue on farm declines.Soil attributes are also important limiting factors affecting crop choices and farm revenue. Other important factors are altitude, population density and infrastructural development. In other words, farmers' optimization decisions are influenced not only by factors internal to the farm but external factors including macro drivers such as agricultural policies. Farmers respond to these factors by farm adjustment and adaptive capacity accumulation. The net benefit of these responses over time translates into the value of land.

2.12. Theoretical Framework

2.12.1 RicardianFramework

There are two main approaches to assessing the impact of climate change (Mendelsohn 2007): One approach is the crop yield simulation models, the parameters of which have to be obtained from controlled experiments; the other way is to conduct a cross-sectional analysis farms to determine how farms are linked to their different local climates. This method, usually referred to as a Ricardian approach, corresponds to the Hedonic Pricing of environmental attributes (Lippert et al., 2009).The Ricardian model pioneered by Mendelsohn et al., (1994) is a spatial land use econometric model that has been widely applied at the farm level. One advantage of a Ricardian analysis is that it is based on real-world adaptation measures which have been brought about by a trial-and-error process involving many farmers well acquainted with their specific local production conditions (Lippert et al., 2009). Given that farmers have a well behaved system of inverse demand functions for all goods and services.

$$P_1 = D^{-1}(Q_1, Q_2, \dots Q_n, Y) \qquad (2.2)$$

$$\vdots$$

$$P_n = D^{-1}(Q_1, Q_2, \dots Q_n, Y)$$

Where the Ps and Qs are prices and quantities of good i for all i up to n, and Y represents aggregate income. Given a set of well-behaved production functions that produce a good Qi using purchased and other inputs:

$$\boldsymbol{Q_i = Q_i(X_i, F), \quad i = 1, \dots, n,} \qquad \textbf{(2.3)}$$

$$\boldsymbol{X_i = [X_{i1}, \dots X_{ij}, \dots X_{ij}],} \qquad \textbf{(2.4)}$$

Where X_{ij} is the amount of purchased good $j(j = 1, \dots, J)$ used in producing good Qi. Similarly,

$$F = [F_1, \dots F_l, \dots F_L], \qquad (2.5)$$

Where F_l is an exogenous environmental input $l(l = 1, \dots, L)$ in the production of the goods. Farmers produce output based on the inputs on the right-hand side of equation (3.8). Assuming the same production technology is available to all farmers; farmers will make different input and output choices solely because they face different conditions. Given W_j as prices for the inputs X_j, the set of F_l and the production function (technology of the farmer), cost minimization leads to a cost function:

$$C_i = C_i(Q_i, W, F), \textbf{(2.6)}$$

Where C_i is the cost of producing good i, and $W = [W_1, \dots, W_j]$. Treating land, L_i as a separate input with characteristics F and an annual cost or rent of P_{LF} firms maximize profits given market prices:

$$\max_{Q_i} P_i Q_i - C_i(Q_i, W, F) - P_{LF} L_i \textbf{(2.7)}$$

Firms will equate price with marginal cost and under the assumption of perfect competition, this leads to

$$P_iQ_i - C_i(Q_i, W, F) - P_{LF}L_i = 0 \qquad (2.8)$$

If good Qi is the best use for land given F and W, the observed market rent on the land will be equal to the annual net profits from production of Qi. Rearranging for the value of land:

$$P_{LF} = \frac{P_iQ_i - C_i(Q_i, W, F)}{L_i} \qquad (2.9)$$

The land rent should be equal to the net revenue from land. Taking the present value of this stream of revenue over time suggests that land value, VLE, is equal to the present value of the stream of future net revenue.

$$V_{LF} = \int_0^\infty P_{LF^{-rt}}\, dt = \int_0^\infty \frac{[P_iQ_i - C_i(Q,P,F)]e^{-rt}}{L_i(F)}\, dt \qquad (2.10)$$

Equation 3.14 is the Ricardian formulation and postulates that if producing an output, Q is the best use for the land given exogenous factors, the observed rent on the land is equal to the annual profits from producing Q and that farm value is the present value of future rents. The basic intuition is that climate shifts the production function for crops or livestock and farmers at given locations take climate as given and adjust their inputs and outputs accordingly. It assumes perfect competition in both product and input markets. It assumes that the economy has completely adjusted to the given climate so that farm value has attained the long-run equilibrium that is associated with each county's climate.It assumes prices will not change even if supply changes dramatically. The model does not consider carbon fertilization effects and other channels of climate impact such as sea level rise, extreme weather events other than changes in temperature and precipitation. The model is therefore used to examine the relationship between average climate and the observed 2010 farm value, being the assumed equilibrium value resulting from the prevailing climate in 1961 through 2000. The study specifically uses the model to test the null hypothesis that the inverse relationship between climate and farm value is not statistically different ($H0$: $\beta = 0$) when alpha is equal to 0.05.This relationship will be tested using linear and quadratic temperature and precipitation measures for different calendar seasons for plant growth. From literature a mixed climate and farm value relationship of hill and U-shape is expected apriori. From the parameter estimates, marginal estimates of climate will be derived.

2.12.2. Climate Model Simulation

To simulate what the impact will be in the future, future climate is often used. This is generated from General Circulation models (GCMs) through anthropogenic forcing of future human activities and socio economic development. Future climate assumes various scenarios of greenhouse gas concentration and emissions ranging from low to high. The most recent being the range of emissions scenarios known as the Representative concentration pathways for the ARP5 of the IPCC. The low emission scenario represents a future vision where environmental sustainability plays a central role while the high emission scenario represents a future with business as usual where economic growth with little sustainability policies is the priority. Given variation in climate model predictions two models CGCM2 and HadCM3 are used for this study and of mild emission scenarios. Simulated economic impact is defined as the difference between the expected farm value under current climate, and the expected farm value under future climate.

2.12.3. Profit Choice Framework.

In the pioneering application of the Ricardian approach, response by farmers is considered as instantaneous. The profit response model relaxes this assumption and gives an explicit formulation of the implied adaptation process. Several authors have attempted to model the behavioural response of agricultural production systems, in a bit various ways. Examples include Seo and Mendelsohn (2008a, b), Kabubo-Mariara (2008), Arriagada (2005) and Fezzi and Bateman (2011). The intuition is that climate and non-climate factors enter farmers profit optimization process from which the implicit behavioural adjustment can be estimated. Theoretically consider a given farmer with total available land L and l the vector of h land use allocations for the cultivation of q, the vector of k number of possible crops using a [5]well-behaved production function/technology: $q = q(x, z\ L)$. Production possibility is constraint by the suitability of the land in terms of climate weather and soil characteristics as well as other socio-economic variables z.

The objective function of the farmer is to maximize profit determined by vector x input and vector z environmental factors. Given a vector of p output prices and vector w input prices, the profit maximization problem subject to technological constraint is formally expressed as:

$$\pi = \max_x \{pq(x, z, l_1, \ldots, l_h) - wx\}^{6} \qquad (2.11)$$

The solution to the optimization problem consists of input demand ($x = x(p, w, z)$) and output supply ($q = q(p, w, z)$) estimates. Thus for profit maximization, the farmer chooses the optimal crop type, the amount of land used and output level. The crop type, acreage and output intensity per unit land can be analysed in a unified framework (Mendelsohn and Seo (2008a) for livestock, Fezzi and Bateman, (2011) for structural agricultural land use). This study is interested on farmers' cropping decision and views the observed spatial pattern of crop activities in Nigeria as a product of long term changes in climate and other socio economic factors. The premise is that a farmers' profit maximization decision on acreage planted and the level of output depends on the crop type which in turn depend on the suitability of climate and the cost/price of the crop.

Given an array of feasible crop types$j$ (j = 1, 2. . . J) , farmer's problem is expressed as:

$$\arg\max_j \left[\pi^*(Z_{1i}), \pi^*(Z_{2i}), \ldots, \pi^*(Z_{Ji})\right] \qquad (2.12)$$

---

[5]Farmers are both users of resources and suppliers of agricultural products. The production function underlies the process including the technology. Production technology also means the same as production function. It is described through production elasticities, input substitution possibilities, returns to scale and bias in technology. A production function is well behaved if it is differentiable, quasi-concave and monotonic. The first-order and second-order derivatives must satisfy symmetry, convexity, monotonicity and homogeneity conditions. That is the estimated input demand and output supplies are different from zero(non-negativity). Monotonicity means that output increases in output prices and decreases in input prices.

[6]The equation above reflects a restricted profit function because on the variable costs are deducted from the gross revenue.

The farmer will choose the crop that gives the highest profit per unit land. As climate changes, farmers substitute crops and selects that which is beneficial and profitable as an adaptation strategy. π_{ij}^{*} represent the latent profit of farmer i for crop j as a function of z_{ij} a vector of climate and non-climate factors. π_{ij}^{*} is not observable and therefore specified as a response probability function expressed as:

$$P_{ij} = P_{ij}(\beta) = P_j(z_{i1}, \dots, z_{iJ}; \beta) \qquad (2.13)$$

Where parameter vector β is estimated using the log-likelihood function expressed as

$$L = \sum_{i=1}^{N} \sum_{j=I}^{J} \pi_{ij} \; logP_{ij} \qquad (2.14)$$

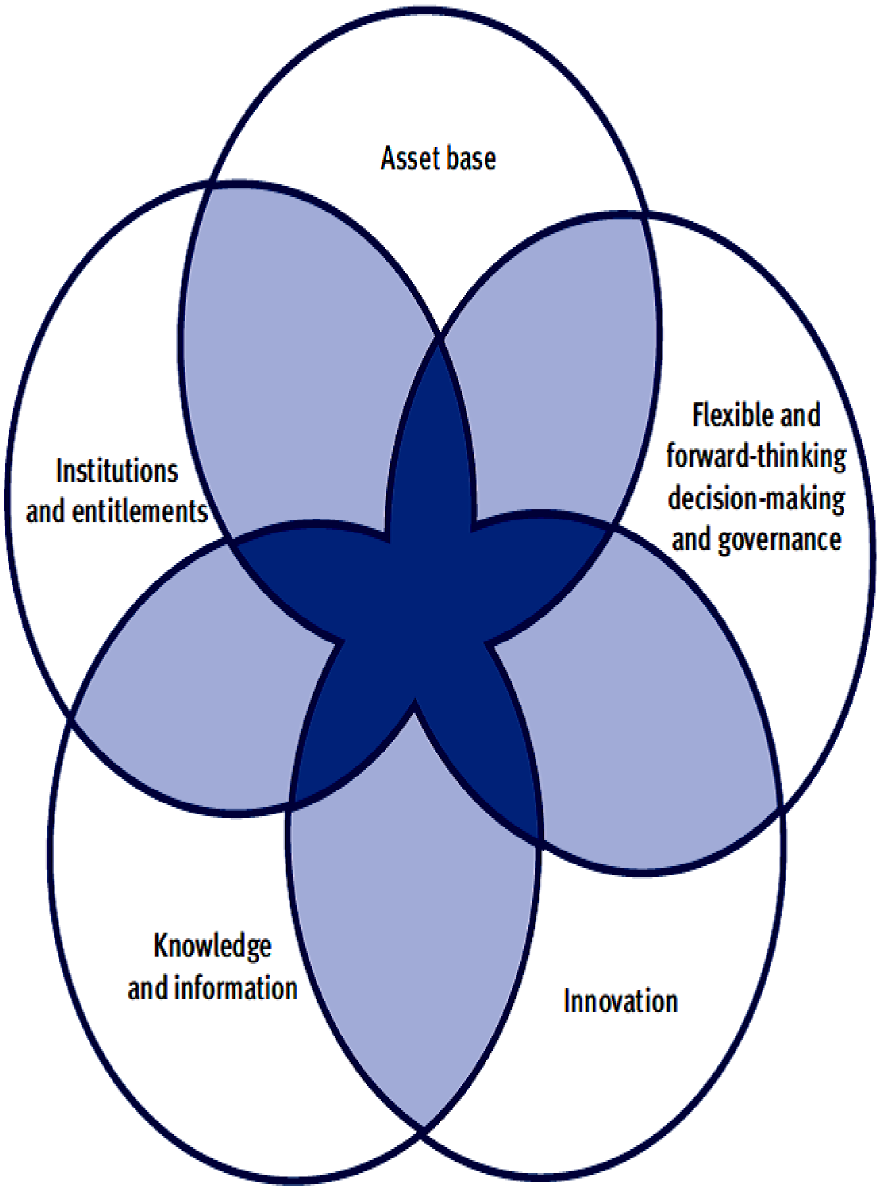
Where π_j denotes observed binary outcome which takes the value 1 if a farmer engages in j crop activity. The importance of probability choice models for the analysis of microeconomic problems is well established in literature (Heckman (1978)). Several approaches have emerged in literature to specify the probability response model. Two common specifications are the multinomial logit (MNL) and the multinomial probit (MNP). In MNL, the errors are independent and identically distributed according to the type 1 extreme value distribution, whereas in MNP model, the errors are not necessarily independent and are distributed as multivariate normal (Greene 2003). The implication of MNL error term assumption is the assumption of the independence of irrelevant alternatives (IIA).

In a mixed farming system, crop choices are interdependent or correlated and therefore MNL might not be appropriate. The multivariate probit (MV) achieves both flexibility and computational practicability (Tse, 1989). It offers a more appropriate specification for modelling crop choices in a mixed farming system such as practiced in Nigeria. However, the complexity that often arises in the use of the multivariate specification is the difficulty of most statistical packages to estimate more than two alternatives jointly. Fezzi and Bateman (2011) reviewed the various approaches that have been proposed in the recent literature on consumer demand system estimation. This includes two-step estimation, minimum distance estimation, simulated maximum likelihood, maximum entropy, generalized method of moments and bivariate approximation. Fezzi and Bateman (2011) used the bivariate approximation to model a sequence of land use share equations with a Tobit specification.

Depending on data availability, analysis can be undertaken at the aggregated level, farm-level and spatially disaggregated level. “Indeed, if the objective is to calculate welfare impacts, farm-level data are the best option. If, instead, the interest lies in capturing the spatial heterogeneity of agricultural land allocation behaviors so as to accurately assess their environmental impact, then spatially disaggregated data are probably the most suitable among those currently available to the applied researcher”(Fezzi and Bateman, 2011). Spatially disaggregated data is a convenient middle ground between aggregated and farm-level analysis and able to produce spatially explicit policy analyses from farm-level data. The disadvantage is that profits data are typically unavailable at this spatial resolution, meaning that the entire structural framework cannot be estimated (Fezzi and Bateman, 2011).

2.12.4. Adaptive Capacity Framework

Adaptive capacity connotes the ability of a system to adjust, modify or change its characteristics or actions to moderate potential damage, take advantage of opportunities or cope with the consequences of shock or stress (Brooks, 2003; Jones et al., 2010). Adaptive capacity is multi-dimensional and “there is no agreement on what constitute it(Jones et al., 2010). Various interdependent characterisations exist from which analysis at the farm level can be undertaken. This is presented in the form of a Venn diagram below.



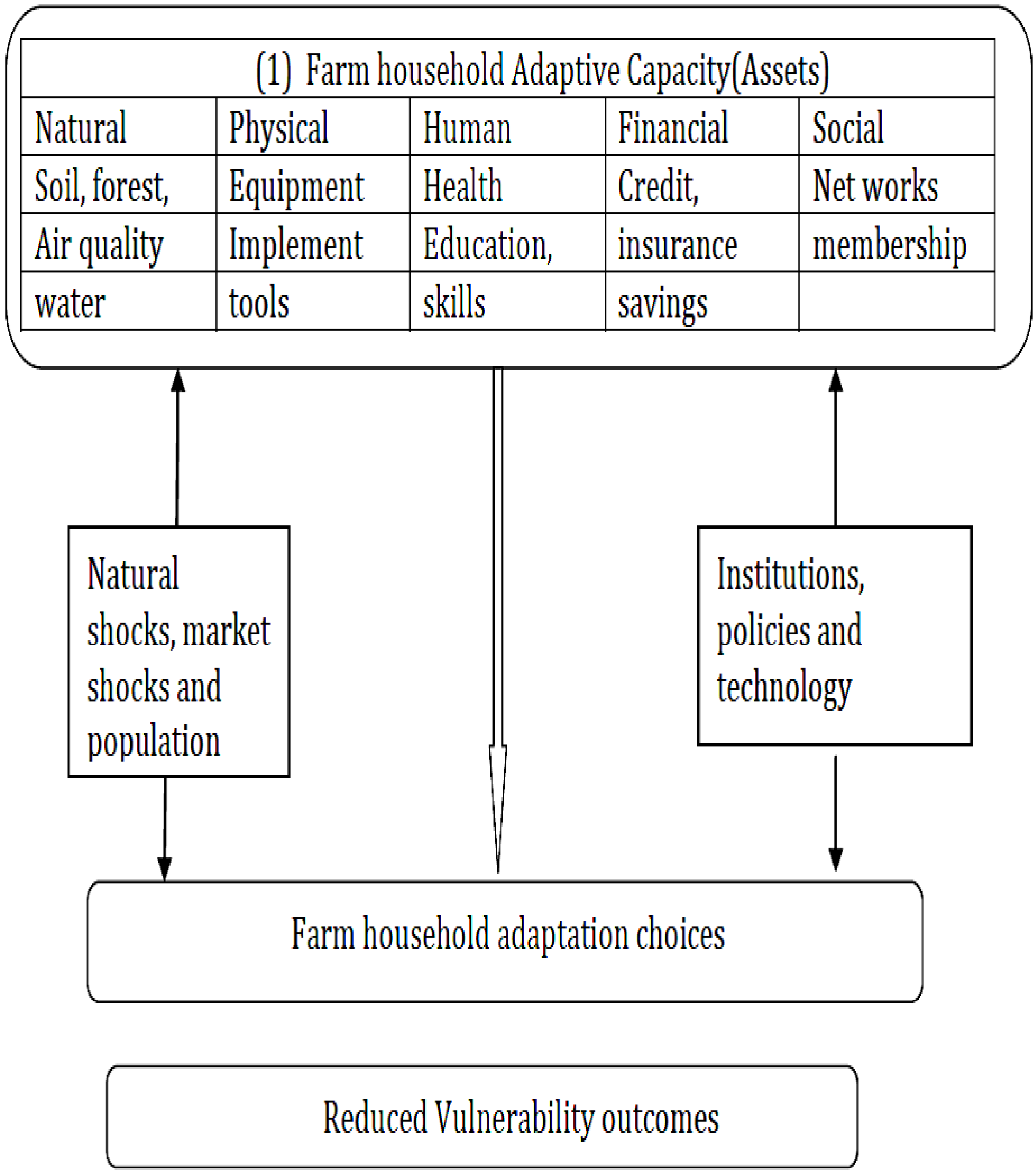
Source: Jones et al.,(2010)

Figure 2.3. Adaptive capacity components

The asset based adaptive capacity characterisation is addressed in this study because it is helpful in understanding the resources at the disposal of farmers. Furthermore reveals the implied processes and functions supporting farm household effective and efficient operation in a changing climate. The nature of adaptive capacity indicators presents measurement problems. Consequently previous studies have generally relied on theoretical underpinning as well as data availability. Several studies have used the sustainable livelihood framework to identify five broad assets at the farm level (Babulo et al., (2008), Aulopng et al., 2011 and Reddy et al., (2004)).These are natural, financial, physical, social and human capital (Carney, 1998; Davies, 1996; Soussan et al., 2000). Thus adaptive capacity defines a vector of assets owned by farm households or in which they have access to in response to perceived climate and non-climate shocks such as drought, flooding, and market prices.

These assets make adaptation choices feasible. For example, it is well acknowledged that resource poor farmers are often reluctant to invest in newly introduced improved agricultural technology because of limited cash resources and/or access to credit. Agricultural production at the farm level depends on access to information, capital and credit, and rural infrastructure. Farmers must have access to information about farmingpractices before they can consider adopting them. Societal construction such as gender discrimination may also make it difficult for some women to gain access to complementary inputs as well as relevant information.

The assets are continually interacting to determine the adaptive capacity of a community or household. For example, social capital may increase adaptive capacity by allowing greater access to bank loans, agricultural labour. Access to financial resources may facilitate access to new technologies and training that will in turn enhance greater networking and political voice.



Source: Adapted from Babulo et al.,(2008)

Figure 2.4. Asset based adaptive capacity analytics

The indexing technique is the commonest approach that has been employed in aggregating several indicators that are interrelated for policy use. Filmer and Pritchett (1998) observed four indexing approaches: subjectivejudgment, (2) use of common factor such as market or shadow prices applied to all the indicators. (3) Multiple regression and (4) principal component analysis (PCA). Decancq and Lugo (2010**)** reviewsthemerit and demerit of each indexing technique**.** The subjective approach is hampered by the difficulty of finding a common factor which could meaningfully be applied to all the factors defining systems vulnerability. Use of market price is difficult in countries where markets are imperfect. Multiple regression approach is unsatisfactory because indicators are often correlated (Langyintuo and Mungoma, 2008). The multivariate approach such as the principal component analysis is often motivated by the problem of interdependency of indicators and double counting. It provides potential advantages in the aggregation of spatially explicit, potentially incommensurable variables.(Abson et al., 2012 for detail description of the PCA).Therefore the commonest approach for estimating interdependent indicators.

Consider a set of k indicators, a_{1j}^* to a_{kj}^* representing the asset of each farm household j. each asset is normalized by its mean and standard deviation expressed as: $a_{1j} = \left(a_{ij}^* - a_i^*\right) / s_1^*$ where a_i^* is the mean of a_{ij}^* across households and s_1^* is the standard deviation. The aim is to scale the variables from 0 to 1. Once [7]normalized, the indicators can be added together.

$$a_{ij} = v_{11}A_{1j} + v_{12}A_{2j} + \cdots + v_{1k}A_{kj} \,\forall j = 1, \ldots, j \qquad (2.15)$$

$$a_{k1j} = v_{k1}A_{1j} + v_{k2}A_{2j} + \cdots v_{kk}A_{kj} \qquad (2.16)$$

The solution for the problem is indeterminate because only the left-hand side of each line is observed. To overcome this indeterminacy, PCA finds the linear combination of the indicators with maximum variance, usually the first principal component A1j, and then a second linear combination of the indicators, orthogonal to the first, with maximal remaining variance, and so on. Technically the procedure solves the equation $(\mathbb{R} -$

[7]without the elementof distortion which would be introduced by widely differing value ranges

$\lambda I)v_n = 0$ for λ_n and v_n where R is the matrix of correlations between the scaled indicators (the as) and v_n is the vector of coefficients on the nth component for each indicators. Solving the equation yields the Eigen values (or characteristic roots) of R, λ_n and their associated Eigen vectors,v_n . The final set of estimates is produced by scaling the $v_n s$ so the sum of their squares sums to the total variance. The scoring factors from the model are recovered by inverting the system implied by eq(1), and yield a set of estimates for each of the k principal components:

$$A_{ij} = f_{11}a_{1j} + f_{12}a_{2j} + \cdots + f_{1k}a_{kj} \forall j = 1, \dots, j \quad (2.17.)$$

$$A_{k1j} = f_{k1}a_{1j} + f_{k2}a_{2j} + \cdots f_{kk}a_{kj} \quad (2.18.)$$

The first principal component, expressed in terms of the original (un-normalized) indicators, is therefore an index for each household based on the expression:

$$A_{ij} = f_{11}(a^*_{ij} - a^*_1)/(s^*_1) + \cdots + f_{1k}(a^*_{kj} - a^*_k) / (s^*_k) \quad (2.19)$$

2.13. Scope and limitation of the Study

The paucity of climate data covering decades and data on production and consumption decisions at the farm level limited the study to cross sectional analysis of farms using the Ricardian model. Analysis was done at the local government level, the finest geographical location possible rather than the plot level because of the absence of plot level geographical coordinates need to downscale plot level climate variables.

Although land value or farm revenue used in the Ricardianis dynamic depending on past and future realisations, a static analysis was applied using weighted ordinary least square regression to capture at least the spatial heterogeneity of the land value estimate

The study is limited by the difficulty in isolating other important factors influencing land value other than climate. Simulated impact analysis assumed constancy of prices, CO_2, technology and infrastructural development over time except for climate variables specifically temperature and precipitation that are assumed to vary. Furthermore simulation was limited to only two Global Climate Model (GCM) projections within the low emission scenarios and a time span of 2050 and 2070. There are projections for low, medium and high Green House Gases emissions for different time spans. These projections often vary across climate models. The study was limited to the use of just two climate models because of the difficulty in downloading the projections. It requires steady and fast internet facility. This was problematic in Nigeria.

Climate data such as temperature and precipitation observed at weather stations are often incomplete particularly in developing countries. In Nigeria, the climate data from the National meteorological agency (NIMET) is ground base but comes with missing data and only few weather stations are available. Not all local government area council have weather stations. Thus the climate data from Worldclim data base was used. This was downscaled for each of the local government area in Nigeria.

It is possible to have done the analysis across ecological zones or geopolitical zones, this study used the agricultural zone classification: North West, North East, North Central, South West, and South East zones, for the purpose of agricultural and farming systems development (Chukwuone et al., 2006). These five zones also align with the ecological differences in vegetation and rainfall pattern.

Only five principal component factors were used to explain the relative importance of the indicators differentiating farmer's access to management imperatives. The choice of the number of PCs to be retained is subjective and is generally based on the interpretability of the retained components (Srivastava, 2002).

Soil quality variables used were assumed to be homogenous within states and heterogeneous between states. This however is a strong assumption because within each locality there could be extensive variation in soil quality. Hydrology is an important factor affecting differences in land value and this was not included because of the difficulty of assessing such data.

CHAPTER THREE
METHODOLOGY

3.1. Study Area

The total area of Nigeria is 923,768km² of which 910,768km² is land, while water takes up 13,000 km². Nigeria's total boundaries are 4,047km in length. The border with Benin is 773 km, with Cameroon is 1,690km, Chad's is 87km, and Niger is 1,497km. It is considered tropical in climate with a wide variety of micro climates. The altitude is generally low with some moderate mountains in the Central Plateau and in the east. Vegetation ranges from mangrove swamps along the coast to Sahel type along the border of the Sahara in the north. Nigeria's climate is characterized by strong latitudinal zones, becoming progressively drier as one moves north from the south. The months between February and April in the south and between March and June in the north are the hottest. The harmattan weather brings about a minimum, temperature below 20c around December. At a soil depth of 5cm, under natural forest conditions, the temperature remains relatively constant throughout the year at about 25+- 2c at 7.30 am and about 27+-2c at 3.00pm. Under base land conditions, diurnal fluctuations in temperature can be between 20c to 30. The rains occur only from April to November in the south, with a short break in August and from May to October in the north. The rainfall intensity rates are similar over the country. High intensity rains are usually of short duration and occur less frequently in the coastal areas of the country and relatively more frequent at inland stations (Ilesanmi, 1972). The kinds of natural vegetation in Nigeria range from mangroves and fresh water swamps along part of the coastal area to the Sahel Savannah in the north. The natural vegetation cover is one of the major factors in determining the kinds and production potentials of the soil developed on the prevailing parent soil material. Agricultural activities are patterned along ecological and agricultural zones. There are 18,176,082 crop holders over a cropped land area of 32,031,825 and tree crop area of 4,757,175.94. Average land size is 1.76 hectares (NBS/CBN/CCC, 2012)

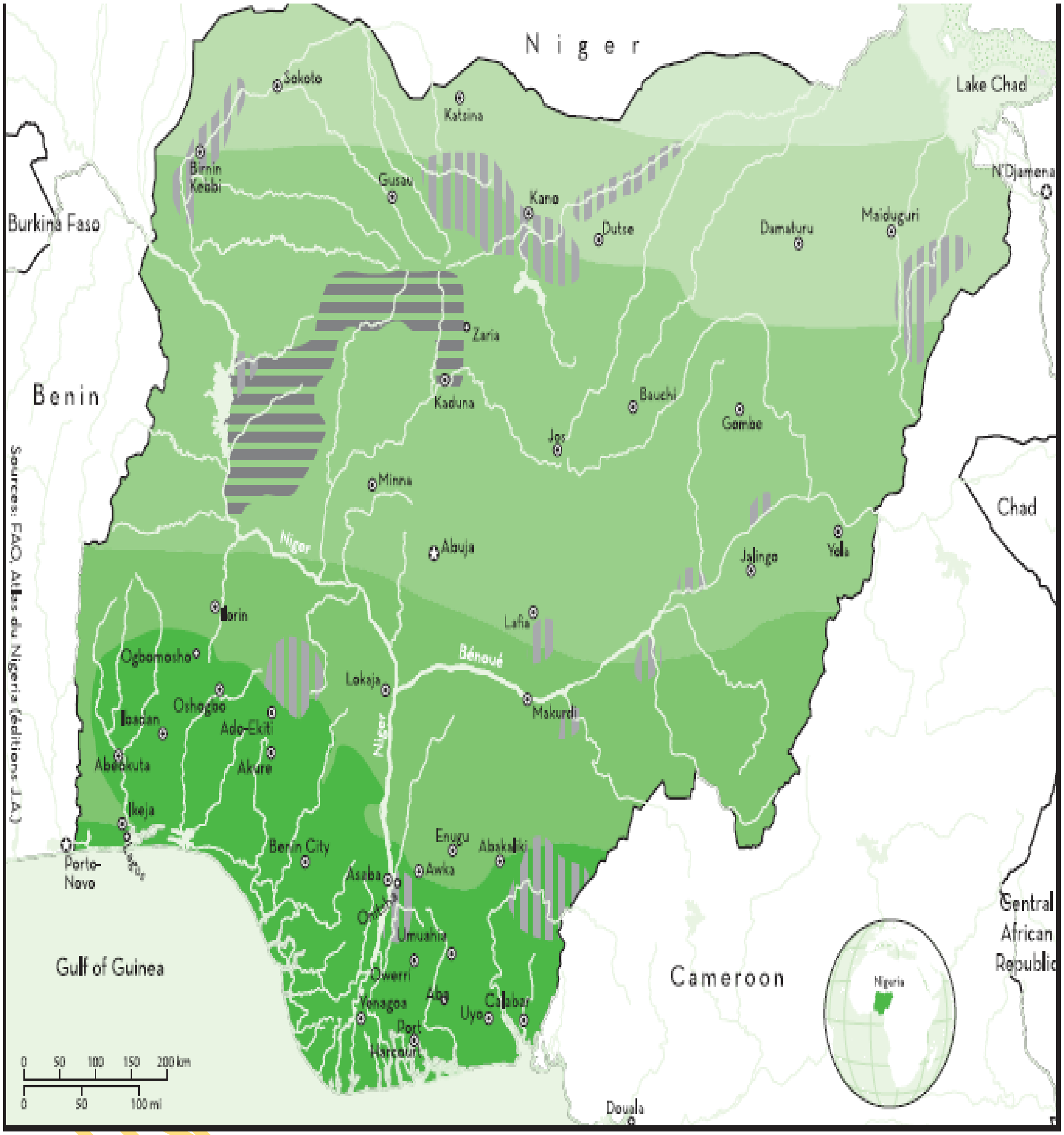


Figure 3.1.Agro ecological map of Nigeria

3.1.1. Sources and Nature of Data

3.1.2. Socio Economic Farm Data Source

Secondary data was used. Farm data and socio economic characteristics of farmers were sourced from the National Bureau of Statistics (NBS). NBS is the National agency in Nigeria that has the speciality of providing robust and timely data for policy makers and researchers. The data set is part of the existing data modules of NBS to help evaluate agricultural and socioeconomic development in Nigeria. Relevant to this study is the first round of the General Household Survey (GHS) data with panel component collected in 2010. The sample frame includes all thirty-six (36) states of the federation and Federal Capital Territory (FCT), Abuja. Both urban and rural areas were covered. Households were selected at the state level using a two stage stratified sample selection process. In the first stage the Primary Sampling Units (PSUs) or Enumeration Areas (EAs) are selected. In the second stage households per EA are systematically selected. The sample size is 5,000 households. The survey covered three sets of data corresponding to household, agriculture and community questions. The data set has household response status of 99.72 %(4,987) out of 5000 respondents interviewed, from this amount, 96.67% of households gave complete information (4676). For analysis that requires farm household level data, plot level information and individual level information were aggregated accordingly while for spatial analysis, data were disaggregated to local government area council. The questions ask for the selection of the variable can be found in the appendix

3.1.3. Baseline Climate Data

The climate data for this study was sourced from the World clim data base (Hijmans et al., 2005, available at http://www.worldclim.org). It was developed from weather stations globally using the Thin Plate Smoothing Spline (TPS) algorithm (Hutchinson, 1995). Different spatial resolutions are possible but the climate surfaces at 30 arc-second spatial resolution (~1km at the Equator) are the finest possible for Nigeria. The datasets are in .*clm*and.*cli* files. These were downloaded. Next, the spatial data were projected into the UTM zone 32N coordinate system using ESRI ArcGIS 10 version.Nigeria boundary map was overlaid on the shape-files to query regions within its boundary. The site has current climate (1950-2000) and Future projected climate (2050, 2070). The various climate parameters for each Local Government Area (LGA) were extracted and exported to Microsoft Excel for further analysis.

3.1.4. Projected Climate Data

The World clim data base also contains future climate data predicted by various Global Circulation Models (GCMs) over various emission scenarios. It starts with the projected change in climate variable computed as the difference between the output of the GCM run for the baseline years (e.g., 1960 -1990) and for the target years (e.g. 2050, 2070). These changes are interpolated to a grid with a high (~ 1 km) resolution. These high resolution changes are then applied to high resolution interpolated climate data for the "current period" (in this case the World Clim dataset). That is the corresponding future climate was derived by applying these changes to the 1km current climate (1950 – 2000) representing the baseline climatic conditions for this study. Some studies done in Nigeria applied the predicted global climate changes on current climate arbitrary. This approach has no real physical basis and does not preserve consistency among climate variables (Roudier et al., 2011). Global climate predictions vary across climate models and emission assumptions. Therefore I used the Hadcam3 and CGMC2 projected future climate for the near term (2050) and the long term (2070) over low and high emission scenario. From the data set, seasonal climate measures were constructed. The annual is the average (January – December) while seasons are wet season (April – October), dry season (November – March) and quarterly seasons using the Excel spread sheet.

3.1.5. Soil/ Population and Altitude

Complementary data on population, soil and altitude for each Local Government Area Council were sourced from National Population Commission (NPC) and Food and Agriculture Organisation (FAO).

3.1.6. Analytical Procedure.

3.1.7. Estimating crop activity choice.

The aim is to examine the spatial pattern of farmers cropping decisions in response to climate change. Given an array of feasible crop choices j(j = 1, 2. . . J), the problem of the farmer is that of profit maximization. Climate and non-climate factors (Z) enter the decision process through the effect on profit from which crop choices are estimated. The profit maximization problem is expressed as:

$$\arg\max_j \left[\pi^*(Z_{1i}), \pi^*(Z_{2i}), \ldots, \pi^*(Z_{Ji})\right] \qquad (3.1)$$

$$\pi^*_{ji} = V(Z_{ji}) + \varepsilon_{ji} \qquad (3.2.)$$

π^*_{ij} represent the latent profit implied by a farmer's choice of crop j as a function of both observable and unobservable factors ε. It takes the value of 1 if a farmer cultivates crop j. Taking the derivative of the equations above with respect to Z gives the probability of observing the jth choice.

$$\Pr(\pi_j = 1) = \Phi(Z`\beta_i), for\ j = 1, \ldots, J \qquad (3.3)$$

In much of Nigeria's farming landscape, mixed cropping pattern is commonest. Some of the crops are substitutes while others are complementary suggesting possible interdependence across crop choices. This study employs multivariate probit model to specify the farmers' implicit choice on the following cropping activities: sorghum(S), millet (L), rice(R), cowpea (P), cassava(C), yam(Y) and maize (M). This results in a joint probability of observing all possible alternatives from a J-variate standard Normal distribution

$$\Pr(\pi_j = 1, \ldots, \pi_J = 1) = \Phi(Z`\beta_1, \ldots, Z`\beta_J; \Sigma), \qquad (3.4.)$$

The seven cropping activity choice equations expressed as:

$$Prob(maize) = V(Z), = 1(\pi_1^* > 0) \quad (3.5.)$$

$$Prob(cassava) = V(Z), = 1(\pi_2^* > 0) \quad (3.6.)$$

$$Prob(sorghum) = V(Z), = 1(\pi_3^* > 0) \quad (3.7.)$$

$$Prob(rice) = V(Z), = 1(\pi_4^* > 0) \quad (3.8)$$

$$Prob(cowpea) = V(Z), = 1(\pi_5^* > 0) \quad (3.9)$$

$$Prob(yam) = V(Z), = 1(\pi_6^* > 0) \quad (3.10)$$

+*

$$Prob(Millet) = V(Z), = 1(\pi_7^* > 0) \quad (3.11)$$

Table 3.1. Dependent Variable Definition

Dependent variables	Definition
Crop selection	
Selection of sorghum	1= sorghum cultivated on plot
	0= no sorghum on plot
Selection of millet	1= millet cultivated on plot
	0= no millet on plot
Selection of rice	1= rice on plot
	0= no rice on plot
Selection of cowpea	1=cowpea on plot
	0= no cowpea
Selection of cassava	1=cassava on plot
	0= no cassava on plot
Selection of yam	1= yam on plot
	0= no yam on plot
Selection of maize	1= maize on plot
	0= no maize on plot

Source: Author's compilation

Z captures a vector of independent variables made up of climate and non-climate variables defined as follows:

Z=vector of independent variables defined as

X1	ANNT(AV.Jan-Dec)^{0}C/month)		X12	Fertilizer _PRICE
X2	SQUARED ANNT		X13	Distance to output market
X3	ANNP(AV. Jan – Dec) mm/month		X14	Distance to input market
X4	SQUARED ANNP		X15	percentage silt in top soil
X5	C_PRICE	N/kg	X16	percentage clay in top soil
X6	M_PRICE	,,	X17	percentage sand in top soil
X7	L_PRICE	,,	X18	Altitude
X8	R_PRICE	,,	X19	Population density
X9	P_PRICE	,,	X20	Socio economic index 1
X10	Y_PRICE	,,	X21	X21=socio economic index 2
X11	X11=Lab_PRICE	N/day		

Climate variables represent the key explanatory variable of farmer's profit choice crop. Temperature and precipitation were specified as annual average from January to December as well as seasonal averages. The seasonal specification includes the wet season average from April to October, and the dry season average from November to March. Also included are quarterly seasons defined as (March – may), (June – August), (September – November) and (December – February). The specification is both linear and quadratic following the extant literature.

Soil/farm Variables

For the environmental variables, clay, silt and sand content are included as rough proxies for soil quality. Other variables included farm altitude. Altitude proxies the diurnal cycle (Reinsborough, 2003

Input and out prices

Crop output prices are found in the GHS community modules. In terms of input, prices for fertilizer and labour were used from the same data set. Differences in prices across local government areas reflect mainly differencesin transportation costs and distance to markets.

Socio economic index/population density

For example growth in income might influence the cultivation of rice for urban population. Also growth in population might drive intensification. Population density captures urban/rural characteristics (Reinsborough, 2003)

The various equation groups are each jointly estimated in stata 11 using the mvprobit program developed by Cappellari and Jenkins (2003). Analysis is undertaken at a spatially disaggregated level whereby the local government area council is the finest location that matches with climate and other environmental land use drivers and at the same time the closest approximation of farm household response behaviour. The advantage of a multivariate probit approach is that it allows correlations among alternative choices as well as potential correlation among unobserved error terms. In the multivariate approach, the error terms jointly follow a multivariate normal distributions (MVN7) with zero conditional mean and variance normalized to unity (for reasons of parameters identifiability), where $(\mu_M, \mu_C, \mu_S, \mu_R, \mu_P, \mu_Y, \mu_L) \sim MVP_7(0, \Omega)$ and the symmetric covariance matrix is given by:

(3.12)

$$\Omega = \begin{bmatrix} 1 & \rho_{MC} & \rho_{MS} & \rho_{MR} & \rho_{MP} & \rho_{MY} & \rho_{ML} \\ \rho_{CM} & 1 & \rho_{CS} & \rho_{CR} & \rho_{CP} & \rho_{CY} & \rho_{CL} \\ \rho_{SM} & \rho_{SC} & 1 & \rho_{SR} & \rho_{SP} & \rho_{SY} & \rho_{SL} \\ \rho_{RM} & \rho_{RC} & \rho_{RS} & 1 & \rho_{RP} & \rho_{RY} & \rho_{RL} \\ \rho_{PM} & \rho_{PC} & \rho_{PS} & \rho_{PR} & 1 & \rho_{PY} & \rho_{PL} \\ \rho_{YM} & \rho_{YC} & \rho_{YS} & \rho_{YR} & \rho_{YP} & 1 & \rho_{YL} \\ \rho_{LM} & \rho_{LC} & \rho_{LS} & \rho_{LR} & \rho_{LP} & \rho_{LY} & 1 \end{bmatrix}$$

The off-diagonal elements in the covariance matrix, for example ρ_{MC} represent the unobserved correlation between the stochastic component of the maize and cassava crop alternatives. If ρ =0, univariate probit model is used to estimate the equations while if, $\rho \neq 0$ joint estimation is required. The multivariate probit equations can be estimated simultaneously or recursively. The estimation of a recursive multivariate probit requires identification of the equations. In the widely used strategy, equations are identified if there exists at least one varying exogenous regressor (Maddala, 1983). This can be operationalized by including all variables in the equations and omitting variables from equations in which they are insignificant. In this study prices of crops are good identification strategy.

Investigating the null hypothesis that the covariance of the error terms across equations are not correlated (p=0) allows the test of substitution possibility and interdependence across crop choices. Secondly investigating the null hypothesis that the linear and quadratic specification of climate variables are not significantly different from zero (b=0, 2b=0) allows us to test the response shape of farmers choices. When the linear term is negative and the quadratic term is positive, the function is U-shaped, and when the linear term is positive and the quadratic term is negative, the function is hill shaped. Several other shapes are possible depending on the relative signs of the linear and quadratic terms (Mendelsohn and Dinar, 2003, Benhin, 2008)**.**The marginal effects are generally not inferred from the parameter estimates because it is the nonlinear functions of the parameter estimates and the levels of the explanatory variables. To estimate the marginal effect on the probability of selection I used the formula as documented in Kabubo-Mariara (2008)

$$\frac{\partial P_j}{\partial F} = \left(1 - P_j\right) * P_j * [\beta_1 + 2\beta_2 F] \tag{3.13}$$

Where

$$\frac{\%\, change in probability of selection P \quad (U)}{\%\, change in temperature or precipitation \quad (z)} = \left(1 - P_j\right) * P_j * [\beta_1 + 2\beta_2 F] \tag{3.14.}$$

$\left(1 - P_j\right)$= Probability of selection when π_j =0

P_j = Probability of selection when π_j =1

β_1= linear specification coefficient

$2\beta_2$= quadratic specification coefficient

F= Average temperature or precipitation.

To operationalize this formula all explanatory continuous variable were centred at the mean by taking deviations from the mean resulting in 0 value for the normalized variable. Thus the quadratic specification infers the shape whiles the linear specification is used to derive marginal impact. Estimated probability is recovered from the MV probit equations (probability of selection) and used to multiply the parameter estimates to give the marginal effect (change in probability of crop or livestock selection). Simulated impact is the percentage change in the probability of livestock and crop selection defined as the difference between the future marginal estimates and the base line multiplied by 100. Thus the output generated is the estimated probability, marginal effect and impact in 2050.

3.1.8. Estimating Climate Change Impact

The equation is a climate-land value regression whereby farm value per unit acre is regressed on climate and non-climate controls.

$$LandValue_i = \beta_0 + \beta_{1i} F + \beta_{2i} F^2 + \beta_{3i} Z + \beta_{4i} S + \varepsilon_i \tag{3.15}$$

Dependent VARIABLES

(1) Farm value(N/ha) (2) Farm revenue (N/ha)

Independent variables

Climate variables (F)	**Non climate variables(Z)**
F1= Av tempt (0C/month)	**Z1=% sand in top soil**
F2=Av. Squared tempt	**Z2= % Silt in top soil**
F1=Av. Ppt(mm/month)	**Z3= % clay in top soil**
F2=Av. Squared ppt	**Z4= latitude**
	Z5= altitude
Soil economic characteristics(S)	**S1= Population density**
S2= Socio economic index 1	**S3=socio economic index 2**

Source: Author's compilation

Where F and F^2 denotes the linear and quadratic specification of various climate variables respectively, Z the soil quality variables and S the socio economic variables. βandε represent the coefficients and error terms. The error term follows the classical assumption of an independently and identically distributed (iid) normal error distribution. F denote the key explanatory variables which are long term climate normal specifically temperature and precipitation which is consistent with the extant literature. However seasonal and monthly specifications have been suggested. In this study, these seasons are defined as wet season (April – October) and the dry season (November – March). Z represents non-climate variables such as percentage clay soil, percentage sandy soil and percentage loamy soil. Population density, latitude and altitude. S denote socio economic characteristics of farmers. In the date set used the socio economic characteristics are many and in order not to make the model noisy, index were created using principal component analysis.

Literature reveals several ways of measuring farm value. There is farmers' own perception of the worth of their farms. There is the net revenue and some studies have also used gross revenue in situations where input variables are not available. The use of land price has also been suggested. This study uses the various land value conceptualization as endogenous variables, testing whether climate change impact predictions are different across land value conceptualization.

The functional form of the model is often linear or semi log specification with a quadratic specification for the climatic variables and linear function for all other determinants. A log transformation of the dependent variable outperforms a linear specification since the distribution of land values is non-negative and typically highly skewed (Fezzi and Bateman, 2012). Thus both functional forms will be explored for the best fit. The unit of analysis is the area council level. This reduces the challenge of linking farm level economic observation with observations collected over larger geographical space such as climate and soil variables. Polsky and Easterling (2001) propose the importance of specifying spatial effects in a Ricardian model. The aim is to capture the role of social interactions in the process of land use and other spatial effects. Mendelsohn used two weighting mechanism, revenue and yield to capture spatial effects on land use. The marginal impact is calculated:

$$\frac{\partial LandValue}{\partial f_i} = (LandValue)^* b_{1i} \qquad (3.16)$$

Where b_{1i} is the estimated coefficient for variablef_i. With squared terms included the marginal effect following the documentation in Mendelsohn et al.,(2009) is calculated as:

$$\frac{\partial LandValue}{\partial f_i} = (LandValue)^* (b_{1i} + 2b_{2i} f_i) \qquad (3.17)$$

The annual marginal values are calculated by summing both the linear and squared coefficients in the above equation and average climate values (*f*) and then multiply by the expected value of the land.

3.1.9. Estimating Adaptive Capacity

3.3.3.1.Selection of Indicators and Measurement

Indicators selected were informed by previous studies that used the sustainable livelihood framework as applied to climate change. Selection was also based on policy relevance in the agricultural sector and to the extent the data set used allowed. In all, 42 indicators were selected and categorised into five broad assets..

Human capital: There are many sources of human capital but we used proportion of households that are literate, number of years of education, household size and age. Literacy and education reflect the ability to access information while age is associated with experience and limitations. Access to health practitioners in the last four weeks prior to the survey and distance to health facilities are included as health variables. Access to government extension services is a reflection of farmers' knowledge and skill on agricultural production and marketing. **Natural capital** is measured in terms of access to underground borehole water sources and surface water sources. Also included is access to forest trees and livestock ownership. **Physical capital** includes machinery and mobile phones. Also included hours of electricity in the last seven days before the survey. Acreage planted is measure in hectares and proxies the availability of land for crop production and livestock rearing. Also included access to both subsidized and commercial seeds and fertilizer, draught animal traction and farm equipment. Access to farm inputs is among the critical factors that discriminate farmers in terms of the capacity to engage in agricultural production in Nigeria.

Financial capital is measured in terms of access to formal and informal credit, wage income and access to agricultural insurance. Access to financial capital in the form of formal and informal rural credit will discriminate farmers in terms of the ability to raise the necessary amount needed to purchase fertilizer, seeds and other inputs. Off-farm income such as remittances and wage income are important sources of income complementing farm income in rural Nigeria. It is common practice that rural households receive transfers in kind or cash from family members and relatives. Access to remittances also proxies' transfers from government agencies or NGOs. Agricultural insurance captures access to formal risk bearing agencies such as National agricultural insurance agency, National food reserve agency and National meteorological services. Income from crop sales is used to reflect the commercial viability of agriculture. **Social capital** includes membership of an association, the number of groups in a community, number of members per association, number of females and number of persons below the age of 30 years. The number of female members reflects the status of women in the decision-making process as well as women's and youth participation in self-help groups. Such indicators reflect equity in terms of coverage and benefit.

3.3.3.2. Indexing of indicators using Principal Component Analysis (PCA)

In the GHS_Panel data set, some of the indicators were measured at the individual and household level while others at the community level. There are also quantitative and qualitative variables. Some of these variables are correlated as stated in the conceptual section. Correlated variables suggest some redundancy in the other variable. This characteristic feature of the data set suggests application of the PCA technique often used to explore multi-variable measure of correlation. It helps to reduce the number of indicators comprising a data set while retaining the variability in the data. Identifies hidden patterns in the data, and classify them according to how much of the information, stored in the data, they account for.

The PCA in STATA 11 computer package was executed. In the initial run all the 42 selected indicators were included. Each indicator is normalized by its mean and standard deviation across the sample. The PCA generated several principal components (PCs) from the original indicators included. It also generated parameters that help to characterise the PCs. The first is the Eigen value. This represents the total variance in the indicators explained by each PC. The proportion of the total variance explained by each PC is also included and together helpful in ranking the PCs in order of their significance and what PC to retain.The second important output is the matrix of factor loadings or Eigen vector. The weights attached to each PCs in determining each observed indicators are called the factor loadings. This is used to assess the relative importance of each indicator selected and sheds information on the best indicators discriminating farm households for each PC. Thus the factor loadings of each PC allow the original indicators to be readily associated with the final indices. Also associated with the matrix of factor loadings are the communalities of the variables. They measure the proportion of variance explained in a particular indicator included. Thus can be helpful in selecting indicators with high proportion of variance explained.Therefore, the first run of PCA gave insight of the indicators to discard. In the second run of PCA, only 15 out of the 42 indicators were included. PCA requires trial and error and continual scrutiny of variables to determine which combination yields the most logical results (Henry et al, 2003).

In the second run, 15 linear principal components (PCs) were extracted from the analysis. All the PCs best explain the variability in the indicators but 5 out of these were selected based on a variance factor (Eigen value) greater than 1. The choice of the number of PCs to be retained is subjective and is generally based on the interpretability of the retained components (Srivastava, 2002). Identifying the most important principal components to retain for further analysis forms one of the steps in PCA. In terms of the explained variation in original variables, the Kaiser Criterion conventional practice of Eigen value>1 is often used. The criterion states that unless a principal component has a standardised variance equal to or greater than 1, it should be dropped from further analysis (Filmer and Pritchett, 2001). Thus only 5 PCs that account for a substantial proportion of the variability in the original data were retained.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1. Descriptive Statistics

4.1.1. Comparison of NIMET and Worldclim climate data sources for Nigeria

Table 4.1 presents the long term average rainfall by months as measured by NIMET and the Worldclim. The table showed coefficient correlation is strongly positive (0.99) confirming the similarity of both data sets.

Table4.1.Average decadal rainfall from January – February for NIMET and Worldclim data sources for Nigeria.

Monthly rainfall(mm)	NIMET (1981 – 2012)	WORD CLIM (1950 – 2000)
January	57.9839	9.3557
February	23.4531	20.0398
March	57.2365	53.5341
April	97.0788	92.8394
May	158.6144	150.3451
June	206.6108	196.1139
July	251.8230	231.9256
August	250.5356	225.5027
September	234.6710	232.2591
October	150.2821	142.0887
November	43.4864	34.7632
December	11.0590	9.7534
Correlation coefficient	0.988931	

Source: Author's computation

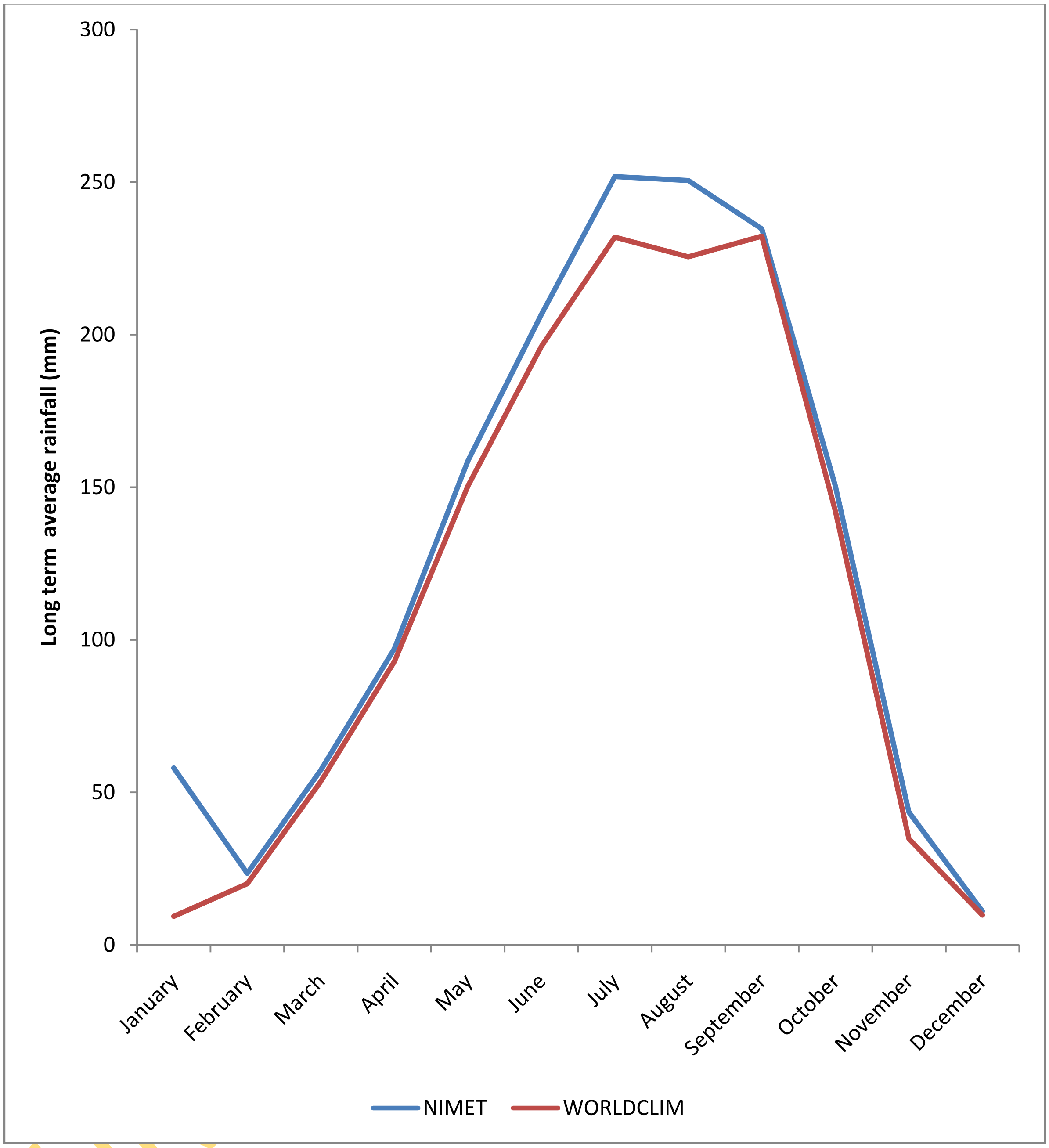


Figure 4.1.NIMET and WorldClimmonthly decadal rainfall for Nigeria

4.1.2. BaselineAverage Monthly Decadal Rainfall Pattern by Agricultural Zones

Figure 4.2presents the average monthly values for rainfall (1950 – 2000) across agricultural zones in Nigeria. The highest average rainfall is observed in the south east agricultural zone during the months of June, July and September with respective values 326.50mm/mo, 344.57mm/mo, 367.05mm/mo. Rainfall pattern follows a decreasing gradient from south east to North east. The months of June – September is often the peak of rainfall with a slight drop in the month of August. April to October period is regarded as the wet growing season. The south east agricultural zone experiences the highest amount of rainfall during this season, followed by south west while the least rainfall is experienced inNorth east agricultural zone. As shown in the figure, there is little or no rainfall for up to 9 months in North east compared to the south east zone where even the little rainfall is much higher than in North east and North West zones. November to March period is also regarded as dry season. September to November period can be viewed as a kind of transition between the wet season and the dry season where most harvesting and dry season planting takes place. March to May period in the southern part in particularly, represents the period of land preparation and planting. It also marks the onset of rainfall in the southern agricultural zones. Late onset of rainfall often ranges from mid-march to late June or early May to late July in northern agricultural zones (Takeshima, 2012).

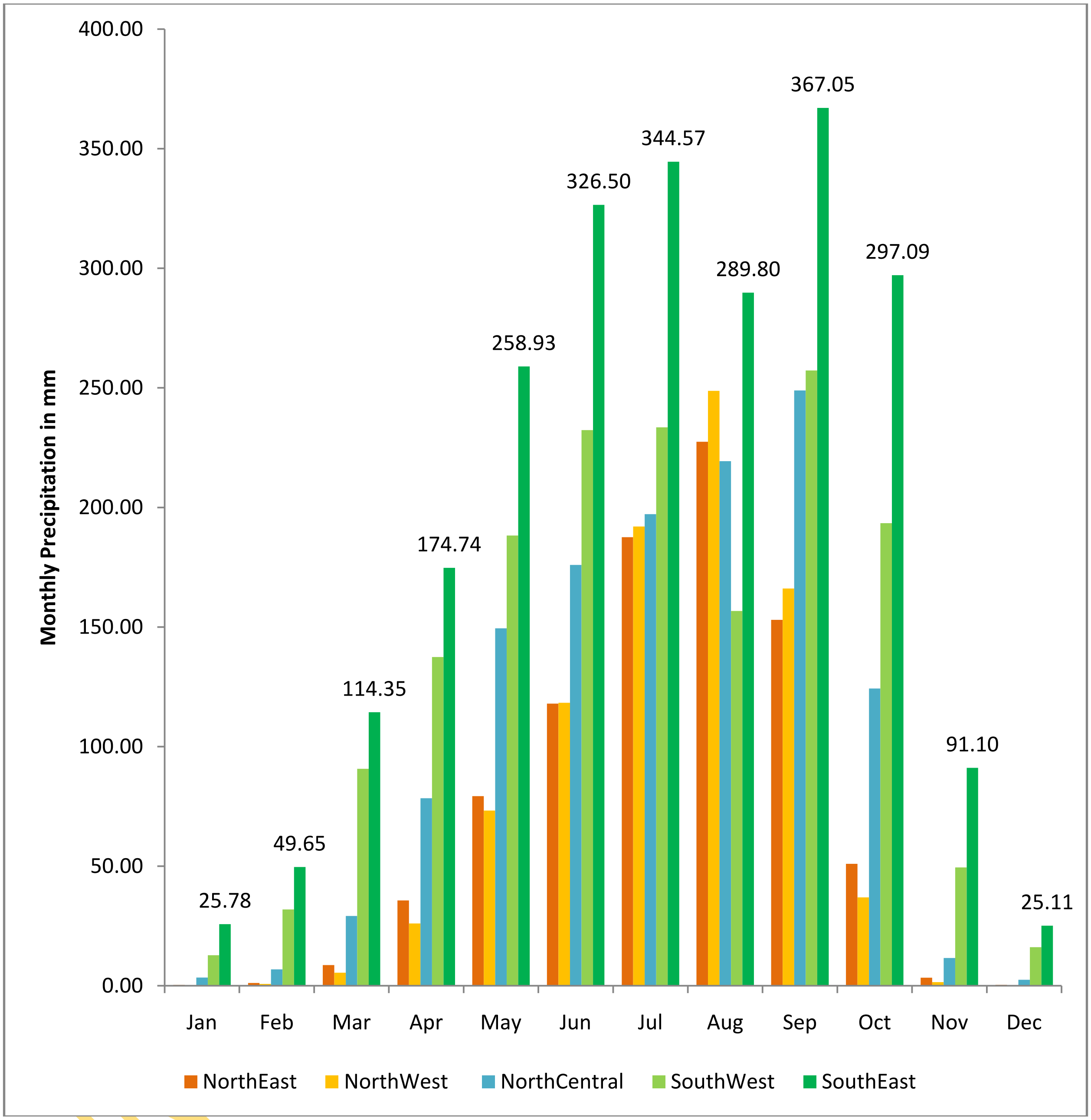


Figure 4.2. Baseline average decadal monthly rainfall pattern in mm (1950 -2000)by agricultural zonesin Nigeria

4.1.3. Projected Absolute Changein Average Monthly Baseline Decadal Rainfall

Table 4.2. Presents projected absolute change in average monthly rainfall by agricultural zones. The absolute change in rainfall is calculated as the difference between the baseline climate and rainfall projections for 2050 under the low emission scenario. Deficit in rainfall is expected in the North east agricultural zone across all seasons with high severity in March, April, May, Jun and October while the months of July, August and September are expected to be moist. Deficit in rainfall is also expected in North West but not as severe as in North east. Much rainfall is expected in North central across all the months with substantial changes in rainfall in the months of August, September and October by 35%, 52% and 32% respectively. Rainfall is also expected in the South east and South west agricultural zones to be deficit in some of the months with severe increases in rainfall in November and December.

Table 4.2.Projected absolute change in Baseline average decadal rainfall by agricultural zonesin Nigeria

Period	North east mm/month	North West mm/month	North central mm/month	South West mm/month	South east mm/month
January	-0.33	-0.02	1.39	0.47	-3.44
February	-0.98	-0.02	3.38	-0.40	-5.37
March	-6.73	-0.84	6.27	-7.88	-5.14
April	-15.73	-6.93	0.02	-24.99	-36.98
May	-13.31	0.35	9.05	-15.35	-32.43
June	-10.67	8.46	3.10	-26.72	-47.19
July	57.84	40.30	5.79	-25.30	-42.78
August	83.12	52.55	35.75	-2.52	-24.44
September	41.42	71.10	52.64	19.78	-6.15
October	-15.27	-2.34	34.94	-2.92	-22.14
November	-1.85	-0.05	9.62	3.51	8.67
December	-0.38	0.01	2.37	0.96	0.78

Author's computation

4.1.4. BaselineAverage Monthly Decadal Temperature Pattern by Agricultural Zones

Figure 4.3. Shows the distribution of mean temperature across agricultural zones in Nigeria. From the figure, there appears little variation across zones but the highest temperature is observed for the months of March – May.

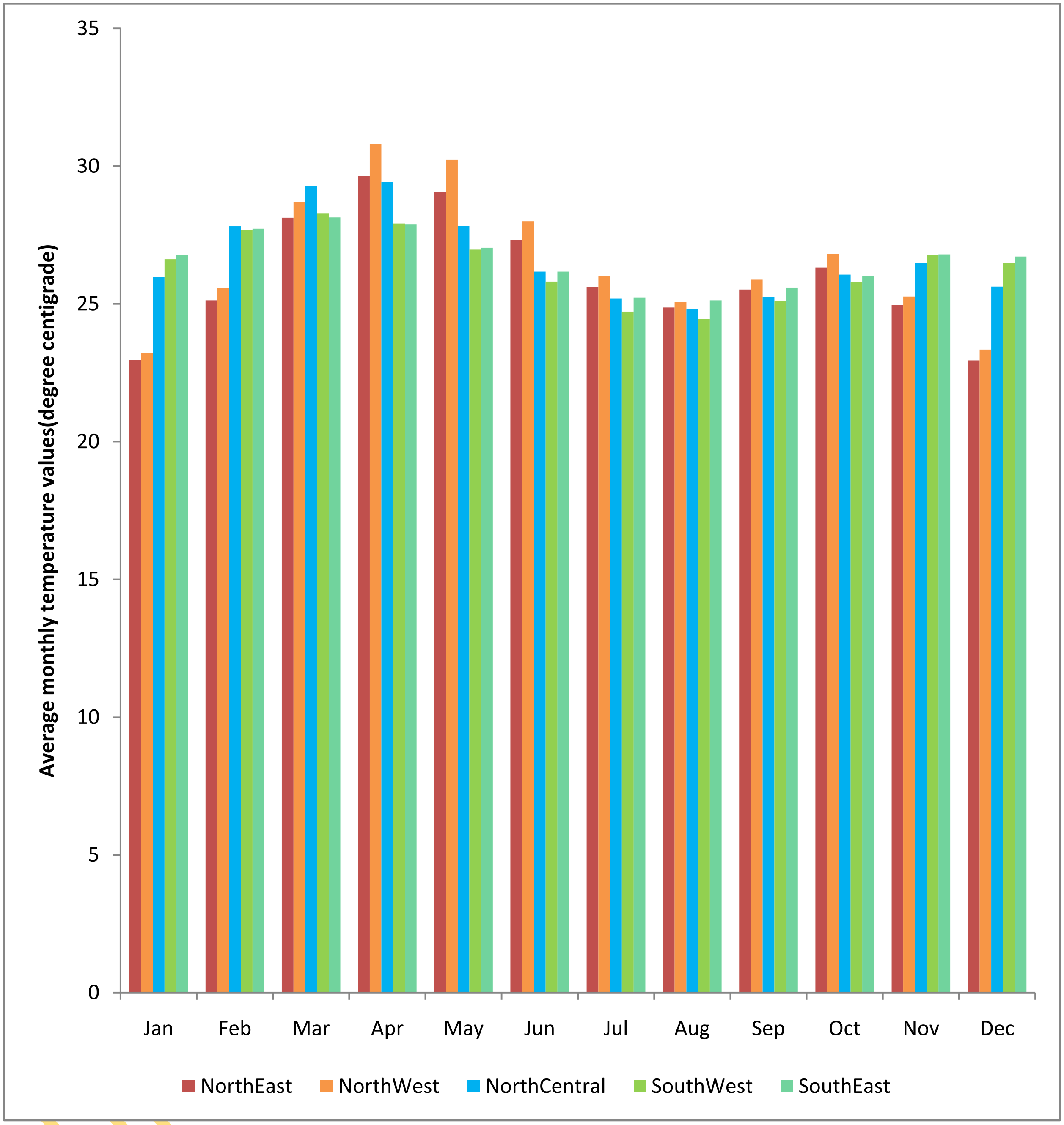


Figure 4.3.Baseline Average decadal monthly temperature pattern by agricultural zones in Nigeria

4.1.5.Projected Absolute Change in Average Decadal Baseline Temperature by Agricultural Zones

The absolute change in mean monthly temperature is presented in Table 4.3. As shown in the table, mean temperature on the average is expected to change across all the zones. South west agricultural zone is expected to have a cooler climate in all the months of the year compared to North east. The North east is expected to have the hottest climate with an average annual change in temperature by 1.72 centigrade. This is followed by North central and South east agricultural zones with temperature changes of 1.29 and 1.25 centigrade respectively. Figure 4.4 shows the visual information

Table4.3.Projected Absolute change in Baseline monthly decadal temperature by agriculturalzones in Nigeria

Period	North east Centigrade	North west Centigrade	North central Centigrade	South west Centigrade	South east Centigrade
January	1.18	0.88	1.70	-0.11	1.43
February	2.07	1.26	1.76	-0.17	1.34
March	1.88	1.03	1.24	-0.34	1.10
April	1.81	0.84	0.97	-0.22	1.26
May	2.24	1.59	1.08	-0.19	1.25
June	2.20	1.61	1.31	-0.02	1.33
July	1.46	0.89	1.14	-0.23	1.19
August	0.75	0.58	1.04	-0.33	1.08
September	1.44	1.25	1.19	-0.24	1.14
October	1.60	1.12	0.97	-0.32	1.14
November	2.30	1.54	1.36	-0.30	1.30
December	1.71	1.19	1.73	0.05	1.44
Average	1.72	1.15	1.29	-0.20	1.25

Author's computation

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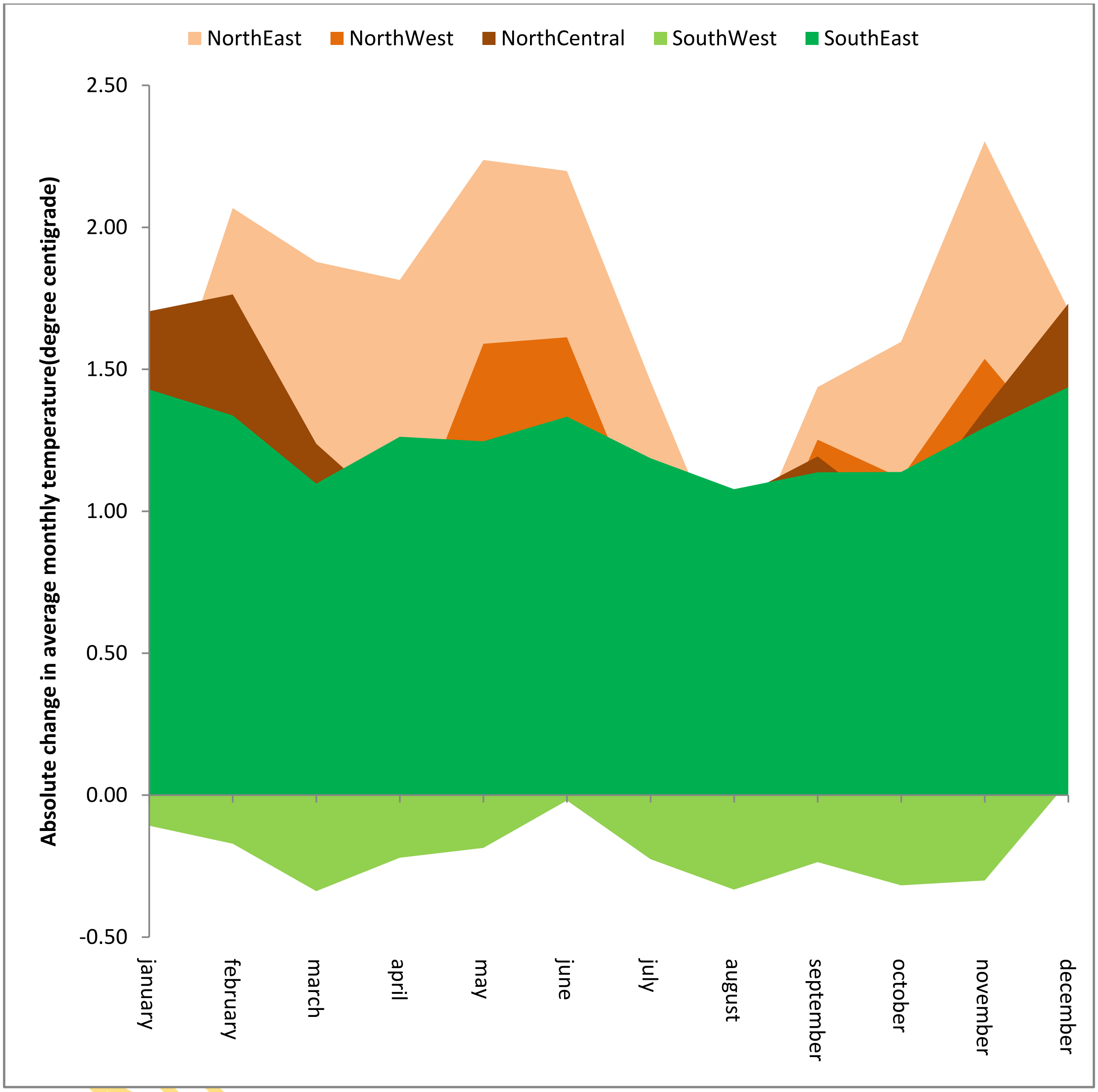

Figure 4.4.Projected Absolute change in average monthly decadal baseline temperaturein Nigeria

4.1.6. GIS Mapping of Baseline and Projected Absolute Change in Rainfall and Temperature.

The maps for average monthly decadal baseline rainfall and the projected rainfall are presented in figures 4.5 and 4.6 respectively. Figures 4.7 and 4.8 present the baseline temperature and the absolute change. South east and south west are expected to experience decline in rainfall by 16.65 and 9.22mm respectively while North central, North east and North West increase in rainfall by 13.26mm, 9.20mm and 12.90mm respectively. The model predicts a rise in temperature across all the zones except in South West that will experience a decline in temperature by –0.27 degree.

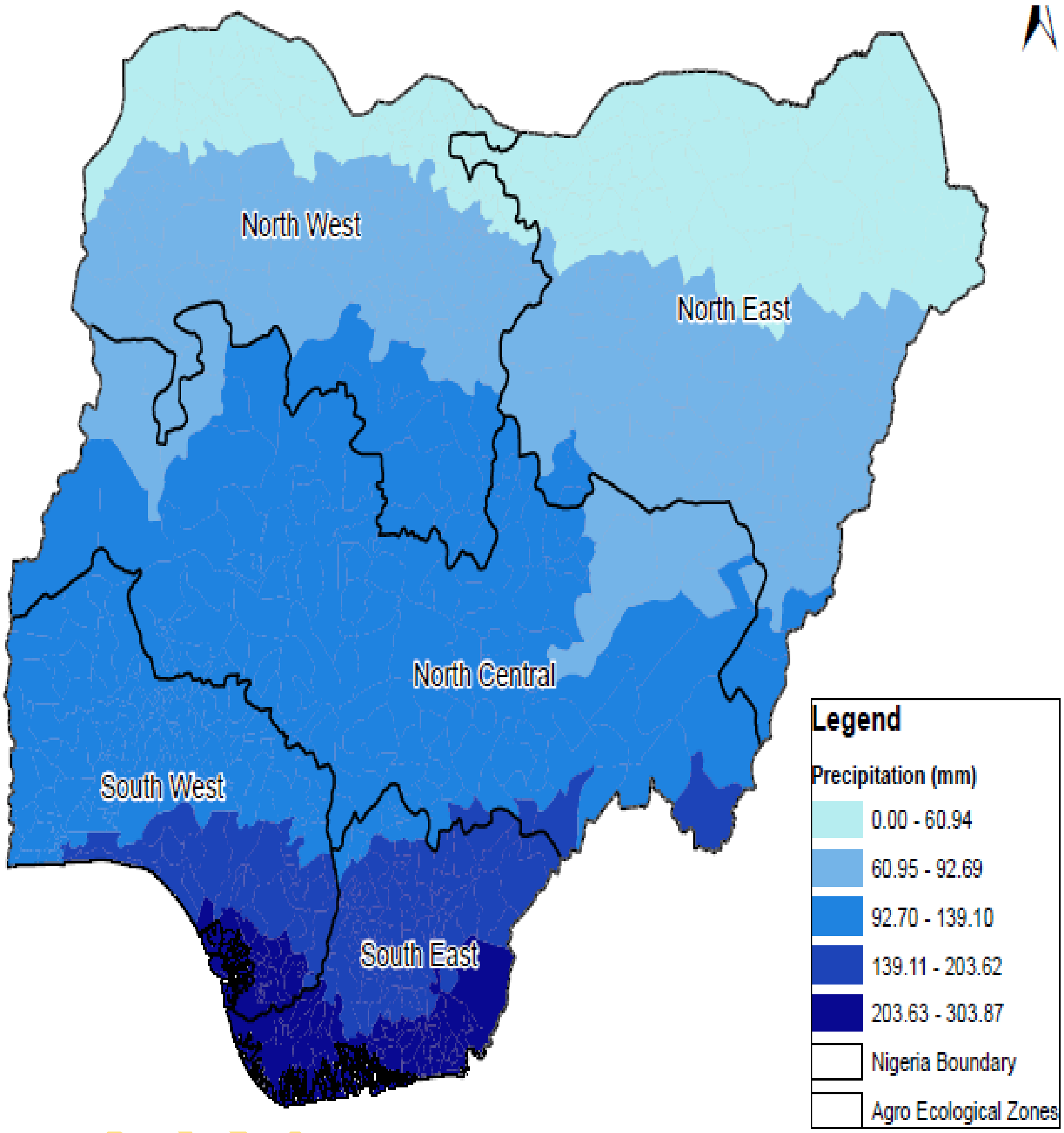

Figure 4.5 : Map of Nigeria showing the spatial distribution of baseline average monthly decadal rainfall(1950 – 2000) by agricultural zones.

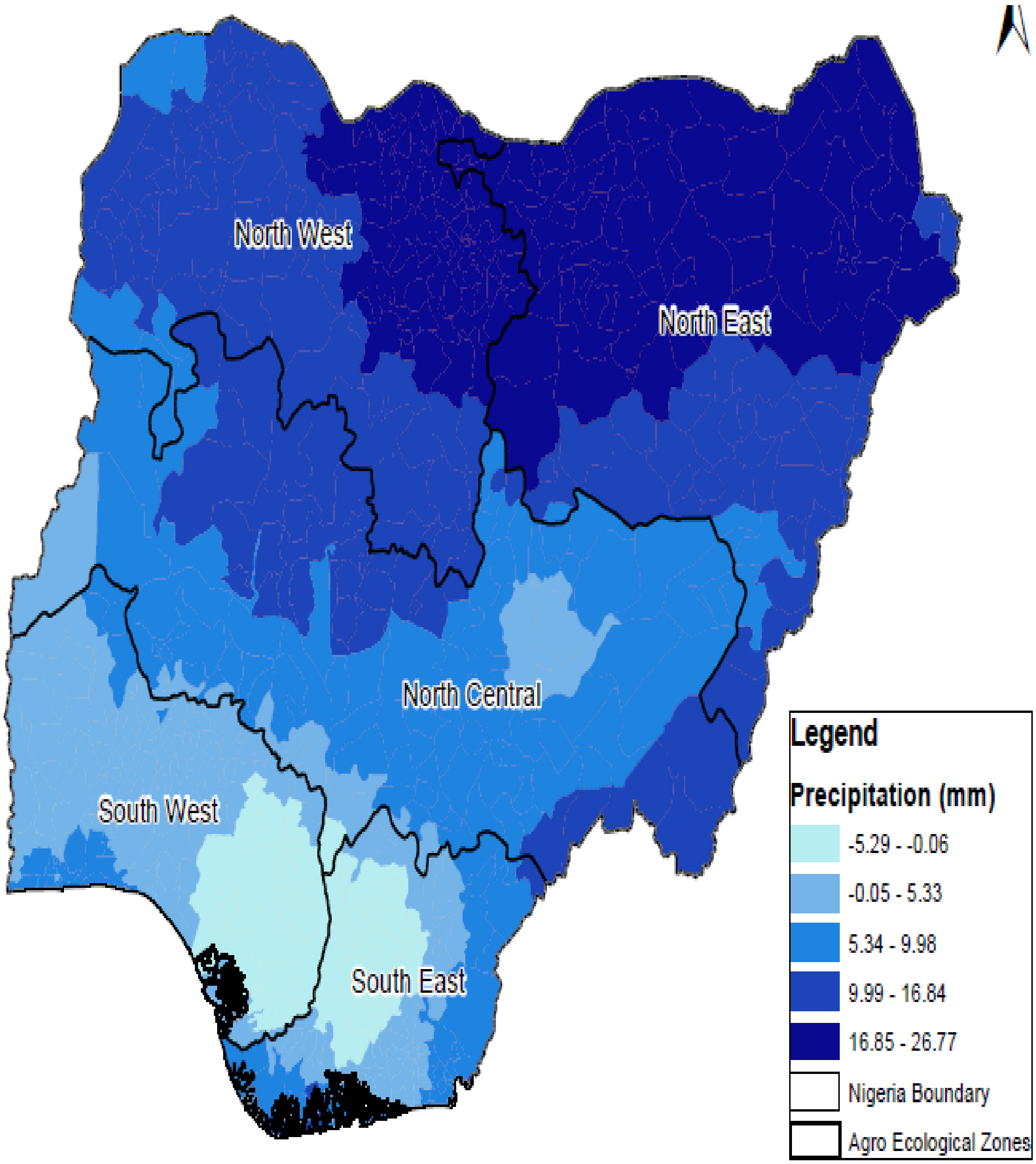

Figure 4.6.Map of Nigeria showing the spatial distribution of projected absolute change (2050) from average decadal baseline rainfall (1950 – 2000) by agricultural zones

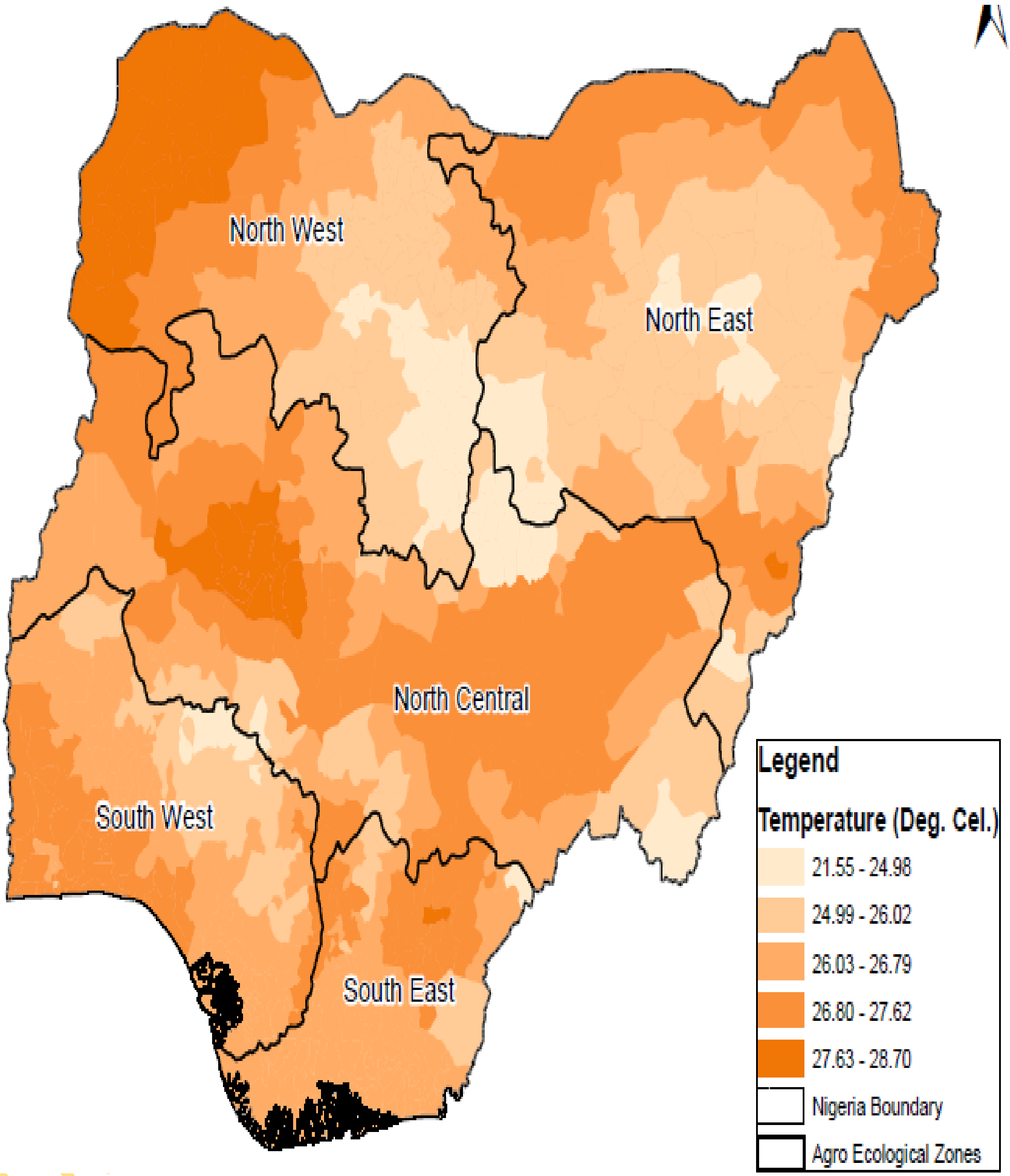

Figure 4.7.Map of Nigeria showing the spatial distribution of baseline average monthly decadal temperature(1950 – 2000) by agricultural zones.

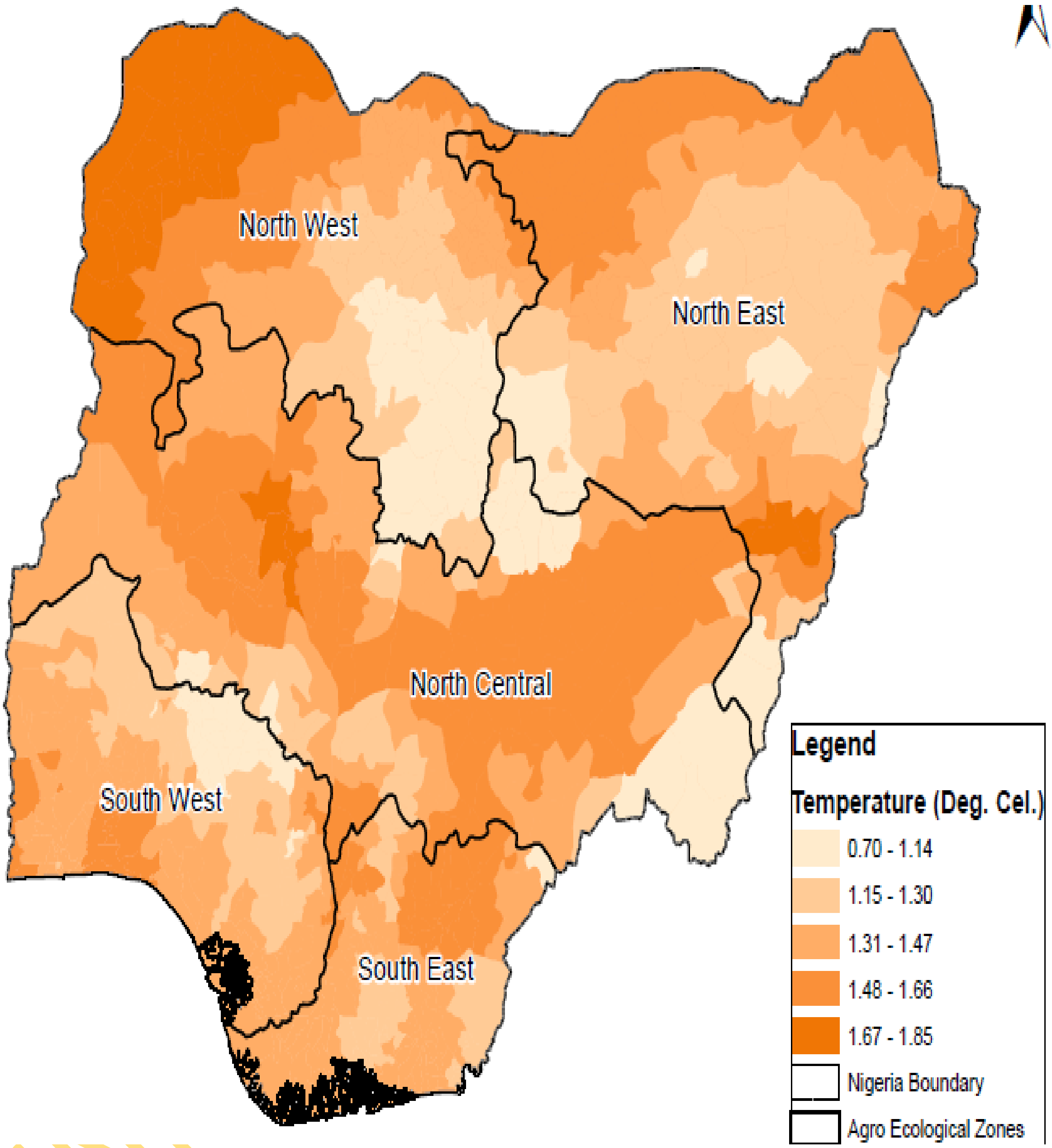

Figure 4.8.Map of Nigeria showing the spatial distribution of projected absolute change (2050) from average decadal baseline temperature(1950 – 2000) by agricultural zones

4.1.6. Pattern of Soil Quality

Table 4.4 shows soil quality indicators by states.Soil varies in texture, chemical composition, pH (acidity and alkalinity), depth and suitability. Based on USDA top soil texture classification, the soil varies from sandy soil with high fraction of sand content and less of silt and clay context. There is also loam and clay soil texture. Soil with increasing clay content is common in South West zones while with increasing sand content in the North West and North east states. Sandy soils are very free draining and rainfall on sandy soil is likely to be absorbed by the ground. However, soils containing clay can be almost impermeable and therefore rainfall on clay soils will run off and contribute to flood volumes. The table also shows the soil pH ranging from 5.0- 7.0 and can be seen as generally slightly acidic. The cation exchange capacity (CEC) value ranges from 4.0 – 13.9 cmol/kg and the low value indicates the kaolinitic parent material of the soils and low nutrient retaining ability. Top soil qualities are important nutrient supply to crops.

Table 4.4. Soil quality indicators by states in Nigeria.

STATES	Soil depth cm	Sand fraction %	Silt fraction (%)	Clay fraction (%)	Soil texture	PH(H2O)	CEC(cmol/kg)
SOKOTO	91.8	65.4	20.1	14.5	Sandy clay loam	6.2	7.5
ZAMFARA	83.6	52.0	27.3	20.7	Sand clay loam	6.5	10.3
KATSINA	77.5	58.1	25.1	16.8		6.5	10.0
JIGAWA	100.0	83.8	9.0	7.2	Sandy	6.2	4.3
YOBE	88.0	65.0	17.7	17.3	Sandy loam	6.6	11.5
BORNO	84.1	52.4	26.7	20.9		6.9	13.9
GOMBE	70.0	58.5	20.2	21.3		6.6	13.7
ADAMAWA	85.0	56.7	22.5	20.8		6.6	12.4
TARABA	88.0	59.6	20.7	19.7		6.1	10.1
BAUCHI	83.6	61.1	20.8	18.1		6.4	11.7
KANO	100.0	81.0	11.0	8.0	sandy	6.5	4.5
KADUNA	67.3	55.4	25.2	19.5		6.7	10.7
NIGER	74.3	53.0	26.0	21.0		6.6	9.9
FCT	55.0	61.0	23.5	15.5		7.0	11.0
NASARAWA	55.0	66.5	20.0	13.5	Sandy loam	6.9	9.8
PLATEAU	77.5	56.3	22.5	21.3		6.5	13.4
KEBBI	86.2	56.1	25.0	18.9		6.1	8.7

Source: Author's computation from FAO climpaq data base

Table 4.4.Soil quality indicators by states in Nigeria.(cont)

STATES	Soil depth cm	Sand fraction %	Silt fraction (%)	Clay fraction (%)	Soil texture	PH(H2O)	CEC(cmol/kg)
KWARA	100.0	58.0	20.8	21.2		6.2	7.2
OYO	61.4	50.4	26.0	23.6		6.9	10.4
OSUN	85.0	46.2	23.0	30.8		6.4	10.8
EKITI	70.0	48.7	21.7	29.7		6.6	11.3
OGUN	90.0	53.0	23.3	23.7		6.1	10.2
LAGOS	100.0	82.0	10.0	8.0	Sandy	5.4	4.0
ONDO	90.0	67.4	18.0	14.6	Sandy loam	6.0	6.9
EDO	85.0	55.2	26.2	18.7		5.8	8.8
KOGI	93.1	62.2	21.0	16.8		6.0	7.0
DELTA	100.0	52.8	28.0	19.2		5.2	9.4
BAYELSA	100.0	34.0	40.5	25.5		5.2	15.0
RIVERS	100.0	49.0	29.3	21.7		5.0	11.0
IMO	100.0	65.7	19.7	14.7	Sandy	5.4	5.7
ANAMBRA	100.0	59.8	24.5	15.8		5.5	6.8
ABIA	100.0	59.0	23.2	17.8		5.0	7.5
AKWA IBOM	100.0	54.8	26.4	18.8		5.0	8.6
CROSS RIVER	100.0	55.6	24.1	20.3		5.5	7.3
EBONYI	100.0	50.0	31.0	19.0		5.5	9.0
ENUGU	100.0	64.8	20.4	14.8		5.4	5.4
BENUE	100.0	68.8	15.9	15.4	Sandy	5.8	5.3

Source: Author's computation from FAO climpaq data base

Soil Groups by States in Nigeria

Table 4.5 presents dominant soil groups by states in Nigeria. The dominant soil groups variesdepending on the parent material and topography. "Soils form a continuum over a landscape" (Simonson, 1968) and therefore, many of the soil groups are found occurring together but with some soil groups more dominant in certain location (Babalola et la., 1978). Examples of soil groups and the percentage of land area covered in Nigeria are documented in Babalola et al.,(1978). These soil groups are oxilsols(16%), Ultisols(26%), Alfisol(40%), Mollisols(0.25%), Inceptisols(5%), vertisols(2.5%), Entisols(10%) and Histosols(0.5%). Soil and climatic factors combine to limit crop production (Babalola et al., 1978)

Table 4.5.Dominant soil groups by states in Nigeria

STATES	Soil groups
SOKOTO	Arenosols, Leptosols, Gleysols, Regosols, FluvisolsAcrisols
ZAMFARA	Acrisols, Lixisols, Fluvisols, Regosols, Leptosols, Arenosols
KATSINA	Arenosols, Lixisols, Leptosols, Leptosols, Regosols
JIGAWA	Arenosols, Fluvisols, Plinthosols
YOBE	Gleysols, Fluvisols, Arenosols, Leptosols, Lixisols, Vertisols, Phaeozems, Plinthosols Cambisols
BORNO	Arenosols, Fluvisols, Vertisols, Planosols, Solonchaks, Leptosols, Cambisols, Phaeozems, Regosols, Plinthosols
GOMBE	Nitisols, Leptosols, Arenosols, Vertisols, Lixisols
ADAMAWA	Regosols, Leptosols, Lixisols, Fluvisols, Vertisols, Arenosols, Plinthosols, Luvisols
TARABA	Acrisols, Lixisols, Leptosols, Fluvisols, Vertisols, Arenosols, Nitisols, Plinthosols
BAUCHI	Fluvisols, Leptosols, Arenosols, Lixisols, Plinthosols, Nitisols, Vertisols
KANO	Arenosols, Lixisols
KADUNA	Acrisols, Lixisols, Cambisols, Leptosols
NIGER	Leptosols, Lixisols, Nitisols, Luvisols, Fluvisols, Plinthosols
FCT	Plinthosols, Leptosols
NASARAWA	Plinthosols, Leptosols, Acrisols, Fluvisols
PLATEAU	Lixisols, Acrisols, Leptosols, Plinthosols, Arenosols, Vertisols, Fluvisols
KEBBI	Arenosols, Regosols, Gleysols, Leptosols, Acrisols, Luvisols, Nitisols, Lixisols
KWARA	Luvisols, Lixisols, Nitisols, Fluvisols
OYO	Lixisols, Luvisols, Leptosols
OSUN	Lixisols, Nitisols, Leptosols
EKITI	Lixisols, Nitisols, Leptosols
OGUN	Luvisols, Nitisols, Leptosols, Lixisols, Vertisols,Arenosols
LAGOS	Arenosols
ONDO	Gleysols, Nitisols, Arenosols, Lixisols, Leptosols
EDO	Gleysols, Nitisols, Leptosols, Lixisols
KOGI	Fluvisols, Lixisols, Nitisols, Leptosols, Gleysols, Plinthosols, Acrisols
DELTA	Nitisols, Gleysols, Fluvisols
BAYELSA	Gleysols, Fluvisols
RIVERS	Gleysols, Ferralsols, Fluvisols
IMO	Gleysols, Nitisols, Ferralsols, Fluvisols
ANAMBRA	Gleysols, Nitisols, Fluvisols
ABIA	Fluvisols, Nitisols, Ferralsols
AKWA IBOM	Fluvisols, Ferralsols, Nitisols, Gleysols
CROSS RIVER	Gleysols, Nitisols, Ferralsols, Acrisols, Cambisols
EBONYI	Gleysols, Nitisols, Acrisols
ENUGU	Nitisols, Plinthosols, Fluvisols, Acrisols
BENUE	Acrisols, Ferralsols, Nitisols, Plinthosols, Fluvisols, Lixisols

Source: Author's computation from FAO climpaq data base

4.1.7. Pattern of Population Densityin Nigeria

Table 4.6 shows the population distribution across states in Nigeria and population density in 1991 and 2006. As at 1991, the average population density was 96.59 persons per km2 and by 2006 population census; it had increased to 151.96 persons per km2. Relative high population densities are noted for states such as Lagos, Anambra, Niger, AkwaIbom, Abia, Rivers, Kano and Ebonyi.Nigeria's population based on 2006 census is put at 140 million and grows annually by 2.43%. Across states, annual population growth rate is highest in Abuja at 4.9% per annual.Population pressure stimulates changes in land use cropping patterns, traditional modes of farming such as shifting cultivation, and extent of land use for agriculture.

Table 4.6.Pattern of population density in Nigeria

States	Total Pop 1991	Total Pop 2006	Land mass '000 Km2	Pop density 1991 Persons per km2	Pop density 2006 Persons per km2
KANO	5,810,470	9401288	20,680.00	280.97	454.61
LAGOS	5,725,116	9113605	3,345.00	1711.54	2724.55
KADUNA	3,935,618	6113503	43,460.00	90.56	140.67
KATSINA	3,753,133	5801584	26,785.00	140.12	216.60
OYO	3,452,720	5580894	27,460.00	125.74	203.24
Rivers	3,187,864	5,185,400	11,077.00	287.79	468.12
BAUCHI	2,861,887	4653066	64,605.00	44.30	72.02
JIGAWA	2,875,525	4361002	22,605.00	127.21	192.92
BENUE	2,753,077	4223641	34,059.00	80.83	124.01
ANAMBRA	2,796,475	4177828	4,844.00	577.31	862.47
BORNO	2,536,003	4171104	71,130.00	35.65	58.64
DELTA	2,590,491	4112445	18,050.00	143.52	227.84
NIGER	2,421,581	3954772	5,430.00	445.96	728.32
IMO	2,485,635	3927563	13,930.00	178.44	281.95
AKWA IBO	2,409,314	3902051	6,187.00	389.42	630.69
OGUN	2,333,726	3751140	16,762.00	139.23	223.79
SOKOTO	2,397,000	3702676	25,973.00	92.29	142.56
ONDO	2,249,548	3460877	14,606.00	154.02	236.95
OSUN	2,158,143	3416959	10,245.00	210.65	333.52
Nigeria	88,992,220	140,003,542		96.59	151.96

Source: National Population commission

Table 4.6. Pattern of population density in Nigeria (cont)

States	Total Pop 1991	Total Pop 2006	Land mass '000 Km2	Pop density 1991 Persons per km2	Pop density 2006 Persons per km2
KOGI	2,147,756	3314043	32,440.00	66.21	102.16
ZAMFARA	2,073,176	3278873	39,762.00	52.14	82.46
ENUGU	2,125,068	3267837	12,440.00	170.83	262.69
KEBBI	2,068,490	3256541	41,855.00	49.42	77.81
EDO	2,172,005	3233366	17,450.00	124.47	185.29
PLATEAU	2,104,536	5198716	58,030.00	36.27	89.59
ADAMAWA	2,102,053	3178950	36,917.00	56.94	86.11
CROSS RIV	1,911,596	2892988	21,050.00	90.81	137.43
ABIA	1,913,917	2881380	5,420.00	353.12	531.62
EKITI	1,535,790	2398957	6,353.00	241.74	377.61
KWARA	1,548,412	2365353	37,700.00	41.07	62.74
GOMBE	1,489,120	2365040	18,768.00	79.34	126.01
YOBE	1,399,687	2321339	45,270.00	30.92	51.28
TARABA	1,512,163	2294800	55,920.00	27.04	41.04
EBONYI	1,453,882	2176947	5,530.00	262.91	393.66
NASARAWA	1,207,876	1869377	27,117.00	44.54	68.94
BAYELSA	1,121,693	1704515	10,773.00	104.12	158.22
FCT ABUJA	371,674	1406239	7,315.00	50.81	192.24

Source: National Population commission

4.1.8. Percentage Distribution of Farmholdersby Social Economic and Farm Characteristics

Table 4.7 presents the farmer and farm characteristics. As shown in the table, the average number of persons in a household is 5.8. Farming systems is male dominated constituting 94% of farmers. The average age of farm headed household is 51.27 years and 53% of these farmers are literate in the narrow sense of ability to read and write in any Nigerian language. 25% of farmers have access to animal traction while 19% have access to farm equipment tractor. 6.5% claim purchase of land. 26.87 practice mono cropping while 3.52% practice inters cropping. 68.65% practice mixed cropping, 0.95% other types of cropping pattern. 5.33% have access to credit and micro finance institutions. 25.89% of farmers receive credit from friends and neighbours while 1.20% had access to insurance. 83.40% belong to one association. While 95% of farmers have more access to production extension services and only 5% have access to market extension services. Government extension service constitutes 33.05%, private extension services, 6.94%. Proportion of farmers with access to NGO provided extension services is 1.67%. Farmer to farmer learning and knowledge sharing constitute 38.33% while 20% have access to media extension services. There are several other facts about the sample that are worth noting. The average altitude for farms is 250m reveal that most farming in Nigeria is rarely done in high altitudes. However, it ranges from as low as 3m in the coastal areas to a maximum of 1341m. Farming in Northern states is often done in higher altitudes than farming in southern states. The percentage of sand in top soil ranges from 39% to 81% with a mean 58%. The average percentage silt in top soil is 23% and ranges from 12% to 40% maximum. The percentage clay in top soil is 18% and ranges from a minimum of 2.5% to a maximum of 27%. These values reflect rough proxies of soil quality.

Table: 4.7 Farmer and farm characteristics in Nigeria

Farmer and farm characteristics	Mean	Standard deviation	Minimum	Maximum
Number of persons per household	5.823	1.573	2	11.6
Age of household head	51.270	15.291	15	108
Proportion of male farmers	0.8837	0.3206	0	1
Proportion of female farmers	0.1163	0.3206	0	1
Proportion of farmers that are married	0.8411	0.3656	0	1
Proportion of farmers that are single	0.1589	0.3656	0	1
Proportion of farmers that are Christians	0.5127	0.4999	0	1
Proportion of farmers that Muslims	0.4652	0.4989	0	1
Proportional for farmers Traditionalist	0.0218	0.1460	0	1
Proportion in Urban location	0.1250	0.3308	0	1
Proportion in rural location	0.8750	0.3308	0	1
Access to credit union	0.0534	0.2248	0	1
Access to Informal credit & savings	0.2567	0.4369	0	1
Access to credit from friends	0.2589	0.4381	0	1
Access to insurance	0.0120	0.1088	0	1
Access to extension services (soli)	0.7977	1.7717	0	15
Access to extension services(unsolicited)	1.6535	2.4975	0	20

Source: Author's computation

Table:4.7. **Farmer and farm characteristics in Nigeria (Cont)**

Farmer and farm characteristics	Mean	Standard deviation	Minimum	Maximum
Proportion membership of association	0.8341	0.3721	0	1
Proportion that are literate	0.5330	0.4990	0	1
Proportion without education	0.0043	0.0652	0	1
Proportion with elementary education	0.0024	0.0493	0	1
Proportion with primary education	0.4808	0.4998	0	1
Proportion with secondary education	0.2672	0.4426	0	1
Proportion with advanced education	0.0085	0.0919	0	1
Proportion with tertiary education	0.1126	0.3162	0	1
Proportion with quaranic education	0.1199	0.3249	0	1
Proportion with adult education	0.0043	0.0652	0	1
Proportion access to Underground water source	0.3492	0.4805	0	1
Proportion access to Surface water source	0.6508	0.4805	0	1
Proportion land ownership	0.0650	0.2466	0	1
Proportion free hold land	0.1028	0.3037	0	1
Proportion community land	0.7406	0.4384	0	1
Pro. Practicing Mono cropping	0.2687	0.4434	0	1
Pro. Practicing Inter cropping	0.0352	0.1844	0	1
Pro. Practicing Mixed cropping	0.6865	0.4640	0	1
Proportion practicing Other cropping types	0.0095	0.0972	0	1

Source: Author's computation

Table: 4.7. Farmer and farm characteristics in Nigeria (Cont)

Farmer and farm characteristics	Mean	Standard deviation	Minimum	Maximum
Access to production training extension	0.9500	0.2182	0	1
Access to market extension training	0.0500	0.2182	0	1
Access to government extension services	0.3306	0.4711	0	1
Access to private extension services	0.0694	0.2546	0	1
Access to NGO extension services	0.0167	0.1282	0	1
Farmer to farmer extension services	0.3833	0.4869	0	1
Access to media extension services	0.2000	0.4006	0	1
Proportion with Irrigated plot	0.0281	0.1653	0	1
Proportion with rain fed plot	0.9719	0.1653	0	1
Proportion with property right to land	0.6261	0.4839	0	1
Proportion with access to subsidized seed	0.0244	0.1543	0	1
Proportion with access to commercial seed	0.1144	0.3183	0	1
Proportion with access to subsidized fertilizer	0.0240	0.1532	0	1
Proportion with access to commercial fertilizer	0.3800	0.4855	0	1
Draught animal traction access	0.251	0.433	0	1
Farm equipment access	0.189	0.391	0	1
Access to pesticide	0.1293	0.3356	0	1

Source: Author's computation

Table: 4.7. Farmer and farm characteristics in Nigeria (Cont)

Farmer and farm characteristics	Mean	Standard deviation	Minimum	Maximum
Access to herbicide	0.2040	0.4030	0	1
Access to remittances	0.1639	0.3703	0	1
Ownership of livestock	0.6616	0.4733	0	1
Ownership of economic trees.	0.1577	0.3646	0	1
Proportion with wage off farm income	0.024	0.153	0	1
Proportion with rental income	0.016	0.126	0	1
% sand top soil	58.131	8.483	39.54	80.76
% silt top soil	23.634	5.172	11.93	36.92
% clay top soil	18.234	4.077	2.51	26.99
Altitude	250.001	215.543	3.00	1341.00
Population density	19079.100	400502.700	1.41	13000000.00
Latitude	8.644	2.793	4.56	13.67

Source: Author's computation

4.1.9. Mean Distribution of Key Economic Variables Across Agricultural Zones in Nigeria

Table 4.8 provides the mean distribution of key economic variables across agricultural zones. The variables are farm size, farm value, and farm revenue. From the table, the average farm size for the whole country ranges from 2.7 hectares on the average to 7.41 hectares maximum. The upper range is the same across all agricultural zones except for south east agricultural zone where the upper range of farm size is 4.71 hectares maximum. In North east and North west agricultural zone, the farm sizes are respectively 3.84 hectares and 3.19 hectares above the average for the whole country. In North central agricultural zone, the farm size is 2.92 hectares higher than the average for the whole country and that for south west (2.57 hectares). These results suggest that farm size in Northern agricultural zones is larger than for southern. It is well known that land increases in size as one moves from north to south. From the table the mean farm value for the whole sample is 194693.3 naira and varies from a minimum of 10,714.29 naira to a maximum of 1,619,433 naira per hectare. The average for North central is 239,528.9 naira and ranges from 195,186.5 to 1,043,536 naira per hectare. For North east and North west, the mean farm values are respectively 91,362.92 naira and 100,030.9 naira per hectare. For south east and south west, the mean values are respectively 299,329 naira and 349,025.6 naira per hectare respectively.

The pattern of crop and livestock cultivated and owned by farmers during the survey period in 2010 is presented in Table 4.9. On average, 29% of farmers cultivated cassava and followed by yam (19.29%), millet (15.74%), sorghum (13.09%), maize (12.41%), rice (2.59%), and cowpea (2.88%). Only 4.62% of households cultivated other crops and includes tree crops, cotton and vegetables. The table also reveals variation in the pattern of cultivation across agricultural zones. While sorghum and millet are virtually not cultivated in south east and south west zones, they are very much produced in the North east and North west zones. Cassava is produced substantially in south east zone (58.97% of households) and south west zone (49.72%). Also to some extent in north central (14.39%).Yam is produced substantially in North central agricultural zone (37.12% households), in south east (30.92%) North east (20.00%) and North West (19.89%) Maize is produced substantially in North central (21.59%), North West (11.76%) and south west (11.05%). The other table shows the pattern of livestock ownership across agricultural zones. 44.74% of farm households owned ruminants such as goats and sheep. This is followed by poultry (24.12%), beef cattle (15.65%) and then dairy cattle (12.75%) other animals such as camel and donkey in the hands of households are very little about 2.74%. Across agricultural zones dairy cattle is concentrated in North West (22.95%) followed by North east (20.00%) and North central (12.71). there is little or no beef cattle ownership in south east and south west but there is some ownership of small ruminants in south east (55.82%) and south west(22.22%).

Table 4.8.Mean distribution of key economic variables by agricultural zones in Nigeria

Summary	Pooled	NC	NE	NW	SE	SW
Farm size (ha)	2.71	2.92	3.84	3.19	1.58	2.57
SD	1.90	1.89	1.57	1.95	1.31	2.08
Min	0.006	0.15	0.0009	0.007	0.04	0.03
Max	7.41	7.41	7.41	7.41	4.71	7.41
chi2(4)=17.8318, Prob>chi2=0.001						
Farm value(N/ha)	194693.8	239528.9	91362.92	100030.9	299329	349025.6
SD	584147	687347.3	471318.3	220593.3	468485.8	992811
Min	10714.29	195186.5	18000	17666.67	41880.28	320367
Max	1619433	1043536	692982.5	355110.9	712796.5	1619433
chi2(4)=712.0551, Prob>chi2=0.000						
farm revenue (N/h)	56884.096	20782.103	100813.91	58781.35	58220.85	25999.33
SD	551162.11	26750.503	1425147.8	523813.8	66951.33	48837.45
Min	3966.194	12932.66	7380	9208.333	4952.381	3966.194
Max	2159244.26	36857.126	2159244.3	1092368	83143.57	74166.06
chi2(4)=1.1e+03, Prob>chi2= 0.000						

Source: Author's computation

Table: 4.9. Percentage meandistribution of farmholdersby crop cultivated and livestock owned by agricultural zones in Nigeria

Crop choices	NC	NE	NW	SE	SW	Total
Sorghum	11.74	26.25	32.47	0	0	13.09
Millet	0.38	37.50	44.24	0	0	15.74
Rice	7.95	3.75	2.35	0.90	0.80	2.59
Cowpea	1.89	8.75	4.94	0.45	0.55	2.88
Cassava	14.39	0.42	0.24	58.97	49.72	29.39
Yam	37.12	20.00	0.71	30.92	19.89	19.29
Maize	21.59	3.33	11.76	6.79	11.05	12.41
Other crops	4.92	26.25	3.29	1.96	18.78	4.62
Dairy cattle	12.71	20.00	22.95	1.32	4.17	12.75
Beef cattle	2.76	39.46	29.75	0	0	15.65
Small ruminant	50.28	34.05	40.23	55.82	22.22	44.74
Poultry	32.60	2.70	3.68	40.74	70.83	24.12
Other animal	1.66	3.78	3.40	2.12	2.78	2.74

Source: Author's computation

4.2. Regression Estimates

4.2.1. Multivariate Probit Estimates

This section presents the estimates of the multivariate probit regression for the following profit choice equations: sorghum, millet, rice, cassava, maize, yam and cowpea. The aim is to derive the marginal impact on the probability that a farmer cultivates a crop type given changes in climate. From the regression estimation, the rho (measure of the correlation across crops) and variable coefficients were generated. Table 4.10 presents the correlation coefficient (rho) between crop pairs possibility that farmers can cultivate while table 4.11 presents the coefficients of the multivariate estimates.

Table4.10.correlation coefficient of pairs of possible crop combination

Crop 1	Crop 2	Rho	Correlation coeff	t-value
Millet	Sorghum	21	-0.170	-0.72
Rice	Sorghum	31	-0.026	-0.13
Cowpea	Sorghum	41	0.293	1.63*
Maize	Sorghum	51	0.442	2.53*
Cassava	Sorghum	61	0.297	1.05
Yam	Sorghum	71	0.089	0.44
Rice	Millet	32	-0.045	-0.19
Cowpea	Millet	42	0.259	1.21
Maize	Millet	52	-0.722	-2.39*
Cassava	Millet	62	-0.053	-0.24
Yam	Millet	72	-0.077	-0.35
Cowpea	Rice	43	0.343	1.64*
Maize	Rice	53	0.224	1.11
Cassava	Rice	63	0.212	0.75
Yam	Rice	73	-0.184	-0.85
Maize	Cowpea	54	0.095	0.56
Cassava	Cowpea	64	0.488	1.96*
Yam	Cowpea	74	0.003	0.01
Cassava	Maize	65	0.433	1.89*
Yam	Maize	75	-0.370	-1.89*
Yam	Cassava	76	-0.027	-0.14

p21 = p31 = p41 = p51 = p61 = p71 =p32 = p42=p52=p62=p72=p43=p53=p63=p73=p54 = p64 = p74 = p65 = p75 =p76 = 0: chi2(21) = 32.1389   Prob> chi2 = 0.0567

Source: Author's computation

The sign of the correlation coefficient reflects the nature of interdependence whether alternatives are complements or substitute. The value of the correlation coefficient reflects the magnitude of association between pairs. The table reveals maize/millet as substitute with a negative sign correlation coefficients estimated at 0.72. With a test statistic estimated at 2.39, it suggests significant interdependence between millet and maize at $p<0.05$. Therefore the null hypothesis that there is no significant difference between crops is rejected. This is also true for yam and maize with a negative sign correlation coefficient and significant at $p<0.05$. The table also reveals positive association for the following crop pairs: Cowpea/sorghum, maize/sorghum, cowpea/rice, cassava/cowpea, and cassava/maize. This suggests complementarity possibility of the crop pairs. For the overall system of crop equations, the table reveals a likelihood ratio of 32.14. This was found to be significant at 0.05. Thus the null hypothesis (H0) that the covariance of the error terms across equations are not correlated p=0 was rejected ($p< 0.05$).

Table 4.11 presents the coefficients of the variables included in the profit choice model. Many of the variables were dropped arising from multicollinearity. All the price variables were dropped except for the price of fertilizer input, and transportation cost to output market. Only all seasons temperature and precipitation were included, the seasonal climate variables were dropped. The result reveals fairly mixed pattern of farmer's crop choice behaviour in response to a unit change in climate. For example, farmer's choice pattern for choice for yam and maize followed a mixed pattern of U-shape and hill shape with temperature over all the seasons at $p<0.1$ and $p<0.01$ respectively while maize exhibited U-shape with annual precipitation at ($p<0.01$). Variable used to control for the true effect of the climate variables also showed interesting results. Percentage clay in top soil is negative for cowpea ($p<0.01$) and yam ($p<0.01$). Fertilizer input price is positive for sorghum ($p<0.1$)while transportation cost to output market is positive for millet ($p<0.1$). Population density is negative for millet ($p<0.1$) and yam ($p<0.05$) while it is positive for cassava ($p<0.1$).

Table 4.11.Multivariate probit coefficient estimates of farmers crop choices in Nigeria

Variables	Sorghum	Millet	Rice	cowpea	Cassava	Yam	Maize
T_Annual	-0.2383	1.4321	5.1858	-1.9798	-0.1454	-5.5286	9.2184
	(1.9592)	(3.3839)	(4.5543)	(3.2158)	(2.5189)	(3.2877)***	(2.4311)*
Tsq _Annual	0.0077	-0.0319	-0.0974	0.0379	0.0019	0.1018	-0.1741
	(0.0375)	(0.0642)	(0.0865)	(0.0615)	(0.0475)	(0.0622)***	(0.0462)*
P_Annual	0.0420	-0.0555	-0.0378	0.0475	-0.0077	0.0029	-0.0265
	(0.0252)	(0.0333)***	(0.0305)	(0.0310)***	(0.0173)	(0.0153)	(0.0126)**
Psq _Annual	-0.0001	0.0003	0.0001	-0.0002	0.0000	0.0000	0.0001
	(0.0001)	(0.0002)	(0.0001)	(0.0001)	(0.000)	(0.0000)	(0.0000)*
Altitude	0.1422	-0.2355	-0.1093	0.2861	-0.0351	-0.0948	0.0227
	(0.0657)**	(0.0887)*	(0.0732)***	(0.0901)*	(0.0532)	(0.0500)	(0.0446)
Latitude	0.1725	0.0083	-0.2068	0.1349	-0.2893	0.0698	-0.0549
	(0.1969)	(0.3162)	4(0.2411)	(0.2765)	(0.1879)	(0.1701)	(0.1375)
% sand	-0.4191	0.9253	0.6649	0.0611	-0.0810	-0.8243	-0.0925
	(0.3189)	(0.4142)**	(0.5355)	(0.3946)	(0.4805)	(0.4343)***	(0.2793)
% clay	0.5399	1.5886	-0.9354	-4.6286	-0.8090	-3.7131	0.5349
	(1.1177)	(1.5124)	(2.2011)	(1.4136)*	(1.6124)	(1.2259)*	(0.8546)

Source: Author’s computation *1% ** 5% ***10% level of significance

Table 4.11.Multivariate probit coefficient estimates of farmers crop choices in Nigeria (Cont)

Variables	Sorghum	Millet	Rice	cowpea	Cassava	Yam	Maize
Input price(fert)	0.0667	0.0365	-0.0356	-0.0269	-0.0043	0.0068	0.0137
	(0.0449)***	(0.0503)	(0.0673)	(0.0602)	(0.0344)	(0.0348)	(0.0365)
Tpt cost(output mkt	-0.0042	0.0066	0.0010	0.0050	-0.0034	0.0021	0.0005
	(0.0035)	(0.0041)***	(0.0059)	(0.0050)	(0.0030)	(0.0028)	(0.0031)
Pop dens	-0.0002	-0.0006	-0.0004	0.0003	0.0005	-0.0005	0.0003
	(0.0003)	(0.0003)***	(0.0005)	(0.0004)	(0.0003)***	(0.0003)**	(0.0002)
_cons	-21.8807	-138.9338	-3.2124	-7.2859	-1.2140	-2.2427	-1.6315
	(9.2346)**	(116.2478)	(0.422)*	(2.3384)*	(0.1366)*	(0.3044)*	(0.0819)*
SML	Draws=5						
P>x2	0.000						

Source: Author’s computation *1% ** 5% ***10% level of significance

4.2.2. Marginal Impact Estimates of Baseline Climate

From the multivariate regression coefficients in Table 4.11 marginal effects of temperature and precipitation variables were generated and presented in Table 4.12.Marginal effect refers to the change in the estimated probability as a result of a unit change in temperature and precipitation. It reveals the level of probability that a farmer cultivates a crop as temperature or precipitation changes. As shown in the table, monthly average temperature increased the probability of cultivating millet (5.8 %), rice (2.4 %) and maize (51.5 %) and reduced the probability of cultivating sorghum (0.7 %), cowpea (2.1 %), cassava (0.7 %) and yam (36.7 %).Baseline monthly precipitation increased the probability of cultivating sorghum (0.5 %), cowpea (0.2 %), and yam (0.1 %) while it reduced the probability of cultivating millet (0.8 %), rice (0.1 %), cassava (0.1 %) and maize (0.5 %).

Table: 4.12. Estimatedprobability of crop cultivation on farms in Nigeria

Crops types	Marginal effect(Change in probability)	
	Temperature	Precipitation
Sorghum	-0.00715	0.0047
Millet	0.058363	-0.0084
Rice	0.023758	-0.0006
Cowpea	-0.02084	0.0019
Cassava	-0.00723	-0.0014
Yam	-0.36743	0.0007
Maize	0.515227	-0.0055

Source: Author's estimation

4.2.3. Simulated Probability Impact of Climate Change

Table4.13 presents the simulated impact of temperature and precipitation on crop choices. They are presented in columns three and four of the table. It is the simulated percentage change in the probability of cultivation given changes in annual temperature and precipitation in 2050 and 2070. The simulation impact is based on the prediction of Hadley model within the low emission pathway. The table reveals reduction on the probability that farmers would cultivate the various crop types in 2050. The probability would reduce most for sorghum (10.52%). However, the probability to cultivate rice will increase by 22.45% in 2050. A further reduction in the probability of sorghum cultivation is expected in 2070 by 43%. Thus there is the possibility of farmers to switch to rice as temperature increases. The change in temperature will reduced the probability of cultivating cowpea by 86% in 2070.The impact of precipitation is favourable for virtually all the crops. Precipitation impact appears beneficial in 2050 and 2070 while temperature impact is detrimental by 5.25% on the probability of choosing rice in 2050, while it could be beneficial by 22.44% in 2050. Similarly precipitation could be detrimental on the cultivation of rice by 25.89% and 43.02% in 2050 and 2070 respectively. Temperature is detrimental on cowpea by 7.36% and 86.32% in 2050 and 2070 respectively. On the contrary changes in precipitation would favour farmer's choice for cowpea by 4.52% and 9.73% in 2050 and 2070 respectively. While temperature impact on cassava cultivation is detrimental by 4.0% and 19.95% in 2050 and 2070 respectively, the beneficial effect of precipitation could increase the probability of cultivating cassava by 4.63% and 4.85% in 2050 and 2070.

Table 4.13.Simulated climate change impact on the probability to cultivate crops in Nigeria.

	TEMPERATURE			PRECIPITATION		
Crop types	Baseline	%change in 2050	%change in 2070	Baseline	%change in 2050	%change in 2070
Sorghum	-0.00715	-10.523	-42.8699	0.0047	5.1806	10.1453
Millet	0.058363	-5.491	-10.0178	-0.0084	-3.4813	0.7770
Rice	0.023758	-5.252	22.4459	-0.0006	-25.8916	-43.0284
Cowpea	-0.02084	-7.361	-86.3205	0.0019	4.5170	9.7337
Cassava	-0.00723	-3.966	-19.9553	-0.0014	4.6309	4.8552
Yam	-0.36743	-6.065	-3.4973	0.0007	14.3101	15.3064
Maize	0.515227	-6.164	-13.0557	-0.0055	-1.7573	-1.6351

Source: Author's computation

4.2.4. RicardianModel Estimates

4.2.4.1. Model Selection

Tables 4.14, 4.15 and 4.16 in the appendix present the estimates of three different regression run for farm value (MODEL1) and farm revenue (MODEL2). Table 4.14 shows the estimates of the first regression run on climate variables only (climate only model) with a linear quadratic specification. Table 4.15 shows the estimates of the second run with climate and non-climate variables (full model) with a linear quadratic specification as well as climate interaction terms. While table 4.16 shows the estimates of the full model but with log linear quadratic specification and climate interaction terms. To control for aggregation bias, share of crop land cultivated was used as weights initially but crop revenue weighting approach showed more consistent results and therefore used for all the estimations. In table 4.14 only 11 variables were significant at $p<0.05$ for the farm value model (MODEL 1) while 8 variables were significant for the farm revenue model (MODEL 2). The farm value model (MODEL2) explained between 7% and 1% of the variance in farm value and with an F-statistic at 0.88 suggesting that the fitness of the model was not statistically significant ($p>0.05$). The farm revenue (MODEL2) explained 61% of the variance in farm revenue and with F-statistic at 17.16 meant that the fitness of the model was significant ($p<0.05$).

In table 4.15 the F statistics for MODEL 1 increased from 0.88 to 2.78 while the variance explained increased from 7% to 35%. However, the number of significant variables reduced from 11 to 4. MODEL2 appeared impressive with the number of significant variables increasing from 8 to 25. The statistical fitness of the model (F-statistic) increased substantially from 17.16 to 222.75. The variance explained also increased from 61% to 98%. These results suggest the importance of controlling for climate variables. Also suggests the good fit of the farm revenue model (MODEL 2) in estimating the effect of climate on production systems. Nonetheless, the standard errors of the estimates of both models were very high suggesting a more appropriate functional specification of the model.

Table 4.16 shows the estimates of the third run. The log linear specification with climate interaction terms was applied. As shown in the table, the number of significant explanatory variables at p<0.05 increased substantially. Of a total of 31 variables included, the number of coefficients for: (MODEL 1= 20) and (MODEL 2= 27). The R-squared for :(MODEL 1= 90%) and (MODEL 2=93%). The F (31,264) statistics for: (MODEL 1= 48.36) and (MODEL 3= 70.50). Also the standard errors are farm much lower. With the log linear specification the farm value model is used to predict the economic impact of climate change on smallholder crop farms across agricultural zones as well as the pooled representing estimate for the whole country. The estimates are presented in Table 4.17.

4.2.4.2. Analysis of Coefficients

This section examines the Ricardian regression estimations for North Central, North East, North West, South East and South West agro ecological zones as well as for the whole country. These estimations are hereafter referred to as NC, NE, NW, SE, SW and WC respectively. The aim is to examine the effect of climate measures on farm revenue accumulation over time. Table 4.17 presents the coefficients and the t-statistic for farm value modelbyagro ecological zones and the pooled. The sign of the coefficients are consistent with apriori expectation. As shown in the table, the coefficients of the quadratic and linear temperature and precipitation measures showed opposite signs in most cases particularly for temperature (see table 7 in the appendix for sign analysis). The sign of the coefficients reveals the direction of causality as well as the shape of climate – farm value relationship. In terms of causality, the negative reflects a reducing impact while the positive sign a beneficial impact. In terms of shape, the negative sign of the quadratic coefficient reflects a hill shaped relationship while the positive sign reflects a U- shaped relationship.

Effect of Temperature

For the pooled data (WC, the whole country), the sign for the linear and quadratic temperature coefficients for September-November, June-August and December-February growing seasons were respectively negative and positive and significant at $p < 0.05$. The findings suggest a hill shape relationship between temperature and farm value. Meaning that there is a maximum level of temperature in which either more or less will decrease farm production (see Mendelsohn et al., 1994).

Table 4.17.Ricardian regression coefficientsfor Nigeria

Variables	Pooled	NC	NE	NW	SE	SW
TEMPERATURE MEASURES						
Sept-Nov	-21.691	173.025	232.3363	-59.837	-295.798	-190.668
	(1.35)	(1.38)	(2.22)	(2.15)	(0.78)	(0.58)
Jun-Aug	-23.423	96.557	-109.33	-59.786	80.0377	911.8163
	(2.39)	(2.32)	(1.06)	(2.48)	(0.68)	(2.77)
Mar–May	40.7234	-313.32	306.7976	79.5435	202.4042	-552.14
	(3.06)	(2.40)	(1.65)	(3.26)	(0.84)	(3.45)
Dec–Feb	-21.407	-80.632	902.1514	-83.27	-25.205	32.1056
	(1.01)	(0.80)	(3.03)	(1.71)	(0.16)	(0.17)
Nov–Mar	16.968	66.6589	-1322.56	118.1608	5.1088	-122.288
	(0.54)	(0.45)	(2.99)	(1.65)	(0.02)	(0.37)
Sept-Nov^2	0.493	-3.102	-6.218	1.2036	5.6182	4.5371
	(1.61)	(1.39)	(2.78)	(2.35)	(0.79)	(0.69)
Jun-Aug^2	0.386	-1.843	3.3935	0.8509	-1.624	-20.137
	(2.19)	(2.55)	(1.89)	(2.05)	(0.75)	(2.93)

Source: Author's computation ( ) T-statistic

Table 4.17.Ricardian regression coefficients for Nigeria (Cont)

Variables	Pooled	NC	NE	NW	SE	SW
TEMPERATURE MEASURES						
Mar–May^2	-0.668	5.5006	-5.645	-1.231	-3.198	10.7522
	(2.97)	(2.45)	(1.74)	(2.98)	(0.80)	(4.09)
Dec-Feb^2	0.369	2.2337	-21.088	1.5069	0.2583	-0.584
	(0.85)	(1.11)	(3.15)	(1.53)	(0.09)	(0.17)
Nov-Mar^2	-0.294	-2.282	29.4565	-2.185	0.0657	2.0364
	(0.47)	(0.80)	(3.08)	(1.57)	(0.01)	(0.35)
PRECIPITATION MEASURES						
Sept-Nov	0.103	2.3919	-9.749	-1.97	-0.419	5.5338
	(0.45)	(1.47)	(1.88)	(3.02)	(0.17)	(2.21)
Jun-Aug	0.130	0.2265	2.3254	-1.546	-0.239	-8.315
	(1.09)	(0.23)	(0.78)	(3.84)	(0.22)	(4.42)
Mar–May	0.378	-1.749	13.7275	2.6799	5.201	8.6082
	(0.86)	(0.64)	(2.41)	(1.9)	(1.21)	(1.98)
Dec–Feb	15.519	61.5304	19.5095	-18.96	1.3797	73.0104
	(4.68)	(1.18)	(0.39)	(1.15)	(0.12)	(4.32)
Nov–Mar	-6.58	-40.117	-29.325	16.8662	-1.656	-49.821
	(2.91)	(1.30)	(0.88)	(1.4)	(0.25)	(3.79)

Source: Author's computation ( ) T-statistic

Table 4.17.Ricardian regression coefficients for Nigeria (Cont)

Variables	Pooled	NC	NE	NW	SE	SW
PRECIPITATION MEASURES						
Sept-Nov^2	-0.00021	-0.00059	0.000645	-0.00049	2.74E-05	0.00164
	(2.24)	(0.84)	(0.26)	(1.24)	(0.08)	(1.27)
Jun-Aug^2	-0.00027	-0.00015	-0.00093	0.000744	0.000105	-7.5E-06
	(5.12)	(0.27)	(0.39)	(3.27)	(0.77)	(0.03)
Mar–May^2	0.000341	-0.0037	0.00607	0.000496	-0.0023	-0.0069
	(1.39)	(1.91)	(1.25)	(0.44)	(1.32)	(1.83)
Dec-Feb^2	0.013	0.0928	1.6273	-0.21	0.00281	-0.043
	(2.93)	(1.20)	(1.19)	(3.57)	(0.38)	(2.41)
Nov-Mar^2	-0.0026	0.00087	-0.591	0.0473	0.000604	0.0092
	(1.51)	(0.05)	(1.09)	(3.25)	(0.14)	(1.40)
TEMPERATURE * PRECIPITATION INTERACTION MEASURES						
Sept-Nov	-0.001	-0.088	0.4013	0.0824	0.0151	-0.238
	(0.11)	(1.40)	(2.0)	(3.33)	(0.16)	(2.29)
Jun-Aug	0.000232	-0.0078	-0.073	0.0492	0.00665	0.3414
	(0.05)	(0.26)	(0.89)	(3.88)	(0.15)	(4.20)
Mar-May	-0.016	0.1002	-0.506	-0.085	-0.157	-0.248
	(1.09)	(1.05)	(2.55)	(1.89)	(1.09)	(1.86)

Source: Author's computation ( ) T-statistic

Table 4.17.Ricardian regression coefficients for Nigeria (Contna)

Variables	**Pooled**	**NC**	**NE**	**NW**	**SE**	**SW**
TEMPERATURE * PRECIPITATION INTERACTION MEASURES						
Dec-Feb	-0.604	-2.336	-0.586	0.9533	-0.055	-2.713
	(4.79)	(1.16)	(0.27)	(1.44)	(0.13)	(4.19)
Nov-Mar	0.2577	1.4491	1.0824	-0.78	0.0564	1.8498
	(3.06)	(1.26)	(0.85)	(1.69)	(0.24)	(3.93)
CONTROL VARIABLES						
Latitude	-0.023	0.118	0.2185	-0.144	-0.256	-0.066
	(0.30)	(0.28)	(0.43)	(1.62)	(0.40)	(0.10)
Altitude	-0.00071	-0.014	-0.0011	-0.00065	-0.00047	-0.0097
	(0.96)	(2.69)	(0.44)	(0.42)	(0.05)	(1.23)
Sand	0.0548	-0.18	0.0434	0.0183	0.0613	-0.11
	(1.57)	(1.30)	(0.26)	(0.44)	(0.39)	(1.10)
Silt	0.0678	-0.085	-0.01		#VALUE!	#VALUE!
	(1.18)	(0.37)	(0.04)	#VALUE!		

Source: Author's computation ( ) T-statistic

Table 4.17.Ricardian regression coefficients for Nigeria (Contna)

Variables	Pooled	NC	NE	NW	SE	SW
Clay	#VALUE!	#VALUE!	#VALUE!	0.0562 (0.61)	0.00581 (0.02)	0.439 (1.57)
Socio economic 1	-0.054 (0.69)	-1.135 (2.42)	-2.817 (2.68)	-0.314 (1.68)	0.2134 (0.76)	0.7521 (5.89)
Socio economic 2	-0.042 (0.58)	-0.504 (2.04)	-0.164 (0.65)	0.2714 (2.86)	0.4118 (1.78)	1.0397 (2.03)
Pop den	-5.5E-07 (0.50)	3.44E-06(1.21)	2.1E-06 (0.46)	7.11E-06 (2.42)	3.07E-06 (0.75)	-1.1E-06 (0.24)
Cons	9.314091 (1.35)	11.95418 (1.38)	-372527 (0.32)	6.583982 (1.76)	10.49828 (0.79)	5.847646 (0.56)
No. of sign variable						
F(37,208)	52.60	2.56	15.71	11.30	4.31	66.33
R-squared	0.8877	0.8815	0.9902	0.9329	0.8261	0.9981
Adj R-squared	0.8708	0.5367	0.9271	0.8503	0.6342	0.9831
No. of obs	246	44	38	59	62	37

Source: Author's computation ( ) T-statistic

Effect of Precipitation

For the pooled data (WC), all the quadratic coefficients for all the growing seasons were negative and significant at $p<0.05$ except for March – May and December - February seasons with positive signs. This reflects a mixed pattern of hill and U-shaped relationship between farm value and precipitation. Therefore for precipitation, there is a maximum and minimum level of precipitation that either more or less will affect farm value. For example, March-May season represents the period of land preparation and planting and there is a minimum level of precipitation beyond or below which germination of seeds or land preparation could become problematic. Climate interaction measures appear significant. The interaction climate terms reveals the importance of the effect of interaction between temperature and precipitation on farm value. Percentage sand and silt in top soil came out stronger in explaining differences in farm value across farms. The socio-economic variables included were both positive and significant at $p<0.05$. Population density is significant and positive at $p<0.05$. Of the environmental variables, latitude is insignificant; altitude has a slightly negative effect, while soil variable proxy by the percentage of clay in top soil had a more negative effect and significant at $p<0.05$.

4.2.4.3. Marginal estimates of baseline temperature and precipitation measures

The coefficients of table 4.17 were used to predict the marginal impact of baseline climate measures on farm value. These estimates are presented in Table4.18 in naira per hectare and in percentages across agricultural zones and for the pooled (WC, whole of the country). For the pooled data, all season's monthly temperature reduced per hectare farm value by -6.01%, while precipitation increased per hectare farm value by 6.50%. This suggests a detrimental temperature effect and a beneficial precipitation effect on farm value. As shown in the table, the overall detrimental effect of temperature (-6.01%) can be attributed to the farm value reducing effect of the following seasons: June-August(-15.96%), September-November (-14.72%) and December-February (-14.60%). On the other hand, March-May (27.71%) and November-March (11.55%) growing seasons had an increasing countervailing effect on the overall impact of baseline temperature. Across agricultural zones, the findings are mixed. For example while overall temperature is beneficial in North East and South West by 0.24% and 4.22% respectively, precipitation appeared detrimental in North east and North West agro agro-ecological zones by -0.27% and -0.44% respectively.

Table 4.18 RicardianMarginal estimates for Nigeria.

Climate variables	WC	NC	NE	NW	SE	SW
TEMPERATURE						
Sept-Nov	-80989.95	52528.92	225011.5	-21568.02	-250265.2	-46166.18
	(14.72)	(20.74)	(7.83)	(13.63)	(47.65)	(9.71)
June-August	-87795.82	29334.44	-104709.7	-21399.02	68180.53	222772.2
	(15.96)	(11.58)	(3.64)	(13.52)	(12.98)	(46.88)
March-May	152451.7	-95239.39	292960.5	28287.57	173779.2	-135034
	(27.71)	(37.60)	(10.19)	(17.88)	(33.09)	(28.41)
Dec-Feb	-80309.36	-24111.24	899094.1	-29579.73	-21130.58	7601.687
	(14.60)	(9.52)	(31.27)	(18.69)	(4.02)	(1.60)
Nov-March	63566.9	20007.53	-1305516	43209.14	4392.464	-29133.52
	(11.55)	(7.90)	(45.40)	(27.31)	(0.84)	(6.13)
All seasons	-33076.5	-17479.7	6840.4	-1050.06	-25043.6	20040.19
	(6.01)	(6.90)	(0.24)	(0.66)	(4.77)	(4.22)

Source: Author's computation ( ) percentage change

Table 4.18 Ricardian Marginal estimates for Nigeria. (cont)

Climate variables	WC	NC	NE	NW	SE	SW
PRECIPITATION						
Sept-Nov	384.53	732.55	-9444.32	-699.93	-354.66	1331.53
	(0.07)	(0.29)	(0.33)	(0.44)	(0.07)	(0.28)
June-August	487.98	69.92	2264.60	-564.96	-198.27	-1983.50
	(0.09)	(0.03)	(0.08)	(0.36)	(0.04)	(0.42)
March-May	1415.62	-522.34	12964.07	956.67	4306.59	2000.29
	(0.26)	(0.21)	(0.45)	(0.60)	(0.82)	(0.42)
Dec-Feb	58122.2	18670.64	4976.21	-6174.65	1201.43	17352.43
	(10.56)	(7.37)	(0.17)	(3.90)	(0.23)	(3.65)
Nov-March	-24637.28	-12055.62	-18397.51	5791.10	-1395.78	-11856.68
	(4.48)	(4.76)	(0.64)	(3.66)	(0.27)	(2.49)
All seasons	35773.06	6895.15	-7636.94	-691.76	3559.31	6844.06
	(6.50)	(2.72)	(0.27)	(0.44)	(0.68)	(1.44)

Source: Author's computation ( ) percentage change

Temperature impact was most detrimental in NC followed by SE while it was more beneficial in SW compared to NE. For North central agro ecological zone, March-May season temperature (-37.60%) and December-February temperature (-9.52%) turned out important factors increasing the detrimental effect of the overall seasonal temperature (-6.90%). Also, in south east agro ecological zone, September-November temperature (-47.65%) accentuated the detrimental effect of the overall temperature effect. In south west, March-May temperature reduced farm value by -28.41%. However, the increasing farm value effect of June-August temperature by 46.88% more than offset the detrimental farm value effect of March-May temperature such that overall temperature effect of the zone turned out beneficial by 4.22%.

4.2.4.4. Climate Change Impact Simulations

This section explores the simulated impact on farm value across farms in Nigeria. The simulation assumes all other conditions such as changes in prices, investment, population and technology are constant. It is not a forecast of how farm value will change but simply what could happen in the future by isolating the effect of climate change on farm value. Climate predictions are mild case scenario of CO_2emissions of Hadley models. The Ricardian simulated impact of climate change using these predictions are presented in the table below. Given Hadley model prediction of 1.89mm increase in precipitation and a 1.03 degree centigrade rise in temperature, the Ricardian model predicts losses in farm land value by -62.79% in the near term(2050)for the whole country. Variation is also observed across agricultural zones. For North central zone, losses of -8.24% in farm value is expected in 2050. Losses of -41.95% and -44.96% are respectively predicted for North east and south west. While climate will be beneficial for south east by increasing farm value by 3.36% in 2050. While HadGEM model predicts -41.95% losses in farm value for North east zone, the value is lower than the average for the whole country but the most detrimental impact on farm value after South west zone estimated at -44.96% in the near term (2050).

These estimates depend on the climate model prediction used. For example using CGMG3 model (absolute mean change in temperature and precipitation:0.78mm and 0.81 degree centigrade respectively), Ricardian model predicted losses in farm value by 33.37% in the near term (2050). Losses in farm value for North east turned out the most across all agricultural zones. Farm value losses for North east is estimated at -20.20%. In contrast, changes in absolute mean climate increased farm value in North central and south east zones by 5.05% and 12.27% respectively in the near term.

Table 4.19 Simulated climate change impact distribution by agricultural zones in Nigeria

Agricultural zones	Baseline(N)	HADCM3 2050(N)	Change(N)	%	MG 2050(N)	Change(N)	%
WC	536508	199610	-336898	-62.79	357460	-179048	-33.37
NC	275924	253179	-22746	-8.24	289866	13941.2	5.05
NE	188892	109653	-79238	-41.95	150736	-38156	-20.2
NW	127620	118438	-9181.7	-7.19	117746	-9873.7	-7.74
SE	475413	491407	15994	3.36	533741	58327.6	12.27
SW	556514	306287	-250227	-44.96	458579	-97935	-17.6

Source: Author's computation

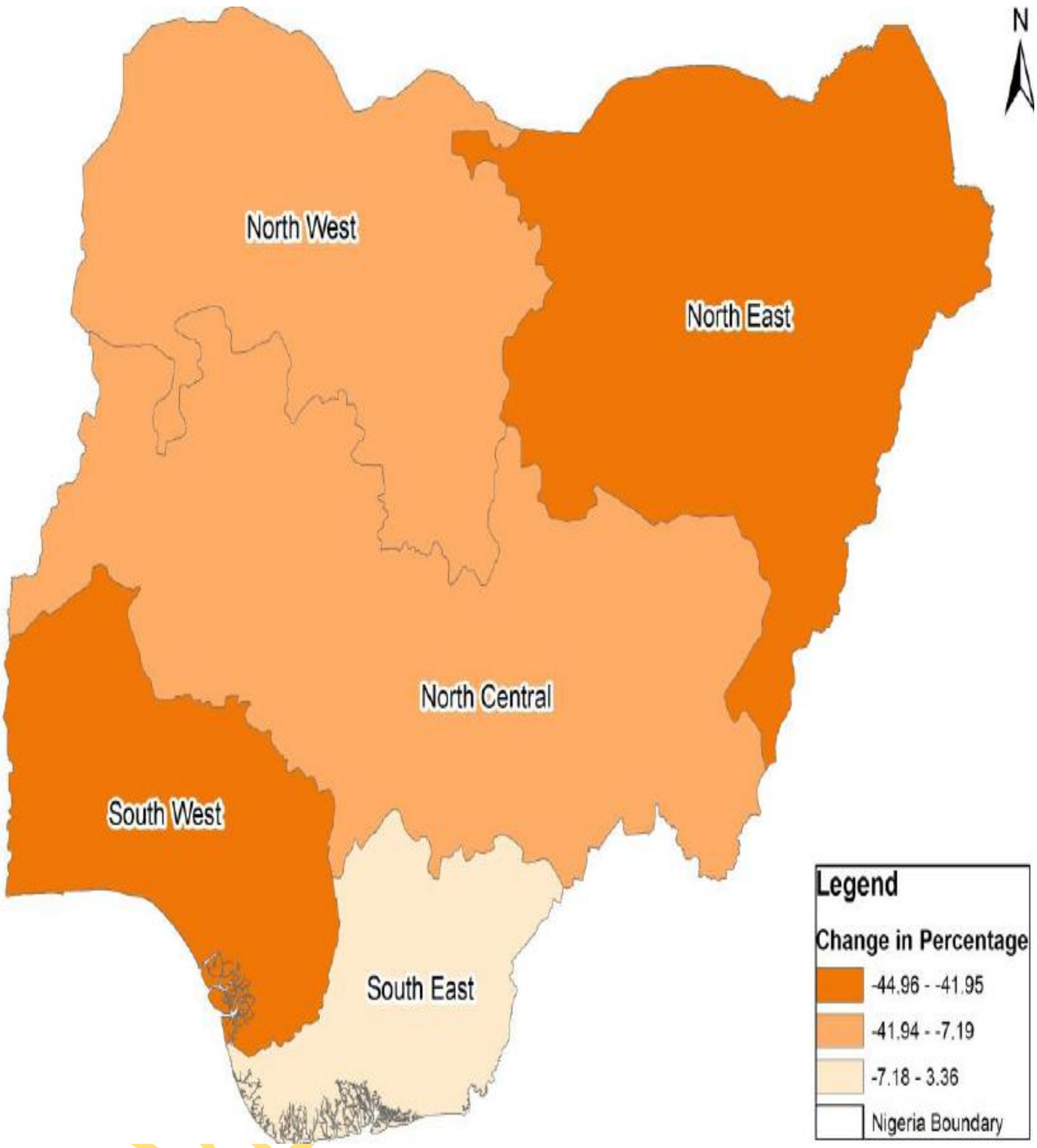

Figure 4.9. Spatial distribution of climate change impact by agricultural zones in Nigeria(HADCM3 2050 + RICARDIAN)

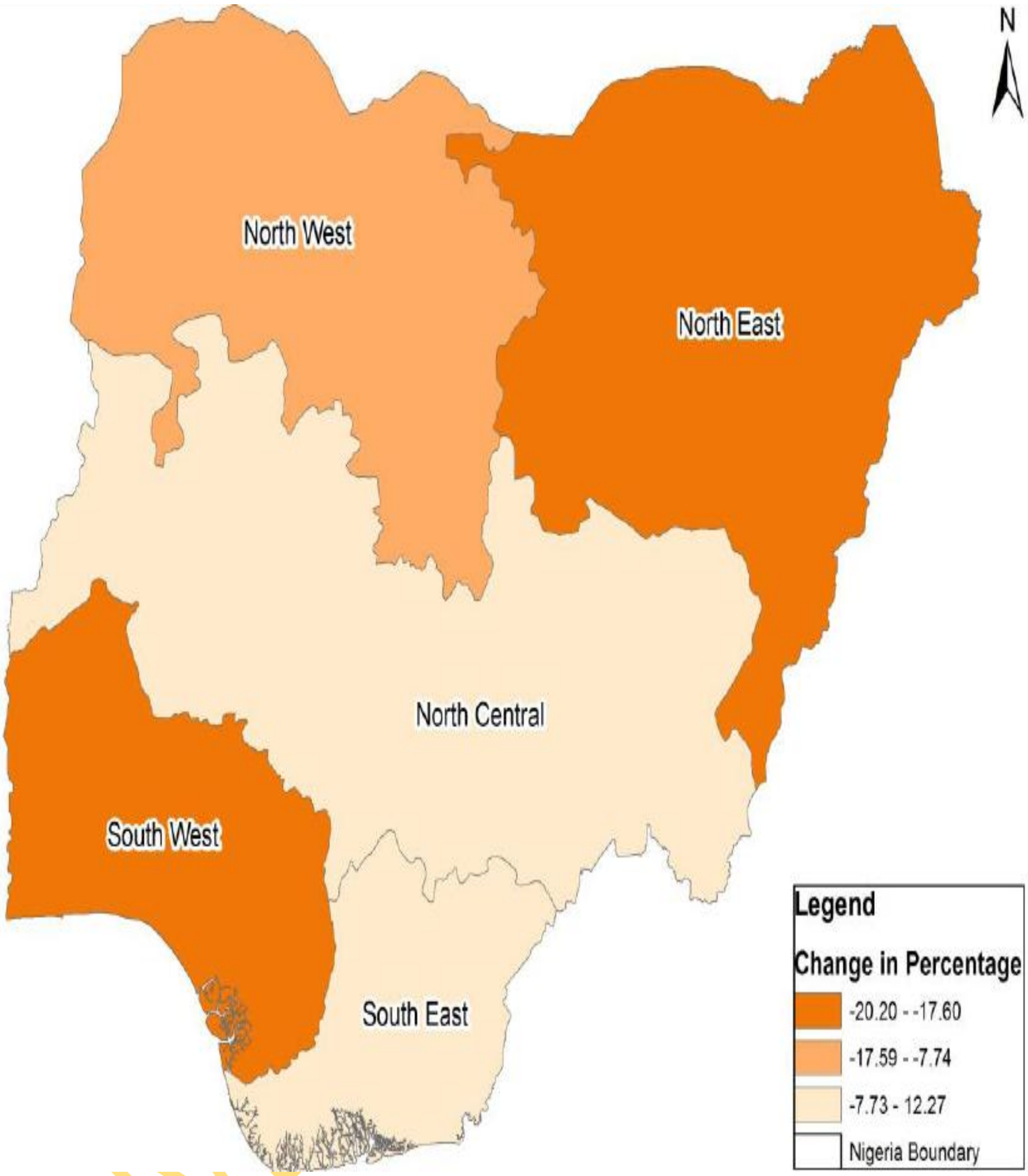

Figure 4.10 Spatial distribution of climate change impact by agricultural zones in Nigeria(MG 2050 + RICARDIAN)

4.2.4.5. Comparing Farm Value and Farm Revenue Climate Estimate

The aim of this section is to compare the estimates of farm value and farm revenue models. The table below presents the coefficients and the t-statistic for farm value and farm revenue models and for the pooled data. Estimations were fitted on area council observations numbering 246 for each of the model. For both models the F statistics were significant at $p<0.0001$. For the farm value model, 89% of the variance was explained by the included variables while for the farm revenue 89% was explained. The number of coefficients that were significant at $p<0.05$ were 17 and 22 for the for farm value and farm revenue models respectively. This suggests more consistent coefficients for farm revenue compared to farm value model. However for both models, the sign of the coefficients were consistent with apriori expectation.

Table4.20.Farm value and farm revenue Ricardian coefficients for Nigeria

Variables	Farm value	Farm revenue
TEMPERATURE MEASURES		
Sept-Nov	-21.691(1.35)	-3.2744(0.19)
Jun-Aug	-23.423(2.39)	-12.0472(1.15)
Mar–May	40.7234(3.06)	-48.5608(3.40)
Dec–Feb	-21.407(1.01)	-108.7765(4.81)
Nov–Mar	16.968(0.54)	178.0038(5.31)
Sept-Nov^2	0.493(1.61)	.0135(0.04)
Jun-Aug^2	0.386(2.19)	.2539(1.35)
Mar–May^2	-0.668(2.97)	.7936(3.30)
Dec-Feb^2	0.369(0.85)	2.0568(4.40)
Nov-Mar^2	-0.294(0.47)	-3.3170(4.94)
PRECIPITATION MEASURES		
Sept-Nov	0.103(0.45)	-.4987(2.04)
Jun-Aug	0.130(1.09)	.1160(0.90)
Mar–May	0.378(0.86)	-1.5262(3.26)
Dec–Feb	15.519(4.68)	-15.8579(4.47)
Nov–Mar	-6.58(2.91)	10.7117(4.43)
Sept-Nov^2	-0.0002(2.24)	.0001(1.20)
Jun-Aug^2	-0.0003(5.12)	-.00005(0.96)
Mar–May^2	0.0003(1.39)	-.0003(1.23)
Dec-Feb^2	0.013(2.93)	-.0138(2.90)
Nov-Mar^2	-0.0026(1.51)	.0060(3.18)

Source: Author's computation. ( ) T -statistics

Table4.20.Farm value and farm revenue Ricardian coefficients for Nigeria (cont)

Variables	Farm value	Farm revenue
TEMPERATURE*PRECIPITATION INTERACTION		
Sept-Nov	-0.001(0.11)	.0158(1.60)
Jun-Aug	0.000232(0.05)	-.0038(0.77)
Mar–May	-0.016(1.09)	.0624(3.96)
Dec–Feb	-0.604(4.79)	.6150(4.56)
Nov–Mar	0.2577(3.06)	-.4185(4.64)
Latitude	-0.023(0.30)	-.0879(1.07)
Altitude	-0.00071(0.96)	-.0030(3.79)
Sand	0.0548(1.57)	-.0947(2.54)
Silt	0.0678(1.18)	-.1315(2.14)
Clay	#VALUE!	(omitted)
Socio economic 1	-0.054(0.69)	.2172(2.59)
Socio economic 2	-0.042(0.58)	.0417(0.54)
Pop den	-5.5E-07(0.50)	-1.36e-08(0.01)
Cons	9.314091(1.35)	20.4566(5.79)
F(37,208)	52.60	65.64
R-squared	0.8877	0.9079
Adj R-squared	0.8708	0.8941
No. of obs	246	246

Source: Author's computation. ( ) T -statistics

Table 4.21 presents the marginal estimates of the two models generated using the coefficients in Table 4.20. From the table, the marginal estimates of the farm revenue model appears more detrimental for most of the seasons compared to the farm value model

Table 4.21.RicardianMarginal estimatesusing farm value and farm revenue Response models .

Climate measures	Farm value	Farm revenue
TEMPERATURE		
Sept-Nov	-80989.95 (14.72)	-1318.01(0.86)
June-August	-87795.82 (15.96)	-4850.26 (3.18)
March-May	152451.7(27.71)	-19559.21(12.80)
Dec-Feb	-80309.36 (14.60)	-43757.79 (28.65)
Nov-March	63566.9 (11.55)	71699.52 (46.94)
All seasons	-33076.5 (6.01)	2214.25(1.45)
PRECIPITATION		
Sept-Nov	384.53 (0.07)	-200.86 (0.13)
June-August	487.98 (0.09)	46.66 (0.03)
March-May	1415.62 (0.26)	-614.19 (0.40)
Dec-Feb	58122.2 (10.56)	-6379.15 (4.18)
Nov-March	-24637.28 (4.48)	4323.06 (2.83)
All seasons	35773.06 (6.50)	-2824.49 (1.85)

Source: Author's computation. ( ) T -statistics

These findings conflicts with the argument that the impact of environmental effects would be exaggerated by a farm revenue model. According to Mendelsohnn et al., (1994) “the magnitude of damages predicted by the gross-revenue (farm revenue) model is generally larger than farm value model prediction.To make both estimates comparable, farm revenue is expected to be adjusted to capture future uncertainty and development pattern within and between farms over time. Farm revenue is the earnings that accrue to farmers at the present time while farm value is viewed theoretically as the discounted value of future streams of annual revenue from the farm. Mendelsohn et al., (1994) suggested two adjusted approaches: Interest rate of capital and the rate of profit on farm. However in subsistence farming with partial commercialization, knowing the rate of interest on capital investment might be challenging. Secondly interest might be different across agro ecological zones since farming risk may not be homogenous across zones. Thus in this study, a scale factor was generated that reflects the rate at which farm revenue accumulates over time. Following Mendelsohn, a 5% interest rate of capital was assumed to derive the time frame using the formula$\frac{FV}{FR} = (1 + r^n)$. Farm revenue (FR) is comparable to farm value (FV) using the formula$FV = FR(r)^n$.

The demeaned climate measures were used to multiply the coefficients presented in the table above and then summed across the climate measures for each of the observation. The values are averaged to arrive at the impact. Using this adjustment approach, farm revenue overestimates damage by 3.6% and statistically significant at 10% as shown in the table. The second table below shows the difference between farm value and farm revenue unadjusted. There is statistical difference between the two estimates at $p<0.05$ but the estimated change appears outrageous at 126%. This reflects the importance of adjustment. This study supports the hypothesis of a farm revenue overestimation of climate effect.

Table 4.22.Estimates test

Farm value	Farm revenue adjusted	Difference	T-statistics
Mean 992902.18	Mean 1028500.2	-35598 3.6%	-1.0125(0.1561)

Farm value	Farm revenue	Difference	T-statistics
Mean 992902.18	Mean -292060.15	1284962 129%	1.4858(0.0693)

Source: Author's computation.

4.3.Adaptive Capacity Estimates

4.3.1. Summary Statistics

Table 4.23 shows the summary statistics of the 42 indicators included in the PCA run. The indicators were selected and categorised on the basis of financial, social, physical, human and natural capital dimensions of farmholders adaptive capacity. After the first PCA run, 15 indicators were selected using the communalities of the indicators which measure the proportion of variance explained in a particular indicator included. Thus indicators with high proportion of variance explained were selected. The selection was also based on their policy relevance. Table4.24 show the indicators across agricultural zones. PCA requires trial and error and continual scrutiny of variables to determine which combination yields the most logical results (Henry et al, 2003).In the second run of PCA, only 15 out of the 42 indicators were included.In the second run of the PCA, 15 principal components (PCs) were generated from the analysis. The analysis generated the Eigen value that captures the total variance in the indicators explained by each PC. The Eigen value and the proportion of the total variance explained by each PC were helpful in ranking the PCs in order of their significance and what PC to retain.

Table.4.23. Mean distribution of various indicators of adaptive capacity grouped bySustainable livelihood framework

Indicators	Mean	Standard dev.
SOCIAL CAPITAL		
How many groups are there in the community in numbers	3.017	13.245
How many members does the group have	83.789	135.140
How many female members does the group have	35.443	90.456
How many members under the age of 30 years does the group have	18.352	23.915
Membership of association dummy	0.920	0.271
HUMAN CAPITAL		
Household size	5.127	1.546
Age	52.453	14.601
Literacy rate	0.648	0.478
Actual extension visits	0.081	0.273
Education in years	9.646	5.642
In the last 4 weeks do you consult a health practitioner	0.131	0.337
FINANCIAL CAPITAL		
Access to credit union	0.120	0.325
Access to informal savings union	0.344	0.475
Access to agricultural insurance	0.000	0.000
Wage income	0.000	0.000
Remittances income	0.276	0.447
PHYSICAL CAPITAL		
Area of land cultivated	1.669	1.675
Access to animal traction	0.256	0.436
Access to farm equipment	0.155	0.362
Access to subsidized seed	0.094	0.292
Access to commercial seed	0.217	0.412

Source: Author’s computation.

Table.4.23. Mean distribution of various indicators of adaptive capacity grouped by Sustainable livelihood framework (Cont)

Indicators	Mean	Standard dev.
PHYSICAL CAPITAL		
Access to subsidized fertilizer	0.016	0.126
Access to commercial fertilizer	0.335	0.472
Access to pesticide	0.146	0.353
Access to herbicide	0.153	0.360
How many hours of electricity in the last 7 days	43.363	55.936
Access to hired labour	0.934	0.248
Access to radio gadget	0.861	0.346
Access to television gadget	0.502	0.500
Access to mobile phone	0.710	0.454
Access to internet	0.004	0.066
NATURAL CAPITAL		
Average monthly rainfall	108.897	53.359
Average monthly temperature	26.557	0.362
Percentage of sand in top soil	59.971	8.345
Percentage of silt in top soil	22.561	4.952
Percentage clay in top soil	17.469	4.078
Access to bore hole/ hand pump	0.364	0.481
Access to well/spring water	0.468	0.499
Access to forest trees	0.129	0.336
Livestock ownership	0.734	0.442
Altitude	263.154	145.051
Education in years	9.646	5.642

Source: Author's computation

Table.4.24. Mean distribution of selectedindicators of adaptive capacity by agricultural zones in Nigeria

Selected indicators	NIGERIA	AGRICULTURAL ZONES NC	NE	NW	SE	SW
	Mean					
Average Area planted in planted in hectares	2.0661	2.4228	3.6481	2.6329	0.8858	2.4833
Proportion with access to draught Animal traction	0.2506	0.0656	0.7912	0.6282	0	0
Proportion with access to Farm equipment	0.1886	0.3552	0.3462	0.0565	0.0166	0.7111
Proportion with access to Subsidized fertilizer	0.0227	0.0077	0.0381	0.0518	0.0075	0.0110
Proportion with access to Commercial fertilizer	0.3524	0.3	0.3475	0.7059	0.2066	0.1381
Proportion with access to Herbicide	0.1303	0.35	0.2881	0.0965	0.0181	0.0994
Proportion having Livestock	0.6459	0.6692	0.7288	0.8259	0.5596	0.3978
Proportion having Economic trees	0.1632	0.1692	0.0424	0.0212	0.2745	0.2376
Proportion having Income from crop sales	0.5450	0.6038	0.9364	0.7365	0.2670	0.5193
Proportion with Insurance support	0.0091	0.0077	0.0085	0.0024	0.0151	0.0055
Proportion with Wage income	0.0210	0.0231	0.0297	0.0024	0.0287	0.0221
Proportion belong to an association	0.8431	0.8731	0.7288	0.9671	0.7994	0.8177
Household size in number	5.8160	5.7743	6.9976	6.7585	5.0943	4.7655
Age in years	51.2653	47.1615	46.6255	47.6188	55.8892	54.9116
Proportion that is literate	0.5530	0.4654	0.4894	0.5906	0.5816	0.5691

Source: Author's computation

Table 4.25.Principal components and the associated Eigen value

Principal Components	Eigen value	Differences	Proportion	Cumulative
1	2.44722	1.06652	0.1631	0.1631
2	1.3807	.0493904	0.0920	0.2552
3	1.33131	.0764962	0.0888	0.3439
4	1.25481	.118586	0.0837	0.4276
5	1.13622	.128505	0.0757	0.5033
6	1.00772	.15342	0.0672	0.5705

Source: Author’s computation

Table 2.25 presents the retained principal components and their associated Eigen values. The selection was based on the a variance factor (Eigen value) greater than 1. The choice of the number of PCs to be retained is subjective and is generally based on the interpretability of the retained components (Srivastava, 2002). Identifying the most important principal components to retain for further analysis forms one of the steps in PCA. In terms of the explained variation in original variables, the Kaiser Criterion conventional practice of Eigen value>1 is often used. The criterion states that unless a principal component has a standardised variance equal to or greater than 1, it should be dropped from further analysis (Filmer and Pritchett, 2001). Thus we retained only 5 PCs that account for a substantial proportion of the variability in the original data. As shown in the table, PC1 appears the most important, explaining 16%, PC2 explained 9% of the total variance, PC3 8% and so on. The 6 PCs together explain about 57% of the variability in the data set.We restricted our analysis to five principal components (PC1 – PC5). They explained 50% of the variance of the original 15 indicators.

4.3.2. Relative Importance of indicators and adaptive capacity mapping.

Table 4.26 presents 15 indicators and their respective relative weights across each of the retained 5 principal component (PC). This constitutes the matrix of factor loadings or Eigen vector generated by the PCA. The five retained PCs can be seen as factors predicting the relative importance of the 15 indicators of farmers' adaptive capacity. Table presents the Eigen vector in which each row gives for each indicator the weights for the five PCs. Each indicator is assigned to the PC that contributes most to the explanation of the variance of the particular indicator. That is assigned to the PC that ascribes the highest absolute value. In this way, the weights help to reveal clearly the predictions of the PCs. To facilitate the readings of the results and clean presentation, weights smaller than 0.3 were omitted from the table (See Federica and Conforti, 2010). Using this approach and taking account of the sign, the indicators that PC1 ascribed as very important in differentiating farmers adaptive capacity were: household size (0.47), Animal traction (0.44), income from crop sales (0.38) and access to forest trees (-0.53). PC1 most probably predicted the extent to which farm households rely on manual family labour and natural resources as well as crop income in coping with shocks.

Table 4.26.Factor weights of selected indicators

Indicators	PC1	PC2	PC3	PC4	PC5
Area planted			0.48		
Animal traction	0.44				
Farm equipment			0.65		
Subsidized fertilizer				0.44	
Commercial fertilizer		0.42			
Herbicide			0.47		
Livestock ownership		0.53			
Ownership of Economic trees	-0.53	0.26			
Income from crop sales	0.38		0.28		
Insurance					0.67
Wage income					0.64
Membership of an association		0.58			
Household size	0.47				
Age				0.50	
Literacy				-0.63	

Source: Author's computation

The relatively high percentage of variance explained by PC1 (12%) reflects the indicators as the most important factors discriminating farm households adaptive capacity. Thus we refer to family labour/natural resources/crop income as important adaptive capacity typology. PC2 was of major importance in explaining membership of an association (0.58), ownership of livestock (0.53), access to commercial fertilizer (0.42) and access to forest trees (0.26). PC3 explains access to farm equipment (0.65), available land for cultivation (0.48), access to herbicide (0.47) and crop income (0.28). PC4 explains age (0.50), subsidized fertilizer (0.44) and literacy rate (0.63). PC5 predicts the importance of agricultural insurance (0.67) and wage income (0.64)

Improvement in these indicators will enhance farmers' adaptive capacity to changes in climate. Other things being equal, availability of land will motivate a household to engage in crop production and livestock rearing. Access to both subsidized and commercial fertilizer is among the critical factors that discriminate farmers in terms of the capacity to engage in agricultural production. Climate change will affect the timing, use and amount of these inputs. Other physical inputs include access to draught animal traction and farm equipment. Crop income reflects accessibility to output markets, motorable roads and commercialization. Possession of farm equipment affects farm household decision to engaging in cropping activity. Possession of farm equipment also reflects the ability of farmers to hire out to other households and in return generate a rental income. Large family size is associated with participation in labour-intensive activities, such as soil conservation works, construction of canals and off–farm activities such as forest collection. Literacy allows access to information and understanding media alert on climate disasters. It also influences the ability of farmers to make decisions against sudden shocks. The age of the household is associated with experience and limitations. PC5 can be viewed as emphasizing off-farm income which is an important source of income complementing farm income in rural Nigeria. Agricultural insurance also captures the importance of insuring farmers against risk and the importance of risk bearing agencies such as National food reserve agency.

Mapping of adaptive capacity across agricultural zones in Nigeria

Figure 4.11 shows the predicted adaptive capacity distribution by PC1. The factor placed emphasis on household size (0.47), Animal traction (0.44), income from crop sales (0.38) and access to forest trees (-0.53) as relatively important indicators defining PC1. This index can best be described as family labour and natural resources. This type of adaptive capacity index was highest for states in North east and North West agricultural zones with an index ranging from 0.52 – 0.6.

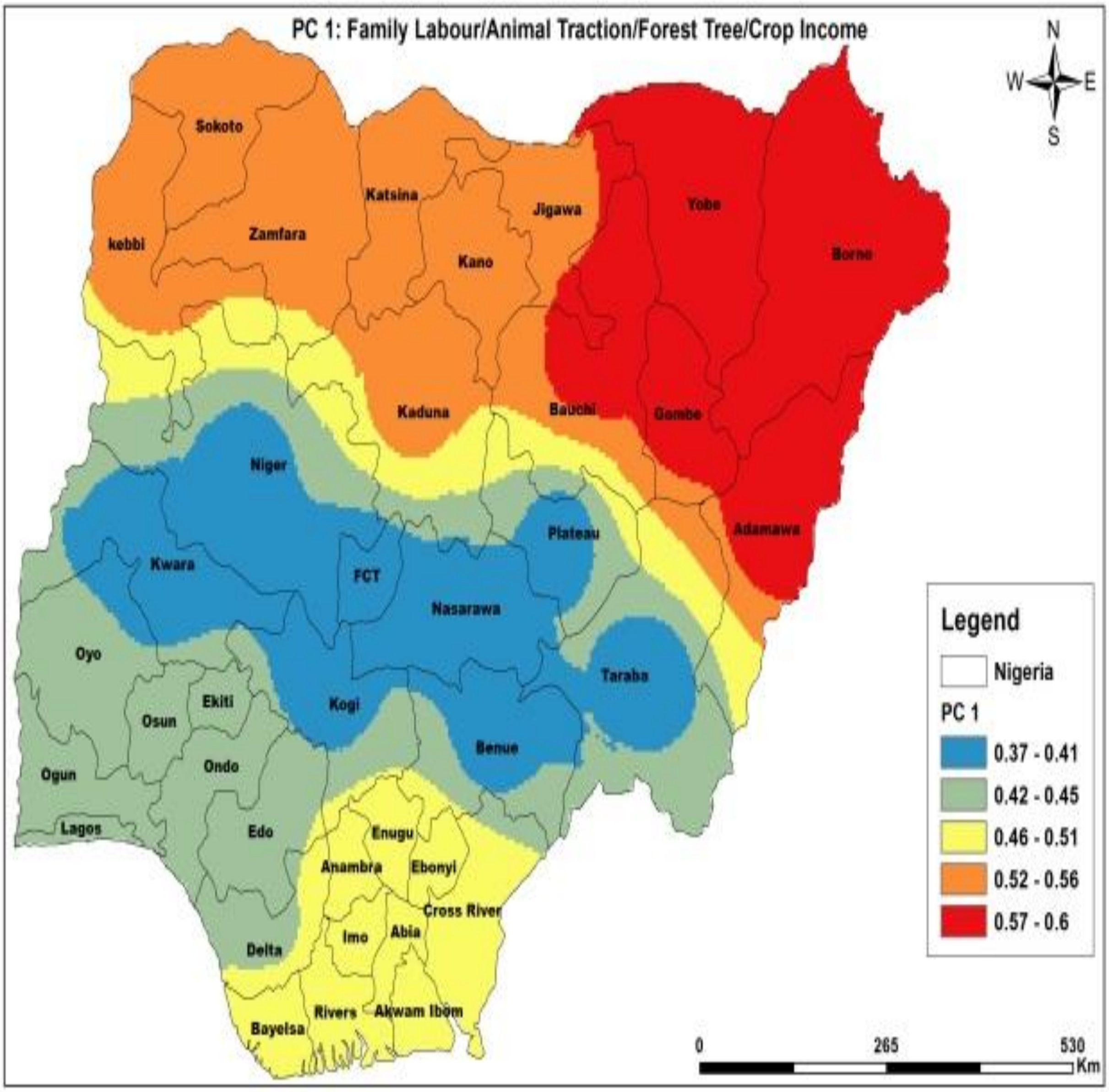

Figure 4.11.Family labour/Animal traction/forest tree/crop income adaptive capacityspatial distribution by agricultural zones in Nigeria

Figure 4.12 shows the predicted adaptive capacity distribution by PC2. This factor emphasizes on membership of an association (0.58), ownership of livestock (0.53), access to commercial fertilizer (0.42) and access to forest trees (0.26). PC2 most probably predicts an adaptive capacity index that relies on social and financial capital. This was highest for states in North West agricultural zones with an index ranging from 0.52 – 0.7.

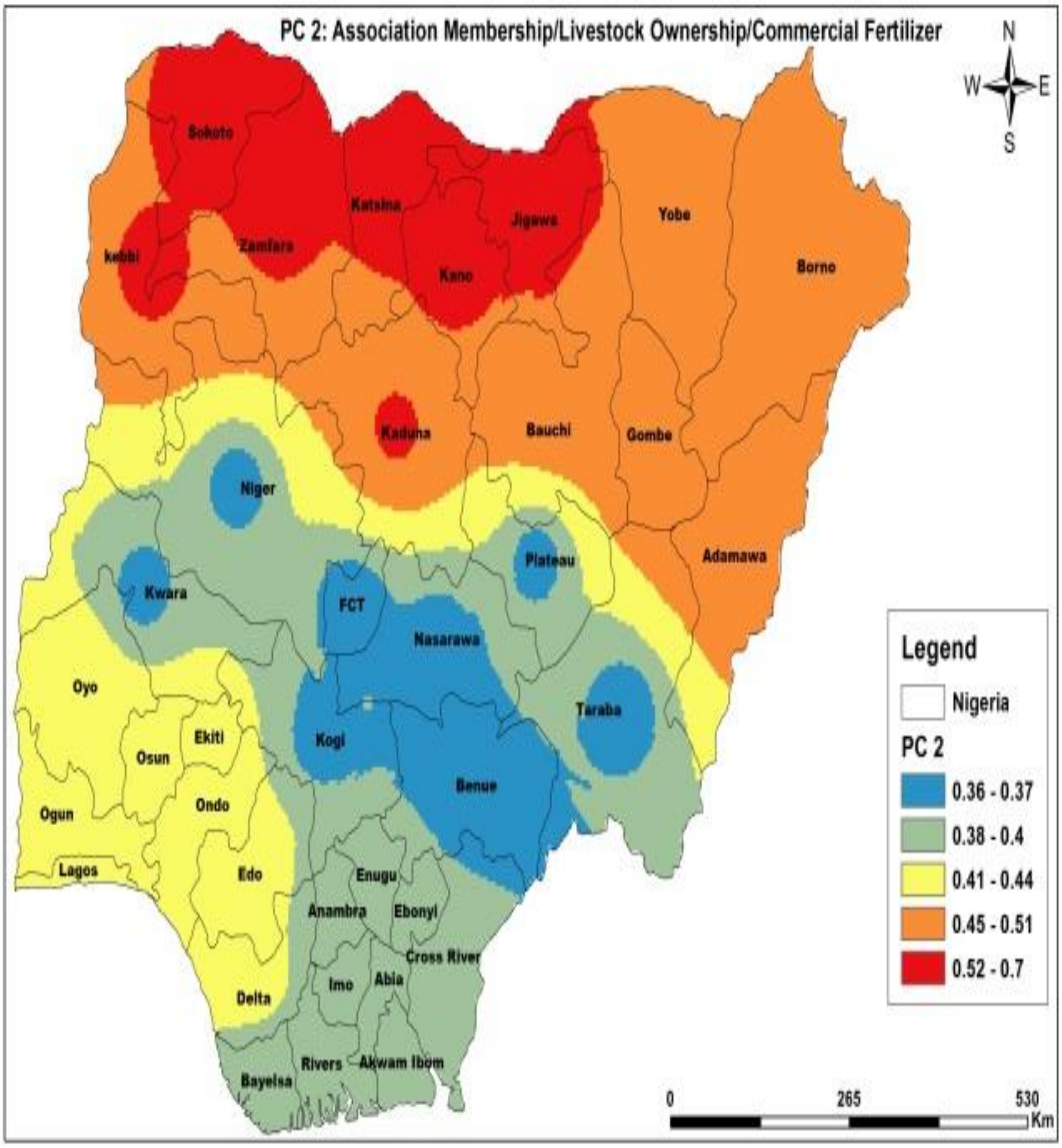

Figure 4.12.Association membership/livestock ownership/commercial fertilizer adaptive capacity spatial distribution by agricultural zones in Nigeria

Figure 4.13 shows the predicted distribution of adaptive capacity by PC3. This factors emphasizes on access to farm equipment (0.65), available land for cultivation (0.48), access to herbicide (0.47) and crop income (0.28). PC3 most probably predicts adaptive capacity that relies on physical asset most especially farm equipment and land. This is most important in south east and south west ecological zones.

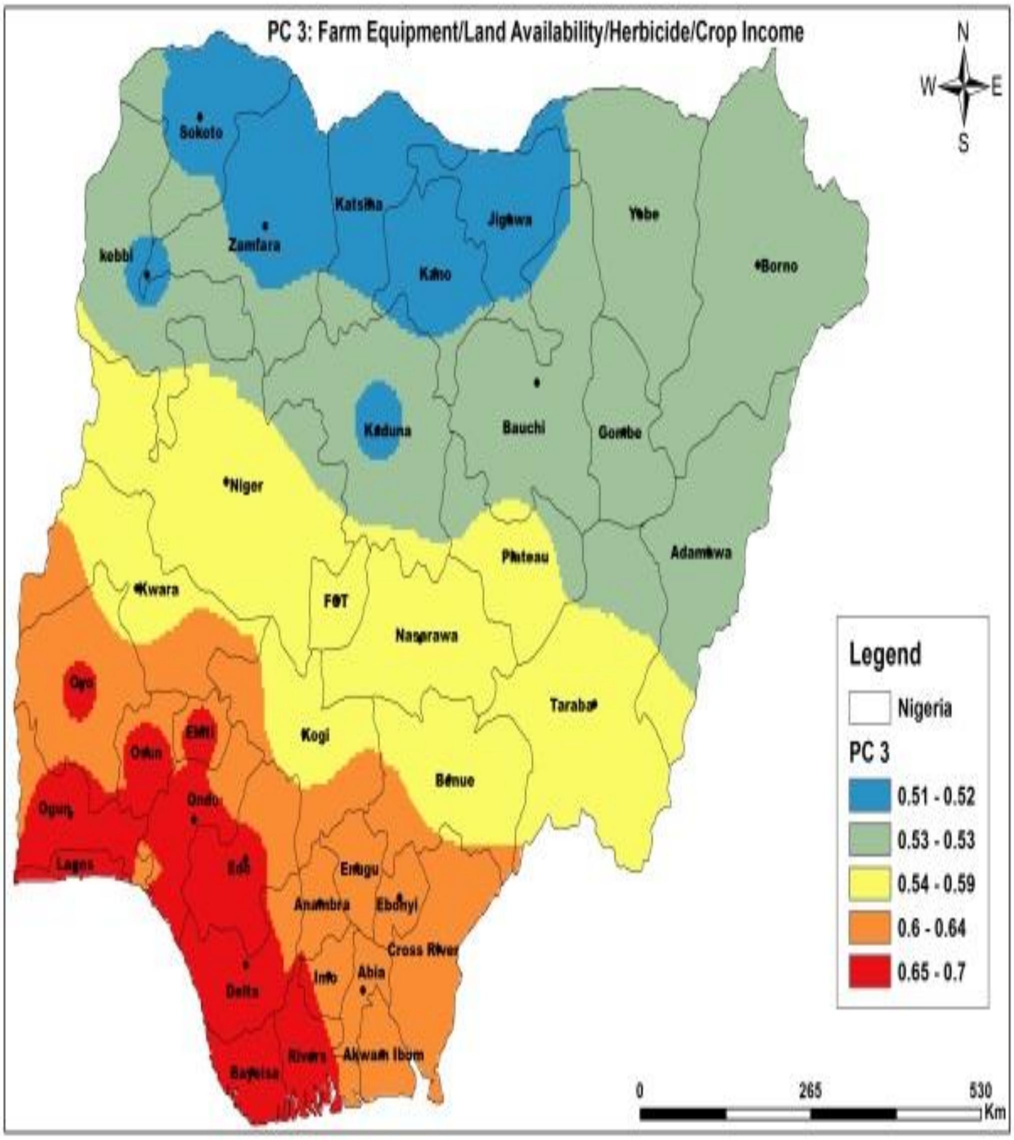

Figure 4.13. Farm equipment/ Land availability/Herbicide/crop income adaptive capacity spatial distribution by agricultural zones in Nigeria

Figure 4.12 shows the predicted adaptive capacity distribution by PC4. This factor emphasizes on literacy rate (0.63), age (0.50) and subsidized fertilizer (0.44). PC4 most probably predicts the importance of human capital in terms of education and experience. The adaptive capacity index is also built on the extent to which farm households have access to subsidized fertilizer. This is most pronounced in the whole of Northern Nigeria comprising north east, North West and North central.

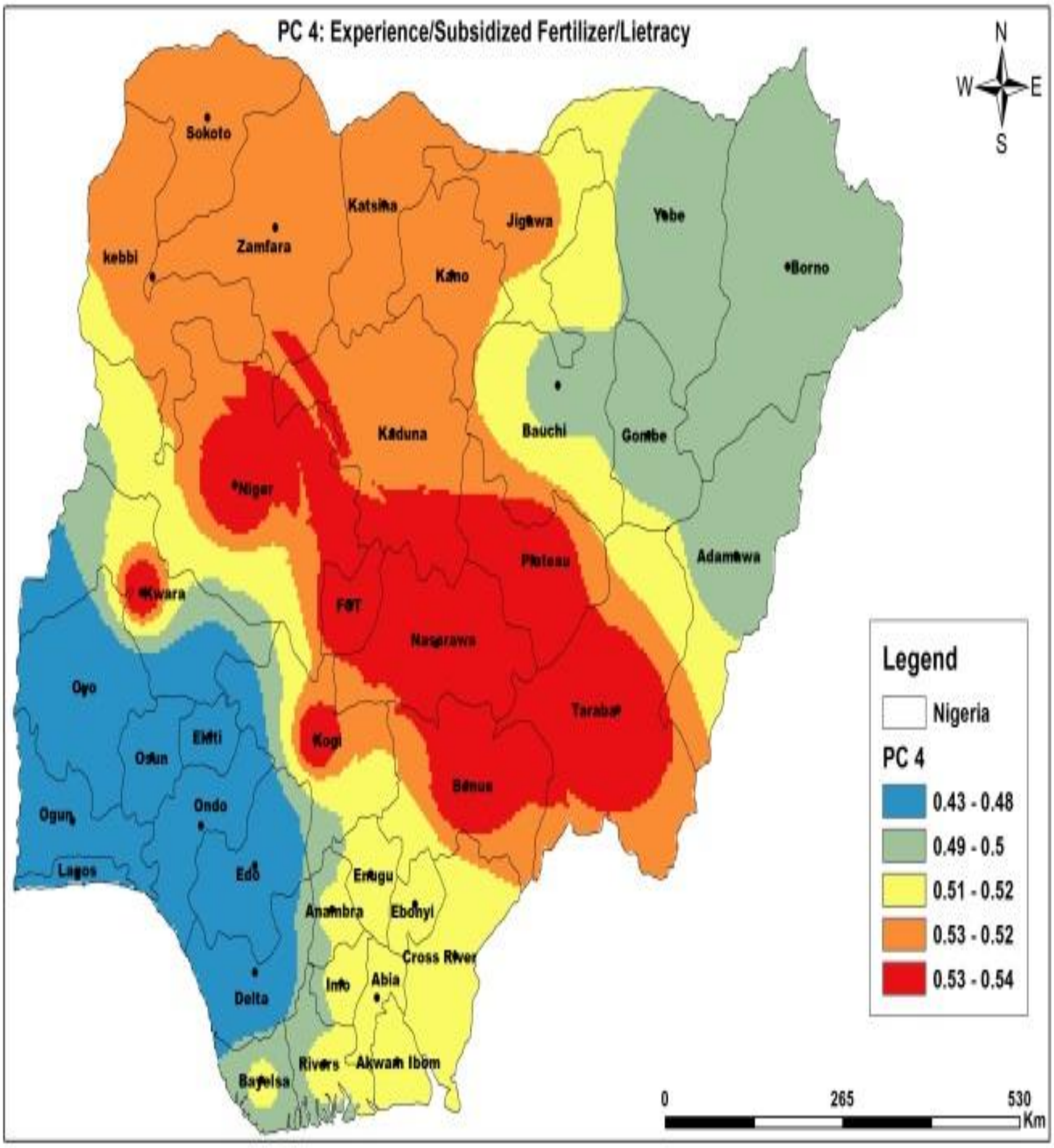

Figure 4.14. Experience/Subsidized fertilizer/literacy adaptive capacity spatial distribution by agricultural zones in Nigeria

Figure 4.15 shows the predicted adaptive capacity distribution by PC5. This factor places more emphasis on agricultural insurance (0.67) and wage income (0.64).PC5 can be viewed as emphasizing off-farm income which is an important source of income complementing farm income in rural Nigeria. Agricultural insurance also captures the importance of insuring farmers against risk and the importance of risk bearing agencies such as National food reserve agency. This adaptive capacity is quite weak in all the agro ecological zones and the weakness is most pronounced in south east.

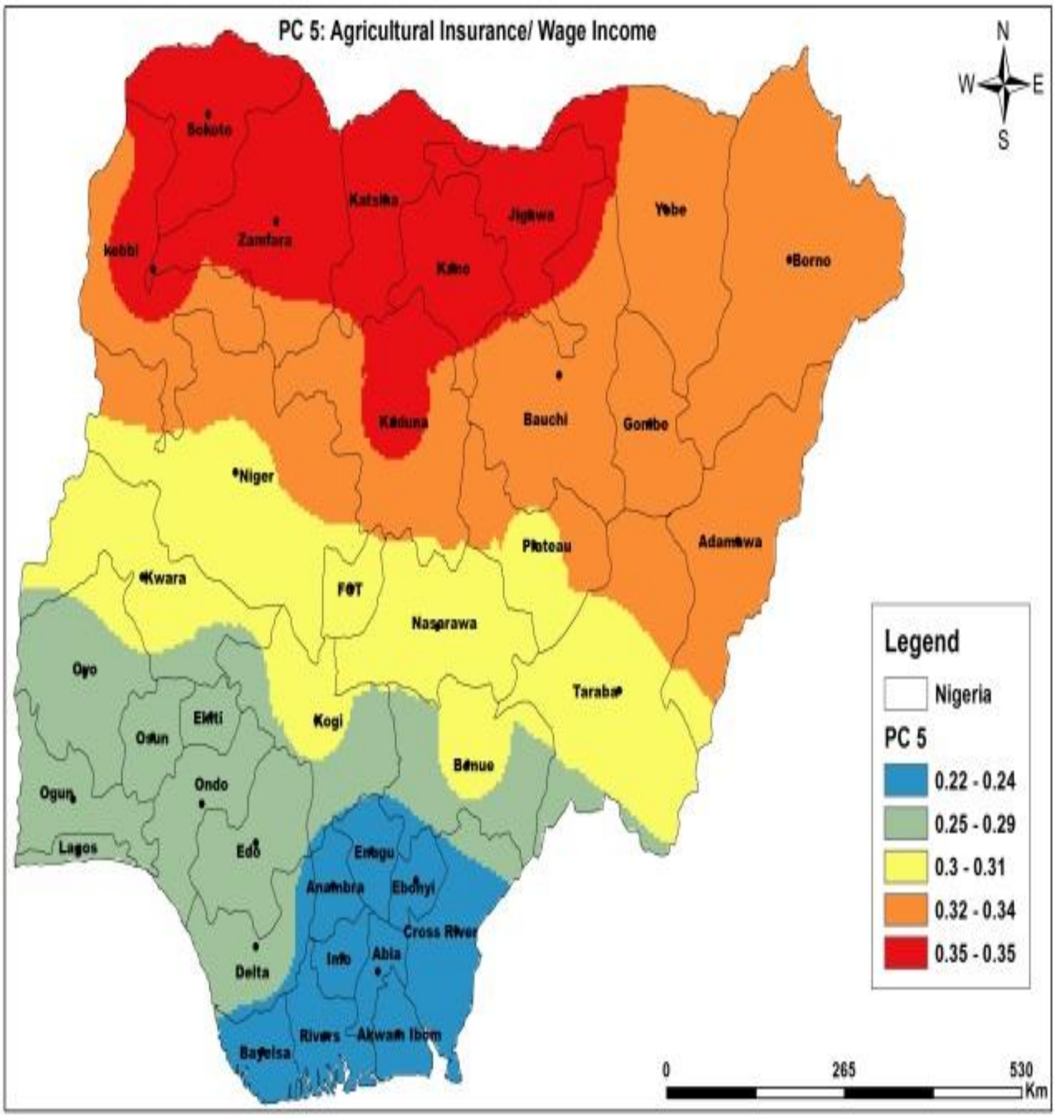

Figure 4.15.Agricultural insurance/wage income adaptive capacity spatial distributionby agricultural zones in Nigeria

CHAPTER FIVE
SUMMARY,RECOMMENDATIONS AND CONCLUSIONS

5.1. Summary

1. The aim of the study was to measure climate change phenomenon from an economic perspective for appropriate adaptation programming and investment at the farm level. The study was premised on the hypothesis that current and future climate conditions have influence on the decisions farmers make and on the cost of farm operation. Farm value isa dynamic outcome of the interaction between the attributes of the farm, other exogenous influences and farmer's characteristics. Exposure to changes in climate haveboth beneficial and detrimental effect on farm value and also have a response component in terms of adaptation and adaptive capacity.

2. General household survey data on smallholder farms collected by the National Bureau of Statistics (NBS) in 2010 was used together with baseline climate observations from 1950-2000 and projections (2000-2050) of the World Climate Data Base (WCDB). Complementary data on population, soil and altitude for 774 Local Government Areas (LGA) were sourced from National Population Commission (NPC) and Food and Agriculture Organisation (FAO). Variables from NBS included farm value, farm revenue, crops cultivated, land size, area planted, household size and age. Variables from WCDB were Mean Temperature (MT) and Mean Precipitation (MP) for wet and dry seasons.

3. The study employed econometric techniques to generate information on the aggregate net economic damages and benefits of climate change on farm value; information on crop choice responses by farmers to current and future climate

conditions. Also generated adaptive capacity typologies across agro ecological zones.Analytical tools included descriptive statistics, multivariate probit and Ricardian models and Principal component analysis. The study was limited to cross sectional analysis of farms at a point in time and therefore a static analysis. The climate change impact simulation assumed constancy of prices, CO_2, technology and infrastructural development over time while climate variables specifically temperature and precipitation were assumed to vary. Soil quality variables used were assumed to be homogenous within states and heterogeneous between states. This however is a strong assumption because within each locality there could be extensive variation in soil quality. Hydrology is an important factor affecting differences in land value and this was not included because of the difficulty of assessing such data.

4. From the descriptive statistics, rainfall pattern followed a decreasing gradient from south east to north east. The months of June – September was observed as the peak of rainfall with a slight drop in the month of August. The south east agricultural zone experienced the highest amount of rainfall, followed by south west while the least rainfall was experienced in north east agricultural zone.

5. The absolute change in rainfallreveals deficit in rainfall in the north east agro ecological zone across all seasons with high severity in March, April, May, Jun and October while the months of July, August and September are expected to be moist. Deficit in rainfall is also expected in north West but not as severe as in north east. Much rainfall is expected in north central across all the months with substantial changes in rainfall in the months of August, September and October. Deficit in rainfall is also expected in the south east and south west agricultural zones in some of the months with severe increases in rainfall in November and December.

6. There appeared little variation in temperature across zones but the highest temperature is observed for the months of March – May. The absolute change in mean monthly temperature reveals expected change across all the zones. South west agricultural zone is expected to have a cooler climate in all the months of the year compared to north east. The north east is expected to have

the hottest climate with an average annual change in temperature by 1.72 centigrade. This is followed by north central and south east agricultural zones with temperature changes of 1.29 and 1.25 centigrade respectively.

7. The average number of persons in a household as 5.8. Farming systems is male dominated constituting 94% of farmers. The average age of farm headed household is 51.27 years and 53% of these farmers are literate. 25% of farmers have access to animal traction while 19% have access to farm equipment tractor. 68.65% practice mixed cropping, 0.95% other types of cropping pattern. 5.33% have access to credit and micro finance institutions. 25.89% of farmers receive credit from friends and neighbours while 1.20% had access to insurance. 83.40% belong to one association. 33.05% have access to government extension service while 6.94% have access to private extension services. Proportion of farmers with access to NGO provided extension services is 1.67%. Farmer to farmer learning and knowledge sharing constitute 38.33% while 20% have access to media extension services.

8. Average farm size for the whole country ranges from 2.7 hectares on the average to 7.41 hectares maximum. The upper range is the same across all agricultural zones except for south east zone where the upper range of farm size is 4.71 hectares maximum. In north east and north west agro ecological zones, the farm sizes are respectively 3.84 hectares and 3.19 hectares above the average for the whole country. In north central agricultural zone, the farm size is 2.92 hectares higher than the average for the whole country and that for south west (2.57 hectares). The average farm value for the whole sample is 194693.3 naira and varies from a minimum of 10,714.29 naira to a maximum of 1,619,433 naira per hectare. The average for north central zone is 239,528.9 naira and ranges from 195,186.5 to 1,043,536 naira per hectare. For north east and north west, the mean farm values are respectively 91,362.92 naira and 100,030.9 naira per hectare. For south east and south west, the mean values are respectively 299,329 naira and 349,025.6 naira per hectare respectively.

9. On average, 29% of farmers cultivated cassava and followed by yam (19.29%), millet (15.74%), sorghum (13.09%), maize (12.41%), rice (2.59%), and cowpea (2.88%). Only 4.62% of households cultivated other crops and

includes tree crops, cotton and vegetables. The result reveals variation in the pattern of cultivation across agricultural zones. While sorghum and millet are virtually not cultivated in south east and south west zones, they are very much produced in the north east and north west agro ecological zones. Cassava is produced substantially in south east zone (58.97% of households) and south west zone (49.72%). Also to some extent in north central (14.39%).Yam is produced substantially in north central zone (37.12% households), in south east (30.92%) north east (20.00%) and north West (19.89%). Maize is produced substantially in north central (21.59%), north West (11.76%) and south west (11.05%).

10. The decision to cultivate two or more crops was interdependent across smallholder farms and farmers either cultivated more of a particular crop and less of another or complement crops in response to current climate conditions. Current climate conditions as measured by average temperature and precipitation influenced the probability of crop cultivation across smallholder farms. The relationship was both cup and hill shaped suggesting optimum temperature and precipitation levels beyond which land use cost and crop choices were affected. Temperature impact on the probability of cultivation was higher compared with precipitation impact. Baseline MP increased the probability of cultivating sorghum (0.5%), cowpea (0.2%), and yam (0.1%) while it reduced the probability of cultivating millet (0.8%), rice (0.1%), cassava (0.1%) and maize (0.5%). Baseline MT increased the probability of cultivating millet (5.8%), rice (2.4%) and maize (51.5%) and reduced the probability of cultivating sorghum (0.7%), cowpea (2.1%), cassava (0.7%) and yam (36.7%). Projected MT reduced the probability of cultivating all crops with the highest probability on sorghum (10.5%). While the effect of projected MP on the probability of cultivation was mixed across crops, the highest probability of reduced cultivation was observed for rice (25.9%) and the least for maize (1.8%).

11. Farm value showed a mixed pattern of hill and U- shape relationship with climate across various seasons. The hill shape was more pronounced for temperature and less for precipitation. In other words there is a maximum level

of temperature beyond which land use for crop cultivation becomes costly and a minimum level of precipitation beyond which there is a cost implication. Average temperature reduced per hectare farm value by -6.01%, while precipitation increased per hectare farm value by 6.50%. This suggests a detrimental temperature effect and a beneficial precipitation effect on farm value.The Ricardian simulated impact of climate change using Hadley model prediction of 1.89mm increase in precipitation and a 1.03 degree centigrade rise in temperature, revealed losses in farm land value by -62.79% in the near term(2050)for the whole country. Variation was also observed across agricultural zones. For north central zone, losses of -8.24% in farm value is expected in 2050. Losses of -41.95% and -44.96% are respectively predicted for north east and south west. While climate will be beneficial for south east by increasing farm value by 3.36% in 2050.This could be lower or higher depending on the climate model prediction used.

12. Farmers' Adaptive capacity are of different typologies and varies across agricultural zones.The 15 indicators included in the adaptive capacity calibration were reduced to 5 principal components that explained 57% of the variance in the original 15 indicators.The principal components (PCs) are derived factors that help to predict the relative importance of each of the 15 indicators. Using this approach, PC1 predicts household size (0.47), Animal traction (0.44), income from crop sales (0.38) and access to forest trees (-0.53) as relatively important indicators across farm households. PC1 most probably predict an adaptive capacity index that is built on family labour and natural resources. This type of adaptive capacity index was highest for states in north east and north west agricultural zones with an index ranging from 0.52 – 0.6.

13. PC2 predicts membership of an association (0.58), ownership of livestock (0.53), access to commercial fertilizer (0.42) and access to forest trees (0.26). PC2 most probably predicts an adaptive capacity index that relies on social and financial capital. This was highest for states in north westagricultural zones with an index ranging from 0.52 – 0.7. PC3 predicts access to farm equipment (0.65), available land for cultivation (0.48), access to herbicide (0.47) and crop income (0.28). PC3 most probably predicts adaptive capacity that relies on

physical asset most especially farm equipment and land. This is most important in south east and south west zones. PC4 predicts literacy rate (0.63), age (0.50) and subsidized fertilizer (0.44). PC4 most probably predicts the importance of human capital in terms of education and experience. The adaptive capacity index is also built on the extent to which farm households have access to subsidized fertilizer. This is most pronounced in the whole of northern Nigeria comprising north east, north west and north central. PC5 predicted agricultural insurance (0.67) and wage income (0.64).PC5 can be viewed as emphasizing off-farm income which is an important source of income complementing farm income in rural Nigeria. Agricultural insurance also captures the importance of insuring farmers against risk and the importance of risk bearing agencies such as National food reserve agency. This adaptive capacity was quite weak in all the agricultural zones and the weakness is most pronounced in south east.

5.2. Conclusions

Based on the findings of the study, the following conclusions are hereby made:

- Farms in Nigeria are family-based production system for crops or livestock or both. The farm employs labour, land, equipment, knowledge and capital resources to produce goods–which are consumed or marketed or both.

- The ability of smallholder farms to sustain continual output of crops for local and regional markets depend critically on the optimal climatic conditions of the farm. Crop production is affected negatively when exposed repeatedly to adverse climatic conditions. Thus climate change would impose additional cost on farmholders. It also affects the choices that farmholders make in attempt to sustain the optimum level of production.

- Climate change affected revenue and crop cultivation of smallholders and could affect food security in the near future. Impact was huge for the whole country and varies across agricultural zones.

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5.3 Recommendations

Based on the findings and conclusions, the following recommendations are hereby made:

1. Climate justice and compensation of farmersare paramount.
2. Promotion of improved varieties of crop that can withstand the adverse effect of climate change.
3. Provision of irrigation facility to maintain the optimal level of temperature and precipitation for optimal plant growth.
4. Adaptation policy should be equity oriented since the impact of climate change is not evenly distributed across agro ecological zones.
5. Monitoring of climate change and disseminating information to farmers are critical policy interventions.
6. Polices for building adaptive capacity for farmers should consider the existing typologies of farmers adaptive capacity and the peculiarities across various agro ecological zones.
7. Risk bearing programmes such as agricultural insurance schemes should be promoted. Agricultural insurance typology was quite weak in all the agro ecological zones and the weakness is most pronounced in south east agro ecological zone.
8. Use of stress tolerant technologies (irrigation, and drought tolerant seeds) and institutional support would enhance coping capacity against climate change risk.

5.4. Further Studies

Further research is however necessary in this emerging area of research. It is also important to explore other modelling techniques such as dynamic systems modelling that consider both adaptation and mitigation. Use of GMM for spatial consideration and panel data for the Ricardian modelling.Use of a unified framework to estimate the impact of climate change on profit, land area used and crop choices. To simulate climate change impact beyond two climate models and to explore General equilibrium analysis.

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APPENDIX

Table 4.14 CLIMATE ONLY MODEL

Variables	Farm value	Farm revenue
TEMPERATURE MEASURES		
Jan-Dec	(omitted)	(omitted)
Sept-Nov		-5676891 (2.57)
June - August		2187853 (1.49)
Mar-May	-3755026 (1.64)	
December to February		-8622128 (2.70)
November to March		1.27e+07 (3.04)
Aril to October	(omitted)	(omitted)
Jan – December ^2		
Sept-Nov^2	2405702 (1.31)	
June-August^2	3034697 (1.62)	
Mar-May^2	2579310 (2.02)	
Dec-Feb^2	2216957 (1.75)	1473235 (2.23)
Nov-Mar^2	-3064361 (1.50)	-2168643 (2.05)
April-Oct^2	-5277147 (1.82)	
PRECIPITATION MEASURES		
Jan-Dec	(omitted)	(omitted)
Sept-Nov		-24313.45

		(1.35)
June - August		
Mar-May	95230.62 (1.32)	
December to February		
November to March	-591369.2 (1.33)	
Aril to October	(omitted)	(omitted)
Jan – December ^2		
Sept-Nov^2		
June-August^2		
Mar-May^2	1258.757 (1.49)	
Dec-Feb^2		
Nov-Mar^2		
April-Oct^2		2053.224 (1.73)
Constant	-4146502 (1.69)	
No. of significant variables	11	8
F(24,271)	0.88	17.16
R-squared	0.072	0.610
Adj R-squared	-0.010	0.575

( ) T-statistics

Table 4/15 Linear quadratic functional form (Full model)

	Farm Value	Farm Revenue
TEMPERATURE MEASURES		
Jan-Dec	(omitted)	(omitted)
Sept-Nov		-1332053(1.57)
June - August		-683306.8(1.40)
Mar-May		2369857(4.79)
December to February		
November to March		
Aril to October	(omitted)	(omitted)
Jan – December ^2		894907.7(1.89)
Sept-Nov^2		-753885.6(2.42)
June-August^2		-1143742(3.69)
Mar-May^2		-706465.8(3.06)
Dec-Feb^2		571631.4(2.32)
Nov-Mar^2		-951702.2(2.42)
April-Oct^2		2081992(3.96)
PRECIPITAION MEASURES		
Jan-Dec	(omitted)	(omitted)
Sept-Nov		-22949.34(3.21)
June - August		6708.773(1.76)
Mar-May		26200.46(2.30)
December to February		-451578.1(4.07)
November to March		338352.5(4.47)
Aril to October	(omitted)	(omitted)
Jan – December ^2		
Sept-Nov^2		
June-August^2		-142.7971(2.07)
Mar-May^2		
Dec-Feb^2		
Nov-Mar^2		
April-Oct^2	-841.5653(1.45)	
TEMPERATURE * PRECIPITATION INTERACTION		

Jan-Dec	45184.67(1.49)	
Sept-Nov	-31058.81(1.48)	
June - August		
Mar-May	-33680.09(1.49)	32072.87(2.31)
December to February		170982(2.64)
November to March		-148120.6(3.45)
Aril to October		
Latitude		
Altitude		-837.2845(2.78)
Sand		
Silt	(omitted)	(omitted)
Clay		
Socio economic 1		-89488.62(2.70)
Socio economic 2		-72831.32(2.62)
Pop den		.6383218(1.46)
Cons		1343972(2.51)
No. of Sign variables	4	25
F(39,205)	2.78	222.75
R-squared	0.346	0.9769
Adj R-squared	0.222	0.9726

Table 4.16.Log linear functional form

	Land Value	t-statistic	Farm Revenue	t-statistic
			TEMPERATURE MEASURES	
Sept-Nov	0.1643893	0.57	-0.52532	-1.79
Jun-August	-0.4084255	-2.03	0.250473	1.22
Mar-May	0.3867133	2.61	-0.73436	-4.84
Dec-Feb	-0.04052161	-0.11	-1.60179	-4.35
Nov-Mar	-0.1755088	-0.38	2.673079	5.64
Sept-Nov^2	0.004709188	0.76	-0.00439	-0.69
Jun-August^2	0.01410374	2.79	-0.01865	-3.61
Mar-May^2	#VALUE!		#VALUE!	
Dec-Feb ^2	0.007694554	1.36	0.017356	2.99
Nov-Mar^2	-0.01295364	-1.45	-0.02554	-2.79
			PRECIPITATION MEASURES	
Sept-Nov	0.002925802	0.95	-0.00742	-2.34
Jun-August	-0.000832657	-0.43	0.005672	2.83
Mar-May	0.00541236	1.06	-0.02239	-4.27
Dec-Feb	0.1770121	4.25	-0.17377	-4.08
Nov-Mar	-0.08525271	-3.04	0.124452	4.34
Sept-Nov^2	0.000001399	0.76	-4.6E-06	-2.42
Jun-August^2	0.00000076	0.42	-6.4E-06	-3.46
Mar-May^2	0.000003162	0.81	-4.6E-06	-1.14
Dec-Feb ^2	0.000144132	3.05	-0.00014	-2.95
Nov-Mar^2	-0.000040051	-1.57	6.98E-05	2.67
		TEMPERATURE * PRECIPITATION INTERACTION		
Sept-Nov	-0.000119168	-0.41	0.000516	1.72
Jun-August	0.000039894	0.2	8.45E-05	0.41
Mar-May	-0.000201628	-0.74	0.001053	3.79
Dec-Feb	-0.006853807	-4.11	0.006854	4.02
Nov-Mar	0.002855466	2.54	-0.00461	-4
Latitude	-0.000571648	-0.72	-0.00012	-0.15
Altitude	-0.00000551	-0.7	-2.6E-05	-3.21
Sand	0.000418295	1.11	-0.00065	-1.69

Silt	0.000433755	0.7	-0.00071	-1.11
Clay	#VALUE!		#VALUE!	
Socio economic 1	-0.000417093	-0.52	0.002313	2.79
Socio economic 2	-0.000259664	-0.36	0.000186	0.25
Pop den	-7.21E-09	-0.63	4.09E-09	0.35
Cons	11.50566	0.57		-1.79
No. of sign variable	20		27	
F(39,205)	48.36		70.51	
R-squared	0.90		0.931	
Adj R-squared	0.88		0.91	

Selected Economic farm variable characterisation

Questions asked	Variable
How much in total was paid for this[PLOT] (Include both cash and payments in-kind)?(section 11b, No.5) If the [PLOT] were to be sold today, how much could it be sold for? Interviewer: ask respondent to estimate value even if land cannot be sold(section 11b, No. 15)	**Land price in Naira/plot** **value of land**
What was the total value of [CROP] sales since the new year? Estimate the value of in-kind payment(section 11h-marketing, No.3	Crop revenue in naira
How many [ANIMALS] are owned by your household now (present at your farm or away)? If you would sell one of the [ANIMAL] today, how much would you receive from the sale?(section 11i, Animal holdings, Nos. 3&4)	Livestock value
What was the total value of sales? Estimate the value of in-kind payments(section 11i-Animal holding, No. 17)	Livestock revenue in naira
What was the total value of sales of [BYPRODUCT] since the beginning of the year? Estimate the value of payments in-kind (section 11k-agricultural by-product, No. 6)	Other agricultural income in naira
How much was spent in CASH and IN KIND on [ITEM] in the last 12months?(section 11j-Animal cost, No. 2	Animal production cost in Naira
What is the area of [PLOT]? Enumerator: Ask the farmer to estimate the area. Measure the plot using GPS(section 11a-Plot roster, No 4)	Land size
What was the total area planted on this [PLOT] with the [CROP] since the beginning of the year?(section 11f-planted field, No.1)	Land area cultivated
How much [CROP] do you expect to harvest from this [PLOT] from plantings since the beginning of the year? (section 11f-planted field, No.4)	Land area harvested

Crop production cost	
How much was spent in cash on the pesticide you have used on your [PLOT] since the new year?(section 11c-input cost, No.4) How much was spent in-kind on the pesticide you have used on your [PLOT] since the new year?(No.5)	Cost of pesticide in naira
How much was spent in cash on the herbicide you have used on [PLOT] since the new year? How much was spent in-kind on the herbicide you have used on [PLOT] since the new year?(section 11c-input cost, Nos. 13&14)	Cost of herbicide in naira
How much was spent in cash on renting these animals for [PLOT] since the new year? How much was spent in-kind on renting animals since the new year? (section 11c-input cost, Nos. 23&24)	Cost of renting draught animal in naira/day
How much was spent in cash on renting the machine/equipment since the new year? (section 11c-input cost, Nos. 32&33)	Cost of renting farm equipment in naira
What was the value of the [FERTILIZER] that you purchased since the beginning of the new year? (section 11d-fertilizer acquisition, No. 18)	Cost of fertilization in naira
What was the value of the [SEED] that you purchased since the beginning of the new year? (section 11e-seed acquisition, No. 20)	Cost of seed in naira
How much did you pay for transportation to acquire the [FERTILIZER] since the beginning of the new year?(Sect 11d-FERTILIZER ACQUISITION, No.16)	Transport cost to fertilizer market
How much did you pay for transportation to acquire the [SEED] from [FIRST SOURCE]since the beginning of the new year? Section 11e-SEED ACQUISITION, No.18)	Transport cost to seed market in naira
What was the total cost of transportation associated with the [CROP] sales ? Section 11h-MARKETING, No.8	Transport cost to output market

Zone	North central	Northeast	Northwest	Southeast	Southwest	NIGERIA
PRECIPITATION						
WTP	170.51	121.70	123.10	294.10	199.84	181.85
DSP	10.71	2.78	1.60	61.20	40.19	23.30
SSP	128.28	69.09	68.23	251.75	166.72	136.81
WNSP	197.51	177.66	186.39	320.29	207.50	217.87
SMSP	85.67	41.21	34.96	182.67	138.79	96.66
FSP	4.25	0.63	0.33	33.51	20.27	11.80
All season	99.49	68.85	69.10	190.59	128.89	111.38
TEMPERATURE						
WTT	26.39	26.91	27.54	26.15	25.82	26.56
DST	27.04	24.83	25.21	27.23	27.17	26.30
SST	25.93	25.60	25.98	26.13	25.89	25.91
WNST	25.39	25.93	26.35	25.51	24.99	25.64
SMST	28.85	28.95	29.91	27.69	27.73	28.62
FST	26.47	23.69	24.04	27.08	26.93	25.64
All season	26.68	25.99	26.51	26.63	26.42	26.45

Climate measures	NC	NE	NW	SE	SW	WC
Base line_(1961 – 2000)						
Precipitation	99.49	68.85	69.10	190.59	128.89	111.38
Temperature	26.68	25.99	26.51	26.63	26.42	26.45
Absolute change(Hadley_ 2050) (low scenario emission)						
Precipitation	13.26	9.20	12.90	-16.65	-9.22	1.89
Temperature	1.31	1.72	1.15	1.26	-0.27	1.03
Absolute change Cgm3_2050 (low scenario emission)						
Precipitation	16.89	-6.64	2.89	-8.67	-0.60	0.78
Temperature	1.08	1.39	0.78	1.19	-0.38	0.81
Absolute change Hadley_2070 (low scenario)						
Precipitation	20.74	14.22	17.95	-21.73	-8.81	4.48
Temperature	1.88	1.98	1.61	1.93	0.44	1.56
Absolute change Cgm3_2070 (low and high scenario)						
Precipitation	-26.24	-42.75	-35.22	-63.14	-37.89	-41.05
Temperature(85)	3.06	3.02	2.37	3.16	1.56	2.63

NEAR AND LONG TERM CLIMATE SENSITIVTY FOR NIGERIA (HADLEY MODEL MILD SCENERIO PREDICTION)			
CLIMATE MEASURES	Mean Current climate 1961-2000	Absolute future change in climate 2050	Absolute future change in climate 2070
PRECIPITATION			
WTP	181.85	3.5	4.58
DSP	23.30	-0.12	4.34
SSP	136.81	12.16	4.10
WNSP	217.87	6.42	4.23
SMSP	96.66	-10.34	-8.75
FSP	11.80	-0.26	18.35
All season	112	1.91	4.47
TEMPERATURE			
WTT	26.56	0.96	1.69
DST	26.30	1.13	1.41
SST	25.91	1.01	1.66
WNST	25.64	0.91	1.64
SMST	28.62	1.03	1.70
FST	25.64	1.15	1.28
All season	26.44	1.03	1.56

	Mean Current climate 1961 - 2000	Mean change in climate 2050	Mean change in climate 2070	Mean change in climate 2070 high scenario emission
PRECIPITATION				
WTP	181.85	-2.67	-0.76	X
DSP	23.30	5.08	1.33	X
SSP	136.81	5.93	-8.25	X
WNSP	217.87	-14.42	-111.08	X
SMSP	96.66	12.07	-86.48	X
FSP	11.80	-1.33	0.11	X
All season	112.01	0.75	-29.29	X
TEMPERATURE				
WTT	26.56	0.76	X	2.56
DST	26.3	0.88	X	2.90
SST	25.91	0.79	X	2.28
WNST	25.64	0.83	X	2.05
SMST	28.62	0.72	X	5.67
FST	25.64	0.89	X	0.33
All season	26.45	0.81	x	4.74

PREDICTED PRECIPITATION AND TEMPERATURE CHANGES IN THE NEAR TERM AND UNDER LOW EMISSION SCENARIO (REPRESENTATIVE EMISSION SCENARIO 26)

HADcm3 MODEL

Zone	North central	Northeast	Northwest	Southeast	Southwest	NIGERIA
WTP	20.19	18.2	23.36	-29.55	-14.67	3.5
DSP	4.6	-2.05	-0.18	-0.54	-2.39	-0.12
SSP	32.4	8.1	22.9	-5.63	3.02	12.16
WNSP	14.88	43.42	33.77	-37.19	-22.75	6.42
SMSP	5.11	-11.92	-2.47	-24.51	-17.9	-10.34
FSP	2.39	-0.56	-0.01	-2.49	-0.6	-0.26
All season	13.26	9.20	12.90	-16.65	-9.22	1.89
WTT	1.1	1.64	1.13	1.2	-0.3	0.96
DST	1.56	1.83	1.18	1.32	-0.23	1.13
SST	1.17	1.78	1.31	1.2	-0.36	1.01
WNST	1.17	1.47	1.03	1.21	-0.29	0.91
SMST	1.09	1.97	1.15	1.2	-0.3	1.03
FST	1.74	1.65	1.11	1.4	-0.14	1.15
All season	1.31	1.72	1.15	1.26	-0.27	1.03

Cgm3 MODEL

Zone	North central	Northeast	Northwest	Southeast	Southwest	NIGERIA
WTP	22.33	-10.24	5.18	-22.66	-7.96	-2.67
DSP	10.09	-2.15	0.04	8.81	8.61	5.08
SSP	27.53	-10.38	1.93	-1.3	11.84	5.93
WNSP	1.88	-10.37	4.29	-42.76	-25.14	-14.42
SMSP	38.11	-6.14	5.98	11.2	11.18	12.07
FSP	1.41	-0.56	-0.06	-5.31	-2.12	-1.33
All season	16.89	-6.64	2.89	-8.67	-0.60	0.78
WTT	0.88	1.49	0.76	1.03	-0.39	0.76
DST	1.32	1.25	0.81	1.4	-0.36	0.88
SST	1.04	1.42	0.8	1.09	-0.4	0.79
WNST	1.02	1.49	0.84	1.11	-0.28	0.83
SMST	0.75	1.62	0.71	1.01	-0.52	0.72
FST	1.44	1.05	0.76	1.52	-0.33	0.89
	1.08	1.39	0.78	1.19	-0.38	0.81

PREDICTED PRECIPITATION AND TEMPERATURE CHANGES IN THE LONG TERM UNDER LOW EMISSION SCENARIO (REPRESENTATIVE EMISSION SCENARIO 26)

Zone	NC	NE	NW	SE	SW	NIGERIA
PRECIPITATION						
WTP	26.07	17.11	21.94	-30.30	-11.94	4.58
DSP	13.98	10.55	12.87	-10.84	-4.84	4.34
SSP	33.28	12.54	22.48	-37.32	-10.51	4.10
WNSP	18.92	35.65	31.36	-42.48	-22.32	4.23
SMSP	6.99	-11.64	-3.62	-21.01	-14.49	-8.75
FSP	24.94	20.95	22.44	12.06	11.38	18.35
All season	20.74	14.22	17.95	-21.73	-8.81	4.48
TEMPERATURE						
WTT	1.88	2.24	1.83	2.02	0.49	1.69
DST	1.88	1.66	1.33	1.81	0.38	1.41
SST	1.88	2.11	1.85	2.01	0.48	1.66
WNST	1.93	2.03	1.73	2.03	0.53	1.64
SMST	1.84	2.45	1.73	2.04	0.41	1.70
FST	1.85	1.39	1.17	1.65	0.35	1.28
All season	1.88	1.98	1.61	1.93	0.44	1.56

Zone	NC	NE	NW	SE	SW	NIGERIA
Cgm3 26 precipitation 2070						
WTP	15.67	-8.77	11.98	-13.11	-9.58	-0.76
DSP	6.65	-2.16	-0.27	-1.75	4.18	1.33
SSP	9.25	-15.20	-2.21	-25.14	-7.96	-8.25
WNSP	-82.77	-146.50	-150.89	-119.91	-55.32	-111.08
FSP	-80.00	-41.14	-34.69	-155.80	-120.78	-86.48
All season	-26.24	-42.75	-35.22	-63.14	-37.89	-41.05
Cgm3 85 temperature 2070						
WTT	2.35	4.12	3.45	2.26	0.63	2.56
DST	4.33	1.52	0.84	4.63	3.17	2.90
SST	1.83	4.26	3.58	1.73	0.02	2.28
WNST	2.11	3.18	2.49	2.11	0.37	2.05
SMST	6.20	6.67	6.44	5.11	3.95	5.67
FST	1.54	-1.66	-2.60	3.13	1.22	0.33
All season	3.06	3.02	2.37	3.16	1.56	2.63