EFFECT OF RAINFALL VARIABILITY ON YIELD OF SELECTED CROPS IN BENUE STATE, NIGERIA

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ABSTRACT

Crop yield apart from being a source of boost to the economy of a nation, improves the quality of life and aids in the sustenance of human existence. There is therefore the need to investigate the effect of rainfall variability on yield of selected crops in Benue State. Both secondary and primary sources of data collection were employed in the study. CMAP Rainfall data was collected using orbiting satellite image for the period of 30 years from 1988 to 2017 over Benue State. While the crops yield data was collected for 30 years from the archives of Benue State Agricultural and Rural Development Agency (BNARDA). Data from Primary sources were collected with the aid of questionnaire administered to 720 farmers selected through a multi stage sampling technique which saw twelve out of the twenty-three (23) Local Government Areas selected based on the high yield of the crops under study. Each selected LGA was further divided into six (6) extension blocks where the productivity of selected crop yields under study are at maximum, which make a total of 36 extension blocks. Four (4) farming communities were randomly selected from each extension blocks to bring a total of 72 communities. Ten (10) farmers were randomly selected which resulted to a sample size of seven hundred and twenty (720) farmers. That is, 240 questionnaires were being administered from each zone and 60 from each LGA respectively. Descriptive statistics was used to analyse the data and results were presented using frequency tables, charts and figures. Coefficient of variation and Precipitation Variability Index (PVI) were used to determine the rainfall variability. Mann- Kendall test was used to assess the trend of selected crops. Rainfall data from 1988 to 2017 was used to analyse the indices of rainfall (onset, cessation and length of rainy season) and also to determine the effects of onset and cessation on crops yield in Benue. Partial correlation was used to determine the magnitude of zonal rainfall variability. The results of the research show that, precipitation variability index revealed tendency of drought especially the Northern Zone of the State by more than 30% variability followed by the South with variability of 20% to 30% and the East zone with less than 20% variability. Onset of rain begins in the South on the 4th April, followed by the East on the 6th April and on the 9th April for the North. The cessation dates are between 6th October and 17th November across the study areas. The Length of Rainy Season (LRS) is longer in the Eastern Zone (236 days), followed by the Southern Zone (230 days) and then Northern Zone (209 days). It was revealed that the yields of selected crop (cassava, yam, maize, soyabeans and groundnut) show a positive trend while that of rice on the other hand, shows a negative trend over time. In all 73 % of respondents are aware of rainfall variability and have attempted adapting in one way or the other and 69 % affirmed that the method used increased yield. So, it can therefore be concluded based on the findings of the study that, rainfall commences early in the Southern Zone, followed by the Eastern Zone and then the Northern Zone. The onset of rain is similar in all the Zones and crop yields are increasing due to choices for adaptation. The study therefore recommends that other elements of climate such as temperature, relative humidity, and farm management practices should be studied to find the impact of such oncrop yield. There is also need for the intensifying effort towards irrigation farming in order to curtail the uncertainty attached to rain- fed agriculture. Annual sensitization workshops and seminars should be encouraged for farmers, to create awareness among them on climate and its potential impact on crop yield. More extension workers should be deployed in the State owing to their importance to rural farmers. Farmer’s adaptation measures (Changes in planting date and used of improved varieties) to rainfall variability in the State should be harnessed for proper results.

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LIST OF ABBREVIATIONS AND ACRONYMS

AGRA	Alliance for a Green Revolution in Africa
BNARDA	Benue Agricultural and Rural Development Authority
CB	Central Bank
CMAP	Connectivity Merged Analysis of Precipitation
CP	Central Pacific
CRU TS	Climate Research Unit Time Series
CSI	Combined Stress Index
cT	Tropical Continental
CV	Coefficient of Variation
ECA	Economic Commission for Africa
ENSO	El Nino Southern Oscillation

EOF	Empirical Orthogonal Function
EOF	Empirical Orthogonal Function
EP	Eastern Pacific
EPA	Economic Potential Agriculture
EPIC	Emotion Productivity Impact Calculator
EPIC	Erosion Productivity Impact Calculator
FAO	Food and Agriculture Organization
FAOSTAT	Food and Agriculture Organization Statistics
GDP	Gross Domestic Product
GIS	Geographic Information System
GLAM	General Large Area Model
GPCP	Global Precipitation Climatology Project
HMD	Heat Magnitude Day
IFPRI	International Food Research Institute
IITA	International Institute of Tropical Agriculture
IPCC	Intergovernmental Panel on Climate Change
IRRI	International Rice Research Institute
ISSER	Institute of Statistical Social and Economic Research

ITCZ	Inter Tropical Convergence Zone
ITD	Inter Tropical Discontinuity
LRS	Length of Rainy Season
MAM	March-May long rains
mT	Tropical Maritime
NIMET	Nigerian Meteorological Agency
NOAA	National Oceanic and Atmospheric Administration
NPC	National Population Commission
OND	October-December short rains
OT	Optimum Temperature
PERSIANN	Precipitation Estimation from Climate Data Guide
PPI	Precipitation Periodicity Index
PVI	Precipitation Variability Index
REGCM	Regional Climate Model
RegCM3	Regional Climate Model
SDSS	Spatial Decision Support System
SPEI	Standardized Precipitation Evaporation Index
SSA	Sub Sahara Africa

SST	Sea Surface Temperature
TE	Transpiration Efficiency
TRMM	Tropical Rainfall Measuring Mission
UBOS	Uganda Bureau of Statistics
UN HABITAT	United Nations Human Settlement
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
USD	United State Dollars
USSR	Union of Soviet Socialist Republics
WCRP	World Climate Research Programme
WMO	World Meteorological Organisation

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Rainfall variability has become a topical concern largely because of its impacts on natural and human systems. Labiru (2016), noted that the most often cited areas that are affected by rainfall variability include, agriculture, fisheries, hydrology and forestry. Rainfall Variability is defined as the degree to which rainfall amounts vary across an area or through time. Agriculture which is one of the major areas of socio- economic as well as National Gross Domestic Product (GDP) in most countries in Africa is more vulnerable to rainfall variability. Despite the recent technological advancement, weather and climate are imperative determinants in agricultural production. The long- term crisis between farmers and herders mostly in the north- central part of the country is primarily attributed to change in climate and the variability of rainfall. This is because northern the parts of Nigeria are getting drier, and herders have to move down South in search of greener pasture. On the other hand, farmers need to expand on their farm size to maximize higher yield due to the danger posed by climate change.

Rainfall is considered as the leading climatic factor that has effects on crop productivity. Variability of rainfall is progressively becoming a thing of concern, most especially in the agricultural rain- fed places of the world; because of its distributions, pattern and seasonality. In areas where rain-fed agriculture is being practised, the erratic nature of water and its irregularities in both the amount received and its spread, remains a major threat to agricultural production as yields are increasingly becoming poorer and there is high variability in yearly crop production (Agidi, 2014).Therefore, the unpredictable pattern of the onset of rainfall onset, cessationand length of growing season in a location can negatively affect the farmers in an area that depends on rainfall for their farming activities(Agidi, 2017). In Nigeria, rainfall variability affects the rain-fed agriculture in which many of the population depend. In this region, crop loses their viability, and the farmers lost their income source. The reason for crop yield decline may be due to inter- annual variation. The annual variation of rainfall, particularly in northern Nigeria, is large, often resulting in climate hazards, especially floods and droughts with devastating effects on food production and associated calamities and sufferings (Osman, 2015). Despite the great potentials of Nigeria in crop production, the frequent occurrence of drought occasioned by erratic rainfall distribution and/or cessation of rain during the growing season, is the greatest hindrance to increasing production and this is more serious in the northern part of the country where most of the tubers are produced.

Nonetheless, to relate rainfall variability with actual crop yield, model-based simulations are not sufficient. Modelling offers a mechanism to integrate many scales of data developed in/for agricultural research. Surprisingly, little systematic research have focused on the distribution patterns of the impacts of rainfall variability in mapping the spatio-temporal impact using modern equipment. There is no doubt that farmers and Agricultural Agencies increasingly need detailed maps of the Spatial Decision Support System (SDSS) to plan crop planting schemes and monitor yield rates (Labiru, 2016). Study of the impact of annual rainfall variability begins by mapping out direct physical consequences of rainfall variables on crop yields. Generally, the scientific evidence on rainfall variability and its significant impacts on crop yield, is stronger than ever (Hare, 2010). One undisputable cause of 'famine' in the Guinean Savanna region of Nigeria, is the failure of crops resulting from insufficient or untimely rainfall. Inter- Governmental Panel on Climate Change (2012), has studied the inter-annual pattern in climate and particularly the magnitude of rainfall variability impacts on human activities, including crop production. For example, Adamgbe and Ujoh (2012), observed that over the period 1997 to 1999, the north arid zone of Nigeria experienced a decline in annual rainfall which led to a decline in crops- based farming systems. The zonal pattern of rainfall variability, especially in the North Central area of Nigeria, is noted in the differences in the types of crops cultivated and the yield rate (Idris *et al*., 2012).

Studies on annual rainfall variability and the impact on crop yield, used model-based simulations in their analysis. Despite sufficient rain, its irregularity can affect yields adversely if rains fail to arrive during the actual growing stage of crops (Hassan, 2013). According to Odewumi (2013), it is clear that, of the climatic factors which influence the pattern and productivity of rainfed agriculture in Nigeria, the availability of water to crops is by far the most important. Generally, based on rainfall distribution, certain crops are found at a particular geographical location. Odjugo (2013) pointed out that the pattern of rainfall distribution explains why drought resistant crops such as millet and sorghum are grown largely in the Northern part while more moisture- demanding crops such as rice, maize, and cassava are grown in the North Central areas of Nigeria extensively. To date, much of the effort to analyse rainfall patterns in Nigeria as relate to agriculture, has generally focused on the exploitation of the seasonal rainfall (Yamusa *et al.*,2013). However, the season distribution of rainfall and its subsequent effects on crop productivity has received less attention, although its effects may be as important as the total seasonal rainfall. To better understand the issue of rainfall availability in tropical rain- fed agriculture, much more attention needs to be given to the quantification of season rainfall patterns (Yamusa *et al.*, 2013). This will allow a prior assessment of the expected severity and duration of dry spells during the season and provide a sounder basis for developing improved water management techniques in tropical agriculture. Most farmers in developing countries solely depend on traditional farming methods, which place them at a disadvantage with many alterations in nature. The Intergovernmental Panel on Climate Change (IPCC, 2012) observed that, the increasing temperature, erratic rains, drought, floods, desertification, and other weather extremes have a severe effect on agriculture, especially in the developing world. This explains why most developing countries cannot predict and swiftly act in terms of extreme weather hazards. Cassava and yam, (tuber crops), rice and maize (cereal crops), groundnut, and soybeans (legume crops) are considered as the most important food crops in Benue State that are useful for food as well as income to the populace.

1.2 Statement of the Research Problem

Over the years, despite the technological advances to crop production in Benue State, such as the introduction of high yield crops, the application of fertiliser, and provision of extension services, the yield of crops still varies in different parts of Benue State. This results in the hunger and starvation of people who solely depend on these crops for their socio- economic activities. Igwebuike *et al*. (2014), noted that climate prediction and analysis of past and present trends indicate that small- scale farming households in tropical and sub- tropical areas are exposed to increased climate risk and become more and more vulnerable to these risks resulting in the decline of crop yields. The intergovernmental

Panel on Climate Change, (IPCC, 2012), noted that yield from rain-fed agriculture in different African countries could be reduced by up to 50 % by the year 2020. Agidi (2017), noted that the inter-annual rainfall variability and crop yields in Nasarawa State, have resulted in the decline of crop yields due to variability of rainfall pattern. Akpenpuun (2013) observed that the relationship between tuber crop yield variations in Kwara State to climate variation. Emmanuel and Fanan (2013), noted that rainfall is highly variable in Makurdi and maize yield. He revealed that changes in onset and cessation are the main reason for maize yield decline in Makurdi. Nyagba (2013) showed a comparative analysis of the distribution of rainy days in different ecological zones in Benue State. The analysis was based on monthly and annual (yearly) rainfall data from a single ground station, which may not be a true reflection of different zones. Therefore, the current study will depend on one single station data and will use daily rainfall data with the use (Connectivity Merged Analysis of Precipitation) CMAP data. This data is considered more accurate hence it has more spread over the state than the single ground station and also is an improvement on the Akpenpuun (2013) where he researched in just one Local Government Area of Benue State using maize yield as it varies with rainfall. Though studies were carried out based on the relationship that exists between crop and the variability of climate in Nigeria and beyond, there is little or no research that tried to combined different important crops like tubers (cassava, yam), cereals (maize, rice), and legumes (soybeans, groundnut) in Benue State.

Therefore, the current study was able to look into such crops in their respective zones. Hassan (2013) using monthly and annual rainfall characteristics to determine the precipitation periodicity index, revealed that even though rainfall has been declining in Federal Capital Territory between 1990 -2005, crop yields have not declined. This may be because of farmer's adaptation techniques which this study wants to investigate. It is against this background that this research seeks to assess the effect of rainfall variability on crop yield in parts of Benue State.

1.3 Research Questions

i. What is the variability in rainfall in the study area?

ii. What is the trend in the yields of cassava, yam, maize, rice, soybeans, and groundnut in the study area?

iii. What are the effects of rainfall characteristics on the yield of crops in the study areas?

iv. What is the spread of crops in the study area?

v. What are the farmer's coping strategies to rainfall variability in the study area?

1.4 Aim and Objectives of the Study

The aim of the study is to assess the effects of rainfall variability on the yields of selected crops in Benue State, Nigeria.

The specific objectives were to:

i. Examine rainfall variability in the study area from 1988 to 2017

ii. Assess the trend in the yield of the selected crops in the study area.

iii. Analyse rainfall characteristics and their effects on the yield of the selected crops in the study area.

iv. To delineate agro-climatic zones for effective utilisation of the limited agriculturallands in the study area.

v. Identifythe adaptation strategies of farmers to rainfall variabilityin the study area.

1.5 Research Hypotheses

i. There is no significant relationship between rainfall trendsand the yield of some major crops in the study area.

ii. There is no significant relationship between rainfall variability and the yield of some major crops in the study area.

1.6 Justification for the Study

Rainfall variables play a major role in crop production, most especially in tropical regions. Yahaya (2011) cited that despite the influence of climatic factors easily recognised in crop yields, there is generally too little information on rainfall pattern influencing crop yields in the tropics. The situation is particularly serious in Nigeria despite the increasing attention being given to agricultural activities. Farming inBenue State is mainly rain-fed, making crop production more sustainable to any form of weather. Rain- fed agricultural production in Africa in general, is projected to be reduced by up to 50 % by 2020 (IPCC, 2012). Ityo(2013),noted that the variable rainfall pattern has serious repercussions for the inhabitants seriously truncates all efforts being put in place by both individuals, local, state and federal governments to ensure agricultural viability, abundant food supply and food security in the state. As a result, “the food basket of the nation” status is gradually dwindling largely due to the variable weather. Previous studies on rainfall pattern and crop yields in the State were based on some rainfall characteristics such as duration and season, annual amount, monthly and temperature (Ityo, 2013).

Though these studies were comprehensive, the analysis of important rainfall characteristics dates of onset, cessation, length of rainy days and daily rainfall vital to crops are been discussed in this current study. Therefore,this study focuses on examining the rainfallvariability and its effect on crop yields as well as having the critical stakeholder (farmers) involved, to examine their knowledge of climate variability and the strategies used in parts of Benue State with a view to suggesting appropriate adaptive management mechanisms to cope with the pattern of rainfall variability.

1.7 Scope of the Study

This research work was conducted in Benue State, Nigeria. The research focus areas comprisetwelve out of the twenty three Local Government Areas in the State, four Local Government Areas from each Zones where agricultural activities are maximum. The zones include the Northern Zone (Ushongo, Vandeikya, Ukum and Kwande), Eastern Zone (Gboko, Gwer- West, Makurdi and Tarka) and Southern Zone (Gwer- East, Ado Ohimini and Otukpo). The data on crop yields were obtained from the Benue State Agricultural and Rural Development Agency (BNARDA). The Rainfall data was based on CMAP data version from1988 to 2017 across the twelve LGAs under study. Crop yields are the harvested production per unit of harvested area for crop products. In most cases, yield data are not recorded, but are obtained by dividing the yields data by the data on the area harvested. Crop production is measured in tones per hectare, in thousand hectares and thousand tones.

1.8 The Study Area

Benue State lies within the Lower River Benue trough in the North Central Zone of Nigeria. Its geographic coordinates are Latitude 6° 25' to 8° 8' North and Longitude 7° 47' to 10° 0' East. The State shares boundaries with five other states, namely: Nasarawa State to the north, Taraba State to the east, Cross-River State to the south, Enugu State to the south-west and Kogi State to the South East. The state has a total land area of 30,800 sq. km (National Population Commission, 2006). The total population is estimated to be 4,253,641 (National Population Commission, 2006). The State generally has about 5-7 months of rainfall. Temperatures are constantly high throughout the year, with average temperatures ranging from 23°C-32°C (Ityo, 2013).

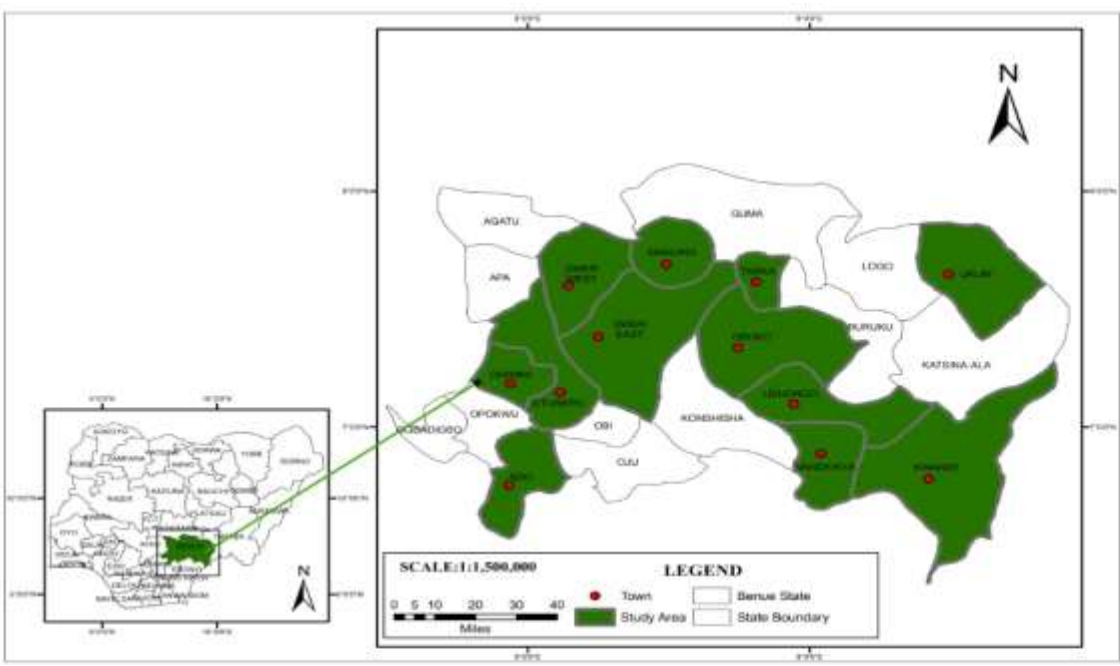

Figure1.1 Map of Benue State Showing theStudy Areas

Source: Adapted from Nyagba, 2013

1.8.1 Population structure and distribution of the study area

The State has a total population of 3,870,476 (National Population Commission, 2006) with an average population density of 99 persons persq.km. This makes Benue the 14th most populous State in Nigeria (Nyagba, 2013). In the 2012 Census the population increased to 4,253,641 which marked Benue State as the ninth ranking populated State in Nigeria. There are highpopulation densities in LGA in the State such as Guma, Gwer, Ohimini, KatsinaAla, Apa, Logo and Agatu, each with less than seventy persons per sq. km. While Vandeikya, Okpokwu, Ogbadibo, Obi and Gboko have densities ranging from 140 persons to 200 persons per square kilometer. Makurdi with its restricted coverage around the ' town has over 380 people per square kilometer.

1.8.2 Climate of the study area

The climate brings both positive and negative consequences to human existence and activities. Regional analysis of climate has helped tremendously in planning agricultural activities in various regions where such studies were carried out. There are different elements of climate but this study was focus only on rainfall.

1.8.2.1 *Rainfall of the study area*

Precipitation in Benue State like elsewhere in the tropics, consists entirely of rainfall, it is the most variable element of tropical climate. Due to its varied nature, rainfall has been greatly used in the delimitation of climate regions in the tropics, and since other climatic elements are uniform, rainfall is particularly important to agriculture, because agricultural practices are mostly rain-fed (Hassan, 2013). Variation in rainfall characteristics has a significant effect, particularly on rain-fed agriculture in Benue State (Binbol, 2014).

Rainfall occurrence in Benue State is frontal, orographic, and convectional rainfall, although the frontal and convectional rainfall is mostly predominant. Frontal rainfall occurs when two contrasting air masses, dry continental air mass (cT) and the moist,humid marine air mass (mT) come into contact. The point where the two air masses meet is the Inter-Tropical Convergence Zone (ITCZ) if they meet on the sea and Inter- Tropical Discontinuity (ITD) if they meet on land. Binbol (2014), noted that in the case of Benue State, rainfall occurrence by November through January, the ITD is at its most Southerly position in the country, thus, the entire State shall be under the influence of harmattan winds, which are dry, cold and dusty winds.

Binbol (2014), noted that as the ITD continues it northward movement at a speed of 160km per month, the lines are at the southern part of Benue State by March. By April it would have moved 11^0N, therefore, subjecting the whole State under the influence of the moist maritime air mass. The early rains in the State are characterised by a thunder storm and a squally activity is as well noticeable when the rain is receding. The mean annual rainfall across the State is between 1400mm and 150mm, with the highest in August of about 1560mm and the lowest in October of about 328mm. The rapid decrease in the monthly rainfall is attributed to the rapid retreating of the ITD at a speed of 320km per month as against 160km for the South North movement (Ayoade,2003).

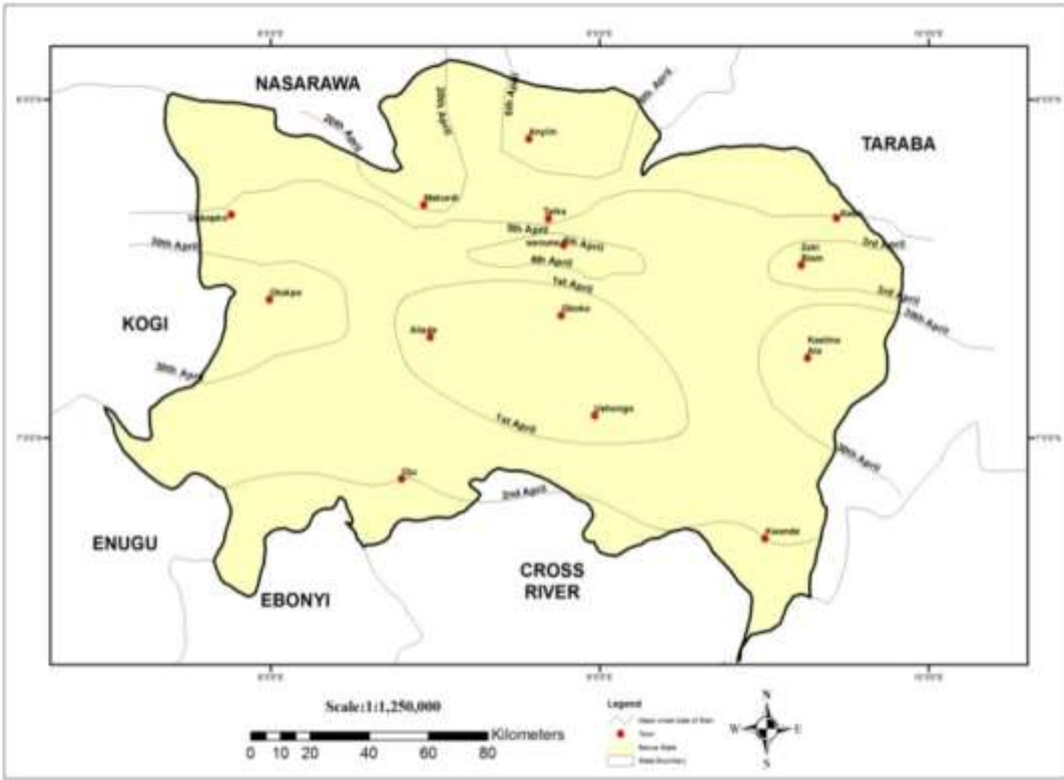

Figure 1.2 Mean Onset Dates of Rains in Benue State

Source: Adapted from Binbol, 2014

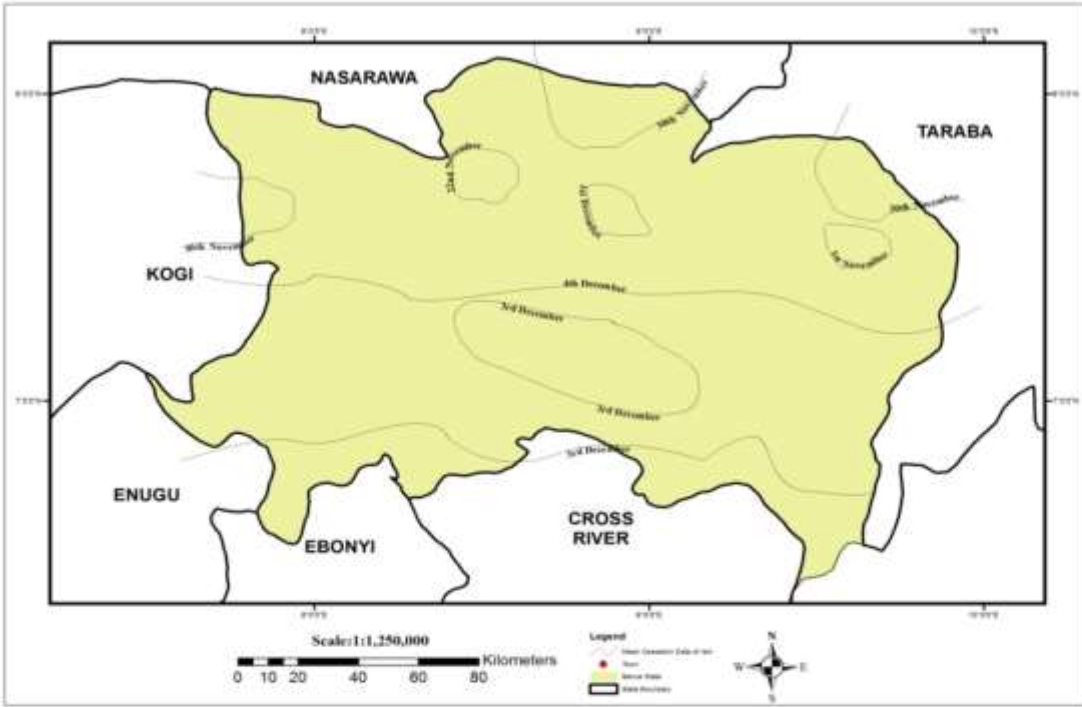

Figure 1.3 Mean Cessation Dates of Rains in Benue State

Source: Adapted from Binbol, 2014

Benue State has a tropical sub- humid climate, with two distinct seasons the wet season and dry season. The wet season last for seven months between April and October, while the dry season is between November and March (Nigeria Meteorological Agency, 2005). The mean length of the rainy days varies in different parts of the State, for instance, places in the Western and Eastern areas including Otukpo and Katsina-Ala have the highest mean Length of Rainy days of about 240 and 241, respectively. While the Central part includes, Ushongo, Aliade and Gboko which have the Mean length of rainy days of 238 and 239 while the remaining areas are below237 as shown in Figure 1.4.

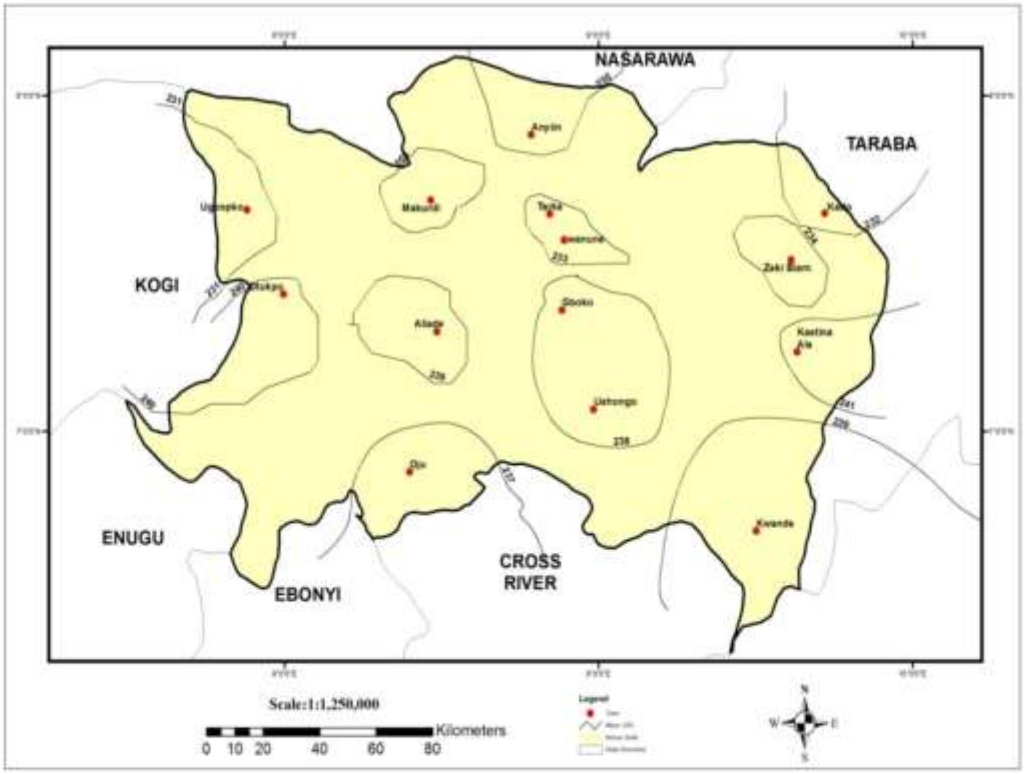

Figure 1.4 Mean Length of Rainy Season (LRS) in Benue State

Source: Adapted from Binbol, 2014

1.8.2.2 *Temperature of the study area*

Temperatures are generally very high during the day, particularly in March and April. Benue State records the average maximum and minimum daily temperatures of 35^0c and 21^0c in the rainy season and 37^0c and 16^0c in the dry season,respectively (NIMET, 2016). A maximum is reached in March when the temperature can be as high as 39^0c. On the other hand Minimum temperatures in the State can drop to as low as 17^0c in December and January (Binbol, 2014). There is a spatial variation in temperature distribution over the State. Mean monthly temperature ranges between 26.8^0c in the southern part to about 27.9^0c in the northern part of the State (NIMET, 2016). The temperature in Benue State is generally high, partly because of its location in the tropical sub-humid climatic belt and the high radiation income in this part of the globe, which is evenly distributed throughout the year (Binbol,2014). There is a gradual increase in temperature from January to March; the onset of rains in April brings a noticeable decline in Temperature. November and December periods also witness a decline in temperature due to harmattan wind. Two main factors strongly influence temperature patterns in the tropics in which the study area lies, and these are cloud cover and elevation. The cloud covers is less or completely absent during the dry season, hence the high temperatures at this time of the year. As a result of differences in elevation between the north and south, the latter has higher temperatures throughout the year than the former.

1.8.3 Geomorphology and geology of the study area

Much of Benue’s areas fall within the Benue Valley/trough,this is believed to be structurally developed. During the Tertiary and possibly the interglacial periods of the Quaternary glaciations, the Benue and Niger Valleys, otherwise known as the Niger/Benue trough, were transgressed by the waters of the Atlantic Ocean(Agidi, 2017).These sediments have undergone varying degrees of metamorphism. These sedimentary materials are underlained at variable depth by basement complex rocks. In the Southern areas such as Ado, Ogbadibo, and Okpokwu, the metasediments may be more than 20m thick. Benue State geology can, therefore, be broad meta-sediments occurring in more than 7.5 per cent of the state, associated with the Benue trough. Basement complex rocks occurring higher ground further away, particular in Kwande and the eastern part of the meta-sediments, are dominantly sandstone and contain shale, siltstone, limestone and quartzite. On the flood plains of the Benue are KatsinaAla Rivers and other smaller rivers, alluvial deposits, comprising an assortment of clays, sand, gravels, and pebbles, overlie the met sediments and form the superficial geology. Phonolite, trachyte, and various types of pyroclastic materials (pummic, bomb lapilli) on the surface. In Benue State, these volcanic materials are well represented in Guma aroundGbajimba. These volcanoes are thought to be responsible for some economic mineral formations, including the salt springs. Basement complex rocks comprising ancient igneous and metamorphic rocks occur mainly in Kwande and the eastern part of Oju. The materials also outcrop in widely scattered locations as upland residuals, such as inselbergs, knolls and ruwares and underlie all of the metasediments. The basement rocks are dominated by porphyritic granites, migmatites, diorites, pegmatites, and gneisses. In much of Benue State, both the tertiary sedimentary rocks and the basement complex have been deeply weathered to produce regolith and saprolite several metres deep. These rocks are rich in solid minerals, such as limestone, baryte, coal, gypsum, salt, shales, silica, sand, and kaolin which are currently being mined.

1.8.4 Relief and drainage of the study area

The land is generally low-lying (averaging 100m - 250m) and gently undulating with occasional inselbergs, knolls, ruwares laterite capped mesas, and buttes. It is only at the boundary area with the Cameroun Republic in Kwande and Oju areas that hilly terrain with appreciable local relief. Here, the terrain is characterised by steep slopes, deeply incised valleys, and generally rugged relief. Elsewhere, such areas are made up of interfluves, broad open valleys, and flood plains. River Benue is the dominant geographical feature in the state (Agidi, 2017).It is one of the few large rivers Nigeria not plagued with waterfalls and rapids. The KatsinaAla is the largest tributary, while the smaller rivers include Mkomon, Amile, Duru, LokoKonshisha, Kpa, Okpokwu, Mu, Be, Aya, ApaOgede and

Ombi. The flood plains, which are characterised by extensive swamps and ponds, are good for dry season irrigated farming. Elsewhere surface drainage is generally good. Though Benue State has a high drainage density, many of the streams are seasonal. Also, the permanent water table in many parts of the state is very low, due to thick overlying permeable metasediments and the great depth to which weathering has reached. Hence, there is an acute water shortage in the dry season in s such as Guma, Okpokwu, Ogbadibo, Gwer -West, and Oju.

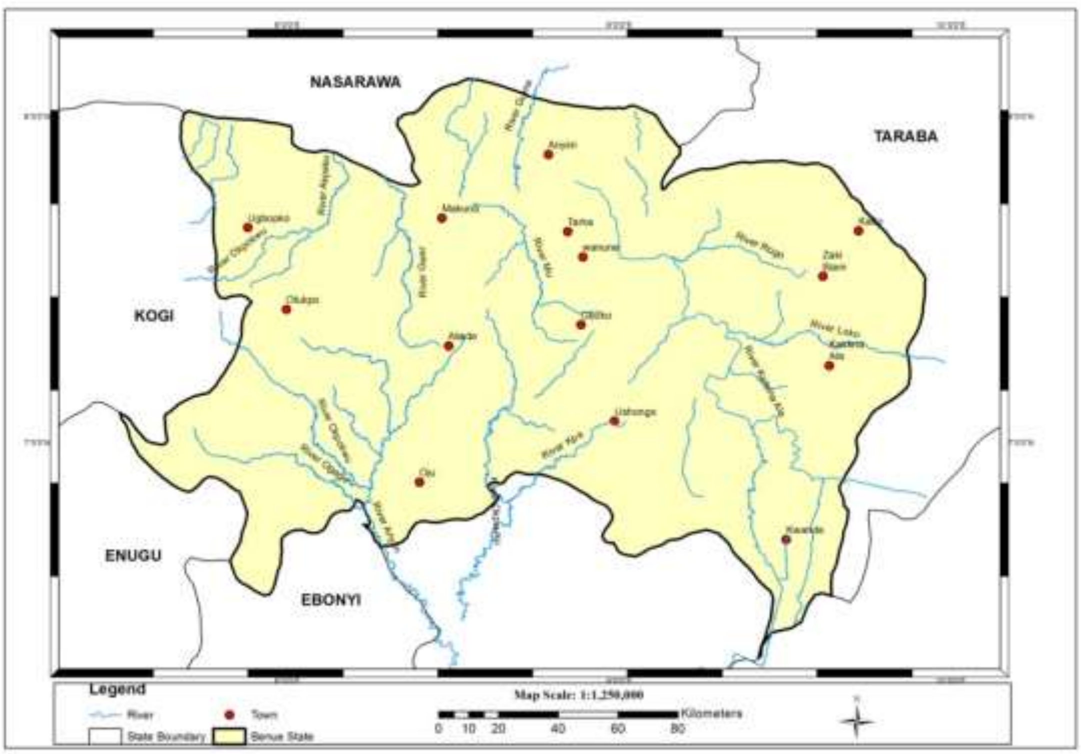

Figure 1.5 Drainage pattern of Benue State

Source: Adapted from Agidi, 2017

1.8.5 Soils of the study area

The soils in Benue State are mainly oxisols and ultisols (tropical ferruginous), which vary over space concerning texture, drainage, gravel content, etc. A typical profile is highly weathered with sandy surface layer overlying mottled clay subsoil. In the southern part of the state, around Vandeikya, Oju, Obi, Otukpo, and Ogbadibo, the soils developed from lateritic profiles with pallid zones. The agronomic significance of this subsoil crust is that it often produces a perched water table which is an important source of capillary water, which keeps the surface moist long after the end of the rainy season (Nyagba, 2013).

Entisols and inceptisols also occur associated with young soils on hill slopes and recent alluvium on flood plains. Around Gbajimba in Guma , Eutrophic Brown Earths occur associated with the volcanic parent materials. Sheet erosion is the dominant form of water erosion in the State. Deep gullies occur in Ogbadibo and represent a northern extension of the eastern Nigerian, meta-sedimentary deepgully system. Other gulled areas in the state include Makurdi North Bank area, TseMker, and Gbem in Vandeikya ,Gbajimba town, stream bank erosion in Gboko town, incised streams on sloppy ground coterminous to Anwase Kyogen Abande ranges in Kwande .

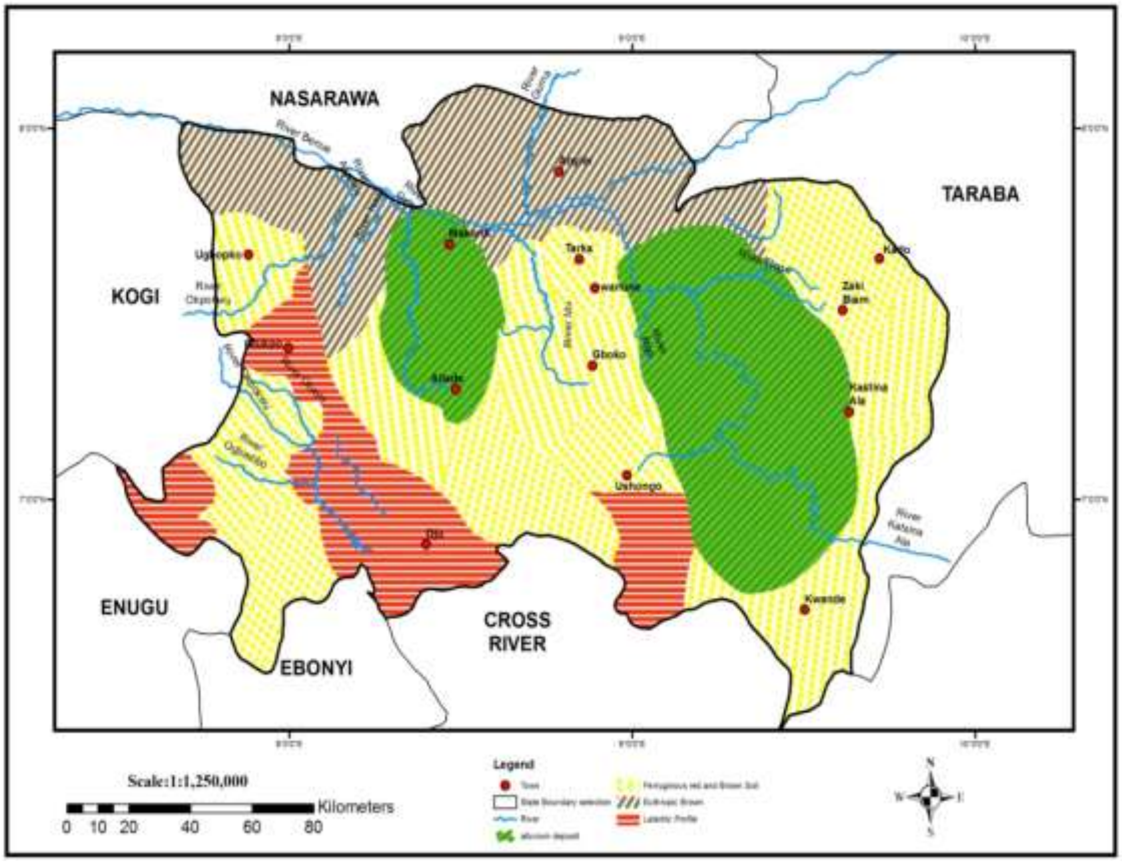

Figure 1.6 Soil Type of Benue State

Source: Adapted from Nyagba, 2013

1.8.6 Vegetation of the study area

Benue lies in the southern Guinea Savannah of Nigeria. Persistent clearance of the vegetation has led to the regrowth vegetation at various levels of seral development and more importantly, parklands with grasses ideal for animal grazing during their early growth. These succulent grasses can be cut with machinery, dried, and baled for dry season livestock feeding.The grasses, however, grow very tall, coarse, and tough on maturity (Nyagba, 2013). The scattered trees are mainly of economic value and include locust bean, shear butter, mango, silk cotton, African iron, Isoberlina, cashew, oil palm, Oliveri, and gmelina. These trees produce valuable fruits, wood, and fibre which can be utilised for small- scale cottage industries. In the southern part of the State, particularly in Oju, Ado, Obi, Ogbadibo and Okpokwu, the vegetation is mainly oil palm bush. The oil palm is utilised for palm oil, palm kernel, palm wine, broom sticks, and several other products. Dense forests are few and far apart, except in a few such as Vandeikya, Kwande, and Okpokwu. Generally, forest vegetation may be grouped into: village forests, gallery forests, and forest reserves. In these forests, typical rain forest trees such as mahogany, Obeche, and Iroko are used for timber. Other economic trees in these forests include African pear, ogbono, bamboo, raffia palm, oil palm, orange, and coconut.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Conceptual Framework

The key issue responsible for embarking on this research work is making useful agricultural decisions understanding the agro- climatic component of a place under study. An approach for the representation of agro- climatic climatology was formulated by considering water availability which is the most critical factor for plant growth and development, leading to high productivity (Labiru, 2016). Thusa diagrammatic representation of how rainfall variability affects crop yields that are moreprone to a rain- fed agricultural environment is shown in Figure 2.1.

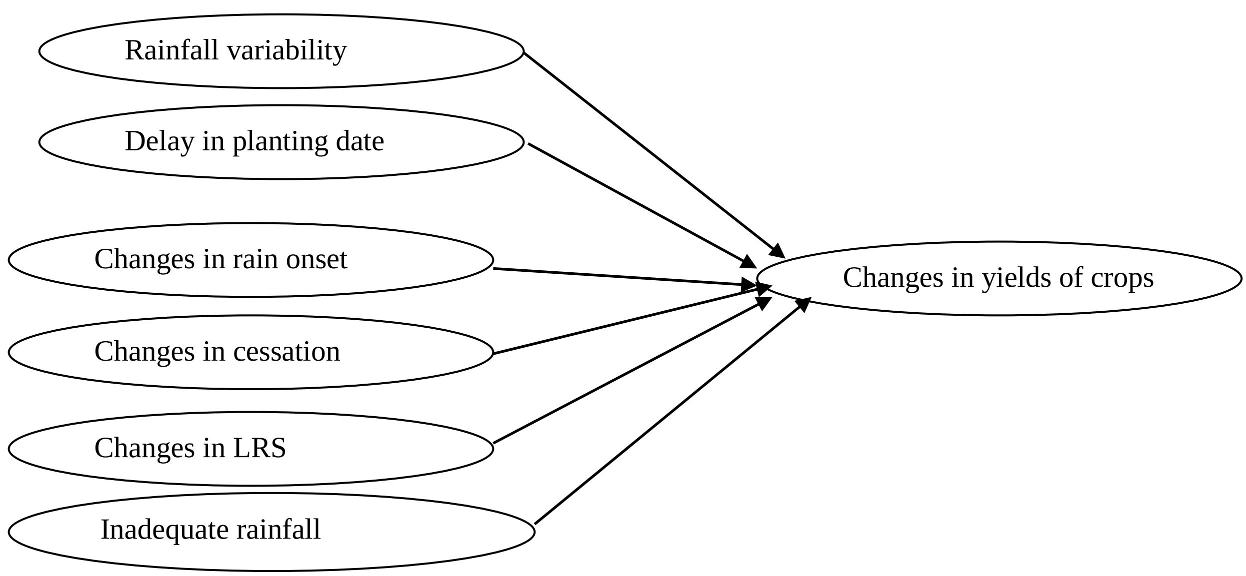

Figure 2.1 Rainfall variability on Crop Yield

Source: Adapted from Labiru (2016)

The conceptual framework of this study in based on the concept of environmental determinism, which state that man is constrained, limited, influenced or controlled by nature. In this case, the yield of crops influenced by the climatic factors,including rainfall, temperature, and relative humidity. The efficient distribution of rainfall in a growing season determines the yield. Changes in the normal pattern of rainfall onset, cessation and growing season will leave farmers with little or no idea thus decreasing in crop yield. Soil moisture is a critical phase of plant growth which is important in determining crop yield. Many studies have shown that crop yield is directly related to the soil moisture availability during a growing season (Siebert *et al*., 2017). Understanding the relationship between rainfall variability and crop yields has occupied the minds of researchers for a while. Thus, three techniques include plant growth and development, climate relationship and agricultural products yield data and climate parameters relationship and plant- climate relationship under a controlled environment (Chima, 2015). Therefore, this study shall adopt the second technique studying the relationship of agricultural product yields data and climatic variables.

Hence rainfall is considered the main influencing factor of crop yield. An increase and decrease in crop yield would greatly depend on availability especially in the tropics with high temperature. In contrast, some researchers insisted that crop yield studies should be approached from the angle of improved crop variety or to look at the soil quality which has high tendency to affect yield.The conceptual approach of this study is based on how variability in climate results in the decreasing length of the rainy season, changes in onset and cessation of rainfall, and agricultural drought, which has adverse effects on crop yield. The climatic elements that affect crop production include solar radiation, temperature, precipitation, relative humidity, pressure, sunshine hours and wind. Precipitation is the most important element affecting agriculture in the tropics and indeed the Benue State of

Nigeria. In Benue State, of all the climatic elements, rainfall is probably the most important crop production. Based on Yahaya (2011) adequacy of water is one of the major climatic factor affecting plant growth, development and yield. Ayoade (2003) noted that when fluctuations in climate constitute significant departure from the normal climate state, there are problems of adjustment and the environment.Man and his socio- economic activities most especially farming become very vulnerable. Based on these concepts, this research is conceptualised to look into the climate crop yield relationship. Therefore, this research examines the influence of climate variability and its effects on crop yield and the perception and adaptation strategies employed by farmers to cope with the situation in Benue State. The result will equip the farmers with the knowledge to improve their farming activities to have a bumper harvest.

2.2 Theoretical Framework

2.2.1 Rainfall trend in Nigeria

Nigeria's population and economy are linked to climate- sensitive activities including rain-fed agriculture. Therefore, understanding current and historical rainfall trends and variation are inevitable to her future development especially in the agriculture and hydrological sectors. Previous studies have analysed rainfall trends over the entire or part of Nigeria. For example, Adefolalu (1986) examines rainfall patterns using 70-year period (1911–1980) rainfall data from 28 meteorological stations. Bello (1998) extended the work and compared the seasonality of rainfall distribution in Nigeria for two climate periods, 1930–1961 and 1962–1993. Ati*et al*., (2016) reported a significant increase in rainfall over nine stations in northern Nigeria between 1953 and 2002. However, the results showed a general decline in the dry season's contribution to annual rainfall i.e. dry period is getting drier. More recently, Oguntunde*et al.*, (2011)analysed rainfall trends over Nigeria using 1901–2002 rainfall data from Global Gridded Climatology of Climate Research Unit Time Series (CRU TS.2.1). They concluded that annual rainfall had been reduced significantly over 20% of the landscape and the amount of annual rainfall reduced by 50–350 mm in 64% of Nigeria. It is important to state that rainfall of Nigeria and West Africa in generally is influenced by the dynamics of continental air mass and maritime air mass which meet a slanting surface called Inter-Tropical Discontinuity (ITD) (Odekunle, 2004).

Varying degrees of convective activity and precipitation occurs at the south of ITD, while little or no cloud development or precipitation occur in the northern part of ITD. Ezekiel *et al.* (2017) in their study of the general impact of Climate Change in Nigeria noted that, within the 105 years studied, rainfall amount in Nigeria dropped by 81mm. The declining rainfall became worst from the early 1970s, and the pattern has continued to date. Although, he noted a general decrease in rainfall in Nigeria, the coastal areas of Nigeria like Warri, Brass and Calabar are observed to be experiencing slightlya increasing rainfall in recent times. He further revealed that the number of rain days dropped by 53 % in north-eastern Nigeria and 14 % in the Niger-Delta coastal areas. The study also showed that while the areas experiencing double rainfall maximal is shifting southward, the short dry season (August Break) is being experienced more in July as against its normal occurrence in August prior before 1970s. These are major disruptions in the climatic patterns of Nigeria. Rainfall trend is an opposite thing in Nigeria, the coastal region having an increased rainfall while the other region having a decreasing rainfall. This further show how un- uniform is the distribution of rainfall across the country and even in time because decades before the 1970s, rainfall as compared to the latter.Oguntunde*et al*. (2011). Conducted research on annual rainfall pattern analysis using Guinea coast and Savanna areas.Theynoted that the annual rainfall amount is normally distributed over each zone as there was no obvious skewness in the distribution curve. This does not imply that there were no extreme events during the study period; such extreme cases are being captured within each climate period especially the drought events of 1968–1973 captured in the third climate period responsible for the significant shift leftward from periods. Quantitatively, a steady leftward jump in-between climate periods characterised rainfall distribution over the Guinea coast and Savanna. At the same time, the shift over the Sahelian zone was only obvious between previous climatic periods. A more recent work conducted by Akinsanaola and Ogunjobi (2014) revealed that, rainfall and temperature pattern in Nigeria using observations of air temperature (0^{C}) and rainfall (mm) from 25 synoptic stations from 1971- 2000 (30 years) shows that there have been statistically significant increases in the rainfall in vast majority of the country.

Analyses of long- time trends and decadal trends in the time series further suggest a sequence of alternately decreasing and increasing trends in mean annual rainfall in Nigeria during the study period. This reveals no uniform pattern in rainfall distribution over Nigeria, although, in a whole, the rains can be increasing.

2.2.2 Rainfallvariability and its impact on crop yield

Rainfall variability is arguably one of the most important challenges facing African countries, largely due to their geographic exposure, low income, greater reliance on climate-sensitive sectors such as agriculture, and weak capacity to adapt to the changing climate(Belloumi, 2014). However, there are limited studies that have documented adverse socio-economic impacts of extreme weather events, specifically in Kenya. The effects have been felt on almost all sectors such as health, agriculture, livestock, environment, hydropower generation, and tourism. Kenya is adversely affected by climatic variability and change because of her dependency on rain-fed agriculture, with variability in rainfall and temperature directly affecting crop and livestock yields.

Climate change was defined by Odjugo (2013) as a change in the statistical distribution of weatherpatterns when that change lasts for an extended period (i.e decades to millions of years).Ngaira (2007) defined Climate change as the changes in long- term trends in the average weather, such as changes in average rainfalls and temperatures. World Meteorology Organization (2010) refers to climate change as a change in average weather conditions, or in the time variation of weather within the context of longer-term average conditions. In the United Nations Framework Convention on Climate Change UNFCCC) refers to a change in climate attributable directly or indirectly to human activity that alters the atmospheric composition.In addition to natural climatic variability is observed over comparable periods (IPCC, 2012). Climate variability refers to shorter- term (daily, seasonal, annual, inter-annual, several years) variations in climate, including the fluctuations associated with El Niño (dry) or La Niña (wet) events (Maduka, 2012). Orindi (2013), climate variability shifts from the normal experienced rainfall pattern of seasons to abnormal rainfall patterns. Therefore, the climate thought of as a long- term summing up of weather conditions, taking account of the average conditions and the variability of these conditions, thus, the fluctuations that occur from year to year, and the statistics of extreme conditions such as rigorous storms or unusually hot seasons, are referred to as climatic variability (UNDP, 2007).

Based on IFPRI (2017) rainfall variabilityand pattern might affect food systems in several ways, ranging from direct effects on crop production (for example change in cropping practices), exchange in markets, food prices, and supply chain infrastructure. Rainfall variability has significantly affected global agriculture in the 21st century, and the Intergovernmental Panel on Climate Change (IPCC) assessment report indicates that most countries will experience an increase in average temperature, more frequent heat waves, more stressed water resources, desertification, and periods of heavy precipitation (IPCC, 2007). The past three decades have been the warmest in history, with each decade being warmer than the preceding period according to (Osman, 2015). Further, the reports indicate that the African continent is warmer than it was 100 years ago;future impacts are projected to worsen as the temperature rises, and precipitation becomes unreliable.Ajetomobi (2010) argued that social vulnerability to climate change is a key dimension in the constitution of vulnerability. It shifts the emphasis onto the underlying, rather than the proximate causes of vulnerability. In Kenya, smallholder farmers have been found to respond to drought through diversification into off-farm employment activities (Downing 2007).Karanja (2012) also showed that adaptation measures in terms of micro-level farm adaptations, market responses, technological developments, and institutional changes have a large potential in reducing the negative impacts of global warming and climate change. Bilham (2014) noted that rainfall had more impact on crop yields than temperature. Thornton and Jones (2013) showed that maize production in Africa and Latin America would reduce by

10% by 2055 and recommended that climate change effects be assessed at the household level so that the poor who depend on agriculture can be targeted advice.

2.2.3 Global crop yield trend

Today, a global food crisis is looming as the world population increases, more people shift towards meat and dairy intensive diets and more cropland is diverted to grow biofuel crops(Godfray, 2010). However, food prices have increased rapidly, and many people have attributed this to climate change problems such as prolonged drought. So many regions are showing significant stagnation and declines in yield improvement. However, several recent studies indicate that yields may no longer be increasing in different regions of the globe (Finger, 2016). Yields are no longer improving on 24–39% of our most important cropland areas (Foley, 2012). Many of these areas are in top crop- producing nations, have a rising population, increasing affluence, or some combine these factors (Tilman, 2014). This may increase the difficulty of meeting future crop production goals, but the key unknown remains for developing and targeting strategies. Adejuwon (2011) used Erosion Productivity Impact Calculator (EPIC) crop model to project crop yield in Nigeria in the 21st century. The study indicated an increase in crop yield across all low land ecological zones as the climate change during the early part of the 21st century. However the yield will decrease towards the end of the century.

Africa is a continent of contrasts with regards to rates of maize yield change. For example, maize yields increase to-2.4% per year in the Nigerian States of Yobe and Adamawa. Similar maize yield improvement rates are found in some other isolated areas of West African nations, Ethiopia, Angola, South Africa, and Madagascar. Nevertheless, maize yields decrease in Morocco, Chad, Somalia, Kenya, Zambia, Zimbabwe, Rwanda, Burundi, and the Democratic Republic of Congo. Elsewhere, rates of yield improvement are lower than population growth, suggesting that production per capita is likely to decline. These trends are particularly troubling in countries such as Burundi, Chad, Kenya, Morocco, Rwanda, Democratic Republic of Congo, Somalia, Zambia, and Zimbabwe, where yields are decreasing −0.2% to −7.6% per year, the population is rising (Dobermann, 2013) and maize accounts for 5–51% of calorie intake.

In Ivory Coast, Togo and Benin in West Africa, and Rwanda, rice yield changes are at double rates. In contrast, yields are decrease by 1% per year in the Gambia and 3% per year in Nigeria. Nearly 8% of the dietary energy in Nigeria is supplied from rice (FAO, 2014). The per capita rice harvests could decrease in almost all the important rice- consuming African nations, example, Guinea, Madagascar, Mali, Nigeria, and Tanzania, unless yields are boosted further. Only in Ivory Coast could there be an increase because its∼2.6% per year yield increases(Dobermann, 2013). He also noted that wheat, while grown in only an extremely small area of Africa, though in many countries, is generally increasing yields at high rates. In Angola, Eritrea, Malawi, Nigeria, Algeria, Sudan, and South Africa, yields are growing at doubling rates (2.4–3.4% per year). In Nigeria and Mpumalanga province of South Africa soybean yields increase at doubling rates, whereas, in Zimbabwe, the Democratic Republic of Congo, and Rwanda, yields are decreasing.

Table 2.1 Summary of Global and Projected yield of maize, rice, wheatand Soybean

	Maize	Rice	Wheat	Soybean
Mean yield change per year (% per year)	1.6	1.0	0.9	1.3
Mean yield change per year (kg/ha/year/year)	84	40	27	31
Projected average yield in 2025 (tons/ha/year)	6.5	4.9	3.4	3.0
Projected average yield in 2050 (tons/ha/year)	8.6	5.9	4.1	3.8
Projected yield in 2025 (million tons/year) at fixed crop harvested areas of 2013	1016	760	741	275
Projected yield in 2050 (million tons/year) at fixed crop harvested areas of 2013	1343	915	891	347
Projected yield shortfall in 2025, as compared to the rate that doubles yield by 2050 (million tons/year)	100	160	157	43
Projected yield shortfall in 2050, as compared to the rate that doubles yield by 2050 (million tons/year)	247	394	388	107
Required extra land (million hectares) to produce the shortfall at 2025 projected yields	15	33	46	14
Required extra land (million hectares) to produce the shortfall at 2050 projected yields	29	67	95	28
Yield in the year 2013 (tons/ha/year)	5.2	4.4	3.1	2.4
90 percent confidence limit in yield change (% year)	0.8-2.4	0.51.4	0.1-1.8	0.3–2.0
90 percent confidence limit in yield change (kg/ha/year/year)	41–124	21–58	4–52	6–50

Source: FAOSTAT, 2012

2.2.4 Global rainfall trend

Changes in rainfall patterns are highly related to the variability of atmospheric circulations. A warming climate example can influence shifts in storm tracks (Trenberth 2011), leading to an increasing trend in global rainfall (Ren *et al*., 2013). As possible causes, some suggest an increase in hydrologic extremes (Westra *et al*., 2013) in response to a warming climate, while others propose location-specific intensification of the global hydrologic cycle, where the wet regions get wetter and the dry regions get drier (Huang *et al*., 2015). At the same time, there is little evidence provided by historical observations supporting the notion that the wet gets wetter and the dry gets drier (Greve and Coauthors, 2014). Furthermore, to achieve any semblance of understanding global historical rainfall trends, spatial aggregation of rainfall is necessary (Fischer, 2013). An initial effort in this direction can be found in previous studies that examine rainfall at both regional and global scales (Wu and Fu 2013) or investigate simulated rainfall response with changing model resolution (Rasmussen *et al*., 2012; MendozaandCoauthors, 2016). However, these studies are interested in model result implications thatemphasise on a single geographical area at a regional scale as a compliment to a single form of global analysisdivision. Other studies (Wang *et al*., 2016; Gu and Adler 2013) use the Global Precipitation Climatology Project (GPCP) at 2.5° resolution to investigate global precipitation trends, but they lack the high resolution needed to do so at varying spatial scales. This is especially important for divisions with highly irregular borders such as political boundaries and watersheds.

A recently released high-resolution global precipitation dataset from NOAA—Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks-Climate

Data Record (PERSIANN-CDR; (Ashouri *et al.*, 2016) provides the ability to reexamine and gain new insights about the global precipitation trends across different spatial scales. PERSIANN-CDR was developed based on the artificial neural network model named PERSIANN (Hsu *et al*., 2007; Sorooshian,2000). PERSIANN-CDR uses brightness temperature retrievals of infrared information from geostationary Earth-orbiting satellites to estimate rainfall and the monthly GPCP rain gauge observations for bias correction. Various validations have shown the usefulness of PERSIANN-CDR for climate studies about rainfall trend (Luchetti *et al.*, 2016;Ashouri *et al*., 2016).

Nigeria′s and the world population and economy are linked to climate- sensitive activities, including rain-fed agriculture. Rainfall is one of the climatic elements that differ greatly on a spatial and temporal basis and has significantly impact agricultural activities (Mwale and Shen, 2014). Therefore, an understanding of current and historical rainfall trends and variation is inevitable to her future development, especially in the agriculture and hydrological sectors. Rimi *et al*. (2015) indicated that “there is a little trend in total precipitation for china as a whole, but there are distinctive regional and seasonal patterns of trends. Annual total precipitation has significantly decreased over southern, northern China, north China, and over the Sichuan Basin but significantly increased in western China, the Yangtse River Valley, and the south-eastern coast. In western China, precipitation increase has been observed for both cold and warm seasons. However, trends differ from one season to another in eastern China. Spring precipitation has increased in southern northeast China and north China but decreased significantly in the mid- reach of the Yangtse River.

2.2.5 Significance of climate factors to farming in Nigeria

Nigerian agriculture depends profoundly on climate since rainfall, radiation, temperature and relative humidity are the principal drivers of crop yield and growth, (Webber, 2017) produce from farm generally need a specific measure of precipitation during growth stages for best yield when this ends up extreme, it prompts poor harvest if by any stretch of the thought. Additionally, when this is added tohigh temperature the condition of the soil will exhibit conducive to the micro-organism, which disintegrates biomass into organic or natural matters. This event will result in soil unproductiveness that may prompt extremely poor yield. This sets changing climate as an essential element in agricultural production for food security for both locals and universally. Climate change influences the natural ecosystem and soil, which altogether impacts generally farming sustenance production.

It was predicted that Nigeria and other West African nations are expected to have agricultural declines of up to 4% of GDP due to climate change***(***Webber, 2017***)***. This is following Nwaobiala (2013) discoveries, who stated "that rural farmers are getting to be poorer because their farming system is described by low and declining productivity because of the impact of climate change". Farming products are essential in ensuring food assurance. The increment in farming strength enhances rural benefits and lower food costs, making it more available and beneficial to the poor. Although, environmental change may incite low farming effectiveness in achieving rural families' food stability, this approach is needed in the study area due to the food scarcity where rural farmlands are rendered ineffective. Crops have been wrecked due to flooding and other environmental- related components combined with the current oil spillage in the area. If food demands increase and farming product diminish persist in the area therefore, the study area will undoubtedly be food insecurity problem in the area, if outstanding actions are not taking to uncover the threat of changing climate that causes flooding and other related hazards which pose a significant danger to food creation. Many rural households in the area are vulnerable to persistent food curtailments, inconsistent supply, poor quality and fluctuating food costs *(*Siebert *et al.*, 2017*)*. According to them, most households in the study areas live in the rural areas and mostly involved in agriculture to produce food for individuals and the State. Developing agreement in the scientific literature revealed that, in the nearest future or decades, higher temperatures and changing precipitation levels caused by climate variability would be unfavourable to crop growth in many regions and countries (Huybers *et al.*, 2016*)*. To know the extent to which climate variability affects agricultural production, the study examined the impacts of temperature and rainfall on cassava and maize farming in Port Harcourt, Rivers State of Nigeria. Climate variability (or change) remains a major challenge to agricultural production and food security in Nigeria (Okorie, 2014). Recent studies link the decline in agricultural production in Nigeria to global warming. The resulting climate change is projected to exacerbate this decline because global warming might induce unfavourable climatic conditions for agricultural practices (IPCC, 2014).

Consequently, the uncertainty and risk associated with climate change/variability and crop yields could make farmers abandon farming or convert the farmlands to non-agricultural enterprise (Oluyole*et al.*, 2013). These negative developments, of course, would worsen the food insecurity in Nigeria. Therefore, Oyewole*et al.* (2014) have emphasised the need to enhance agricultural productivity, increase food production, meet the demands of growing populations, and ensure adequate access to food in Nigeria. Developing a reliable climate crop prediction system for estimating crop yields over Nigeria, will enhance agricultural production. Such a system can optimise agricultural productivity, improve crop management, and facilitate policy formulation on adaptation to future climate change.

It can simulate the influence of climate variability (seasonal and annual) on crop yield and can take weather input from regional climate model simulations (Challinor *et al.*, 2011). GLAM has been validated and adapted for climate-crop modelling in some countries'tropical locations, such as India, Ethiopia, Ghana, and West Africa (Challinor*et al.*, 2011). However, GLAM has never been validated, nor its performance evaluated over Nigeria.Therefore, the study calibrate and validate GLAM in simulating crop (maize, rice, cowpea, and groundnut) yields over Nigeria, West Africa, using climatic data from the simulation of a dynamic regional climate model (RegCM3). This is with a view to: (1) investigate the climate-crop interactions over the country; (2) perform a series of sensitivity experiments to examine the response of the crop yields to change in the default values of some model parameters harvest index, extinction coefficient, optimum temperature (OT), and transpiration efficiency (TE) and (3) fine-tune the GLAM parameters to improve the model performance and optimise the crop yields over the region. Rainfall is the most important variable in agricultural production and its extreme variations affect food production.Droughts, floods, and tropical rainstorms, create foodscarcity problems and mass movement ofpeople(Battistiand Naylor 2009). Agriculture, particularly the crop sub-sector has ever served as man's supplier of foods since the beginning of life. Moreover, the most significant climate variation in Africa Sahel since the late 1960s has been the constant reduction in rainfall. Agriculture remains the mainstay of Nigerians' economy despite its decline during the oil boom of the 1970s that heralded the petrol dollar era.It provides about 42 percent of Nigeria's gross domestic product (GDP) of which crop sub-sector takes larger percentages, the main source of food for most of the population, 50 percent of total employment and the bulk of raw materials used by the mainly agricultural-based industrial sector.Fakorede*et al.,* (2016) affirmed that water availability is the most critical factor for sustaining crop productivity in rain-fed agriculture. IPCC (2014) noted that even if a drought-tolerant trait is introduced, water is not available to crops when there is no water in the soil. In Nigeria, the variability in rainfall exposes several physical and socio- economic sectors in the country to several climatic disasters. Available records (IPCC, 2014) noted that the single largest threat to achieving sustainable food production in Sub-Saharan Africa is the threat from climate variability. This is because, climate- related risks are the major causes of human suffering, poverty, and reduced opportunity, which lead to large -scale human development reversals.

Manifestations of climate variability such as incidents of extreme weather events have left no continent untouched (IPCC, 2014). The 2014 IPCC document further states that almost all regions on the African continent have in recent times experienced, seen, or heard ofcalamitous incidents (for example, flooding, droughts, desertification, and hurricanes) resulting from unpredictable climate.The FAO in 2014emphasised that most land areas in Africa will have warmer weather and fewer cold days and nights and that the content in the coming years will experience a significant increase in temperature but decreased precipitation (FAO, 2014). The report further indicates that this situation will result in a general reduction in potential crop yields in most tropical and sub tropical regions, which indicates that food security will be adversely affected by climate variability. Further projections are that by 2020, some countries in Africa could experience up to a 50% reduction in rainfed agriculture and livestock productivity (IPCC, 2014).

2.2.6 Significance of climate factors to farming in other countries

Global food security weakened by climate variability and environmental change is one of the most critical difficulties in the 21st century to supply adequate food for the increasing population while sustaining the already stressed environment has become more undermining to the continuous development globally *(*Zampieri *et al.,* 2017*).*Barlow *et al.* (2015) noted that global temperatures have been increasing in line with precipitation increases since 1850, mainly due to the accumulation of greenhouse gases in the atmosphere,which lead to high wind, torrential rainfall, heat and cold can bring about far-reaching situations such as typhoons, surge, droughts, avalanche, dry spells and ocean level ascent. Pest and diseases are also embroiled in climate change**.**Agriculture is probably the most important natural asset in Ghana since it is the main livelihood activity of the majority of the population. This sector is the largest in the economy in itscontribution to the Gross Domestic Product (GDP) and employment. The sector accounted for 34.5% of GDP in 2009. Ghana’s agriculture is predominantly rain-fed, and the sector’s fortunes have generally followed the rainfall patterns from year to year. However, climate variability seems tobe taking a devastating toll on crop yield per year. This is evidenced by the changes in the onset and cessation dates of the wet season. Statistics indicate that over the past three decades (1980–2010), the country has experienced a 1ºC rise in temperature. There has been a decline in mean annual rainfall from 1951 and 1970 to between 1981 and 2010 (Owusu*et al.,* 2017). More importantly, Owusu*et al.* (2017) concede that the agro-ecological zone of north-eastern Ghana, which has the same characteristics as other Sahel regions, has experienced a high degree of temporal and spatial variations in rainfall and temperature, and the effect has beenfelt greatly by poor peasant farmers who mostly cultivate millet, sorghum, rice, maize, and sweet potato for food and income. It is further predicted by the Ghana Meteorological Agency that the climatic conditions in the three northern regionsof Ghana, especially the north-eastern portion, are expected to be more severely affected by unpredictable rainfall patterns. This situation will expand the degradation of the natural resource base and increase the frequency and severity of disaster events. This will further reduce the ability of vulnerable farming communities to maintain their fragile landscape and livelihoods.In Ghana, the literature is replete with accounts of farmers' knowledge and perception of the causes of climate variability.

Equally, climate variability adaptation strategies have also captured policy makers' attention and those in academia (IPCC, 2014). While some other research studies on the effect of climate variability on food production (IPCC, 2014), these studies tend to concentrate on the climate variability impact on single crops. The results from such studies tend to be speculative. The literature so far paints a gloomy picture of the relationship between climatic variables (temperature and rainfall) and food crop production. This situation, if not addressed, can lead to a national food crisis, especially in the savannah ecological zone.The evidence presented in the literature shows that the effects of climate on food crop production aregetting worse by the day, making the right to adequate food supply a quest that is becoming more difficult to meet. As food supply reaches a crisis point, the locus of global poverty can also spread towards locations without adequate resources to cope. In Ghana, as in other developing countries, this is happening so fast that those communities that depend on rain-fed agriculture are migrating to urban centres, which has also resulted in what is termed the urbanisation of poverty. This makes it imperative that the world uses every Climate variability and sustainable food production: Insights from north-eastern Ghana71means to ensure that food crop production is sustained to cater for the ever-increasing worldpopulation. It is for this reason that the present study was undertaken.

The study investigates how climate variability has impacted food crop production in north-eastern Ghana, using empirical evidence from yields from maize, millet, rice, and groundnut, the most cultivated food crops in the study area. We hope that the results from the study will help farmers plan and develop strategies to meet the challenges of the variation in climate patterns; it also helps in policy formulation on climate variability adaptation strategies, including climate-smart agriculture and livelihood diversification portfolios. Studies have indicated that a 1°C increase in global temperature will lead to a 17% reduction in maize and soybean (Allen 2013; Thomson *et al*., 2005). Zhang *et al.* (2015) report that rainfall and temperature have opposite effects on yield variability of maize and that rice production is highly correlated with the amount of rainfall from June to September. High night temperatures are commonly associated with increased respiration rates, leading to a decline in yield.High day temperature (32−36 °C) has a significant negative effect on rice grain Ajetomobi (2010), also pointed that increase in temperature due to extreme climatic events may undermine any positive effects by reducing the net revenue for dry-land rice farms (Ajetomobi, 2010). High night temperature has recently become a major rice research area because a narrow critical range of 2−3°C has been shown to result in drastic grain yield reduction in the tropics and sub-tropics.Ajetomobi(2010),analysed the correlation between rice production and monsoon rainfall and showed that the correlation was relatively low. Among the climatic factors affecting variation in rice production, rainfall is the most important limiting factor. Rice yields in China are positively correlated with temperature in some regions and negatively correlated (Zhang *et al.*, 2015). However, there is evidence that high temperatures would limit future yields even in cool environments. Climate variability and sustainable food production: Insights from north-eastern Ghana73 cerealshave been the most important sources of plant food for humans and livestock.The optimum temperature for sorghum, for example, is 20^oC, and beyond this temperature, production declines (IPCC, 2014).

An increase in the frequency of drought and floods is suggested to affect crop production negatively. Rainfall is less a predictor of crop yields at broad scales because of its high variability (Lobell *et al*., 2012). Thornton and Jones (2013), found that the response of crop yields to climate variability in the dry lands of East Africa is insensitive to increases in rainfall. According to Thornton and Jones (2013),rainfall does not directly control any plant processes. However, it indirectly affects many plant growth and developmental processes. Decreased amounts of rainfall can cause an increase or decrease in developmental rates, depending on the stage of development and the species or cultivar. Some species or cultivars are more drought-tolerant than others. However, rainfall must be taken into account since the magnitude, and seasonal variation of both can limit the growth and development of crops. The combined effects of increased temperatures and decreased rainfall are expected to cause changes in crop yields, cropping seasons, scheduling of field operations, and pest conditions. Climate variability is impacts Africa negatively through extreme temperatures, frequent flooding, and droughts (IPCC, 2014). In Africaas a whole, food consumption exceeded domestic production by 50% in drought -prone regions in the mid-1980s and by more than 30% in the mid-1990s.

The impact of technological change is apparent in the yield data series of most crops in most agricultural production regions of the high and low latitude temperate climate zones. Year-to-year variability of climate is the most important contributor to short term variability of yield. For example, US corn yield for 1979 was 68.6 quintals/hectare. In 1980 the yield will be close to 56.0 quintals/hectare, dropping a little over 18 percent. As another example, the winter wheat in the USSR in 1978 was 29.8 quintals/hectare. In 1979 it was 19.7, a drop of almost 34 percent. In the case of the US corn yield change from 1979 to 1980, the major contributing factor was a prolonged drought, with very high temperatures during the critical flowering-pollination period in July. In the USSR winter wheat yield variation, the major contributing factor wasa cool, wet beginning of the winter wheat region growth. In recent research by Zampieri *et al.* (2017) propose a method to study the impact of heat, drought and water excess on wheat yields at the global scale, demonstrating their method's robustness with sub- national yield data for France. The article represents a significant contribution, advancing previous research using a non-parametric approach to disentangle and quantify the effects of heat and soil moisture anomalies on wheat yield. The approach requires neither prior knowledge of the statistical distributions of weather variables nor assumptions about predefined thresholds to calculate heat or water stress. Their composite heat and water stress index, Combined Stress Index (CSI), is mainly data-driven and straightforward to apply. The heat stress index, Heat Magnitude Day (HMD), is calculated using daily maximum temperatures (T_{max}) and their 25th, 75th and 90th percentiles in a two week time window for the period 1980–2010. Similarly, stress arising from drought and excess water are quantified using the Standardised Precipitation Evaporation Index (SPEI), in which precipitation and potential evaporation in a specific year are compared to long-term (1980–2010) time series. HMD is accumulated for three months before harvest, while SPEI is determined for six months before harvest. Both indices are combined in the CSI correlated with global, national or sub- national wheat yields and production.

2.2.7 Impacts of rainfall variability on crop yield

Crop production is an integral part of agriculture, dealing with the cultivation, protection, harvesting and storage of cultivated plants for man's use. It is the total of all activities involved in producing, preparing and processing crops (Akanbi *et al.*, 2014) Arable crops are stapled agricultural food crops that provide the required nutrients for man and livestock. Within the agricultural sector itself, the crops (arable and tree) production sub-sector is the largest, with arable crop production dominating about 30 percent of overall GDP. The arable crop sub-sector is particularly important not only because of the size and employment generation potentials but also because it supplies food and therefore has the potential for dampening the rate of inflation since the price of food accounts for about 60 percent of the overall rate of inflation. In addition, arable crops are important food items to millions of people providing nourishment and generating income. However, Nigeria produces a wide variety of arable crops most of which are consumed as food, the major food crops include rice, maize, cassava, yam, sorghum, millet and cowpea, and the minor ones are cocoyam, melon, sweet potato and plantain. Other arable crops that double as industrial and food crops also include groundnut, cotton, and beniseed (Akinyosoye, 2013).

The effect of climate change on agricultural system can be seen as the interaction between changes in climate variables and the stresses that result from actions taken to increase agricultural production. The Impacts of climate change on crops yield, agricultural productivity and food security vary depending on the types of agricultural practices (Olaniran, 2001). There is growing evidence that further increases in global warming would lead to changes in main climate variables – temperature, precipitation, sea- level rise, and atmospheric carbon dioxide content may significantly affect African agricultural production (Olaniran, 2001). Thus, the importance of focusing on the impact of weather-related shocks on the food crop production context cannot be overemphasised. The local farmers are experiencing climate change even though they have not considered its deeper implications. In addition excessive rainfall, which results in flooding and erosion, destroy farmland and crops. Rainfall pattern from season to season greatly affects soil water availability to crops and poses crop production risks. Several studies on crop climate relations have been reported in different parts of Nigeria (Tyubee, 2013; Adamgbe and Ujoh, 2012). With climate change, food and water supplies will become unreliable and insecure. The available arable land reduced, causing population movements by making certain parts of the world a much less viable place to live (Brown, 2016). Agriculture is by far the most significant user of water resource. Agriculture has faced obvious challenges, and the foremost problem of the sector in Nigeria is that it is still largely informal, subsistent, rain-fed and lacking mechanisation. The agricultural practices depend on natural weather patterns, so variations in rainfall levels results in large variations in total output and farm incomes. Again changes in rainfall will also increase variability in groundwater recharge and river flow, hence affecting all water sources. However, the rainfall characteristics in Nigeria have been examined for secular change which is a dominant trend (Olaniran, 2001). The results show that there has been a early progressive retreat of rainfall over the whole country spanning up to half a century now, and consistent with this pattern, there has also been a significant decline of rainfall frequency, that is, the number of rain days in September and October which respectively coincide with the end of the rainy season in the northern and southern parts of the country. Furthermore, the combined effect of these declines was found to lead to a significant decrease in annual rain days over the whole country. In effect, except for farmers change to early maturing crop varieties, streamline their farming calendars with the changing rainfall regime or have access to irrigation water, the secular changes in rainfall frequency for the country pose a serious threat to the maturity of annual crops and consequently to food security. The agricultural practices depend on natural weather patterns, so variations in rainfall levels result in large variations in total output and farm incomes. Again, changes in rainfall will also increase variability in groundwater recharge and river flow, hence affecting all water sources.

2.2.8 Causes of rainfall variability

Rainfall variability is the fluctuations of rainfall occurrence annually or seasonally above or below a long term normal value. Every year, the rainfall of a location can be different in a specific period, either above or below normal it is the variability. However, around the year, the mean is not different (IPCC, 2012). Inter- annual rainfall variability may be caused by quasi- periodic phenomena, such as El Nino/ Southern Oscillation (ENSO), or longer –term climate shifts, such as those that caused the Dust Bowl in the American Midwest during the 1930s and have caused drought in the African Sahel since the 1970s (Brown, 2016) Precipitation is highly variable, especially when estimated over small areas and/or short periods.

Higher surface temperature leads to greater evaporation (especially over the ocean) and greater instability; therefore, the inter-annual variations in surface temperature, even if averaged across the globe, tend to be related to variations of the same sign in global precipitation. This is evident where one can easily see increases in global precipitation with El Nino, decreases with La Nina and decreases with the two volcanic events (Adler, 2017). The maximum amplitude of the ENSO-related precipitation signal comprises a larger increase over oceans and a decrease over land. Past studies have examined the responses of precipitation to temperature variations on the inter-annual time scale using both observations and model outputs (Adler2012; Liu and Allan 2012). The Global Precipitation Climatology Project (GPCP) was formed by the World Climate Research Program (WCRP) over 30 years ago to assess the long-term mean or climatology globally regionally and improve our knowledge of variations of precipitation at various time and space scales. The GPCP monthly product (Adler 2012; Huffman *et al*.,2015) is the basis for this review of the climatology and large-scale precipitation variations during the satellite era (1979–2014).

This knowledge of the magnitude of global (and large-scale regional) precipitation and how it varies on different time scales is important for many reasons, including understanding global and regional water and energy balances, answering questions related to water resources for humans and agriculture and in order to better understand how environmental changes can affect this critical parameter.Patterns of rainfall anomalies have been numerous studies (Dai*et al.*, 2015; Huang*et al*., 2015; Xie *et al*.,2010; Gu and Adler,2016). However, global estimates from GPCP with the mean impact of ENSO during the satellite era across the globe causes ENSO anomalies.

The effects of the two distinct ENSO flavours (warm SST) anomalies centred in central or eastern Pacific on precipitation are examined as well by a composite analysis (Ashok *et al*.,2017). Four individual winter seasons are chosen for the Eastern Pacific (EP) and Central (CP) Pacific events based on the seasonal mean values of the respective indices derived from an Empirical Orthogonal Function (EOF) analysis of monthly SST anomalies between 30°N and 30°S (Gu and Adler 2016). The years chosen for composites are generally consistent with those of (Yu *et al*.,2012). However, precipitation anomalies associated with CP events are relatively weak and the zone of maximum positive anomalies shifts farther west (near about 140°E), covering a large portion of tropical western Pacific. East of the Dateline, a band of negative anomalies, occupies the equatorial region with a narrow band of positive anomalies north of it, indicating a northward shift of the climatologically inter-tropical convergence zone (ITCZ) (Ashok *et al.*,2017), in contrast to the southward shift of the ITCZ associated with EP events. In the Indian Ocean and Atlantic, different spatial features can also be readily seen between these two ENSO flavours. Additional analysis of impacts of these variations of ENSO on precipitation is also noted by (Gu and Adler, 2016).

Variations of regional precipitation due to ENSO are significant, but since they are associated with an inter-annual phenomenon, these variations do not significantly affect long-term regional changes. Although the global mean precipitation (and even that averaged over land and ocean separately) has a near-zero trend, that does not mean that regional trends are zero. They are not, but it shows the regional trends of surface temperature, total column water vapour (over the ocean) and precipitation during the satellite era (Hansen *et al.,* 1999). The sea surface temperature (SST) trend pattern in the

Pacific during this recent era is different from that of a longer period back through the twentieth century, which shows more uniform warming over the ocean, although still with some variations.

Winds and rainfall over Africa depend on the relative strength of the subtropical marine and high- pressure systems. At the same time, the thermodynamic state of the adjacent Indian and Atlantic Oceans determine the moisture flux (Emmanuel and Fanan2013). Nigeria seasons are governed by the movement of the ITD, a zone where warm, moist air from the Atlantic converges with hot, dry and often dust- laden air from the Sahara desert known as harmattan wind. During the rainy season, the zone of the ITD follows the sun northward, as a result, more and more of the country comes under the influence of moisture- laden tropical maritime air. Thus, much of the country experiences a rainy season between June and September (Bamike, 2010).

2.2.9 Effects of changing pattern of rainfall on farming.

Rainfall variability is already exerting control over development progress, including efforts to address food security and poverty alleviation in sub- Sahara Africa. About 60 percent of the world and 90 percent of sub-Saharan African staple food production are under direct rainfed agriculture. As observed by FAO (2014) if we go by the predicted climate models, then in central and eastern Africa, increased yields of 10 to 30 per cent are possible if rainfall increases and improved agricultural technologies are adopted. However, even these projected increases will not be sufficient to provide adequate food for Africa's growing population. In North America, on the other hand, projections show that average rainfall in central North America will be 10 per cent lower than now. Such regional variations make it difficult to propose general strategies for adapting new agricultural technologies to combat this change.

Akanbi*et al*. (2014) noted that on the whole, in those parts of the world where water availability is set to increase due to higher rainfall, there would not be much problem. This water can be stored efficiently through check dams, bunds, ponds and reservoirs. It will help irrigation in the surrounding areas and increase crop production. Unfortunately, a good proportion of this excess rainfall comes with hurricanes and floods, doing more damage than good. This happened in 2009 in the Philippines, when two back-to-back typhoons unleashed heavy rains. Many farmers in the Philippines lack post-harvest storage and drying facilities and spread their unhusked grains on concrete streets to dry in the sun. Due to this the grain was of poorer quality and fetched lower prices. To add to it, the damage and excess rain made it impossible for them to plant the next crop. The cumulative loss as a result of these typhoons was to the tune of USD 27 million.

The uncertainties in predicting the rain, farmers now delay their time of planting. After the first or second rain, they watch the rain for some time to ensure that the rain falls regularly enough before planting. They observed this to prevent their crops from being killed when rain was delayed (Awoisika*et al.*, 2013). The rainfall changing pattern could devastate the rainfed agriculture on which so much of Nigeria’s population depends to survive. Delay of 1 or 2 weeks in the onset is sufficient to destroy the hopes of a normal harvest (Olaniran, 2001). Farmers adopt some of these methods through indigenous knowledge; planting more than one type of grain staple, mixed land use, intercropping; conservation tillage and mixed cropping; cropping pattern decision based on local predictions of climate variability; varying planting dates based on cultural models of weather; using local germ plasma highly acclimated to withstand harsh climate; and micro-climate manipulation such as afforestation, to tame the adverse effect of climate variability. The loss of agricultural production associated with background variability of rainfall is significantly higher than those associated with spectacular but localized weather- related hazards such as cyclone and flooding (World Meteorological Organization, 2010). The reliability of rainfall, particularly at critical phases of plant development, account for much of the variation in agriculture's potential.

The annual or seasonal variability is a major challenge to rain- dependent agricultural producers (Omotosho, 2010). Also,Awoisika*et al.* (2013) observed that agricultural drought occurs when supply is insufficient to cover crop or livestock water requirements. Moreso, to reduced rainfall, many factors may lead to agricultural drought, some of them not always obvious. Much more than the occasional widespread and severe climatological drought that catchesthe media attention, it is an "invisible" agricultural drought that prevents farmers at the subsistence level from achieving regular and high yields. "Invisible" drought is brought about by environmental degradation as much as by climate issues. Awoisika*et al.* (2013) noted that, adaptation strategies implementation is very important. Farmers may need to implement adaptation measures to invest in soil conservation measures to retain soil moisture. Alternatively, they can plant trees to procure some shading on the soil or resort to water harvesting technologies. On the other hand, if the condition becomes challenging, farmers may see less of a scope for investment (many advantages). They might be forced out of agriculture and migrate with very important implication in terms of livelihood.

2.2.10 Rainfall variability and precipitation effectiveness.

Variability in the timing of the rains has a significant impact on agriculture and early warning of onset and cessation is a regular request from user needs assessments in the region (Owusu *et al.*, 2017), as it would allow farmers to better manage potential risks to their planting and harvesting activity. Over Africa and Nigeria in particular, onset and cessation have generally received less attention from the scientific community than have seasonal totals (Nicholson, 2017). Mean dates and variability of the start and end of the rains over Kenya and Tanzania has been determined for the two rainfall seasons (the March-May long rains, MAM, and October-December short rains, OND). For this location, it has been demonstrated that both onset and cessation are well correlated with seasonal total and correlated with each other during the short rains but not the long (Philippon *et al*., 2015). Long rains cessation has been linked to Indian monsoon onset (Camberlin*et al.*, 2010), and long rains onset here is linked to zonal winds, with anomalous easterlies (westerlies) leading to the late (early) onset and an overall dry (wet) season..

Though the skill of onset forecasts has been evaluated for west Africa (Vellinga *et al*., 2013) and it has been demonstrated using an atmospheric model forced by sea surface temperature (SST) that the onset of the short rains is more reproducible than the long rains (Philippon *et al*., 2015), the level of forecast skill for east Africa has not been described in the scientific literature.Statistically significant correlations for the magnitude of anomalous onset and cessation are found for both seasons. Higher correlations are found for the short rains, consistent with the predictability of seasonal rainfall totals (Nicholson, 2017). They are updating the forecast with the sub- seasonal system gives slightly increased correlation over some regions, particularly over the Kenya-Tanzania border during the long and Somalia during the short rains.

According to Silvakumar (1999), it is important to determine at a reasonable accuracy the probability levels of the onset of rains, cessation of rains and length of rainy period, and their inter relationships to assist in the planning of dry land farming activities. Knowledge of the length and probable dates of the onset and cessation of the rainy season can help farmers choose the right cultivar suitable for their particular location or region (Nguyen, 2017). Research in other parts of the world has shown that farmers are interested in obtaining the dates on which they can start planting, knowing thatcrop failure is minimal (Ati*et al.*, 2016). Climate variability or fluctuations result in a decrease in agricultural output, which often results in food crises. The economic consequence of random rainfall pattern in the form of drought, flooding and storm damage is of great concern, especially in the food supply, because the effects of drought last longer than excessive rainfall (Hassan, 2013). Some of the attributes of rainfall that are important to crop production are the time of onset of the rainy season, the total amount of rainfall distribution, number of rainy days and duration of rainfall and cessation (Akanbi *et al.*, 2014).

Yahaya (2011), also noted that in agriculture, two of the most important phonological aspect of rainfall which isuseful in decision making are the onset (ϕ) and cessation (¢) of the rains. The onset of rainfall is one of the most important occurrences to the farmer; earlier onset allows them to plough land and plant earlier and benefit from the lower evaporative demand, while later onset can cause the critical plant stages that are sensitive to water stress to be aligned with months of lower rainfall and higher evaporative demand, depending on location and timing of the onset of rains.

In most countries in Africa, crop yields from rain- fed agriculture could be reduced by up to 50 % by 2020 (IPCC, 2014). When the growing period is shorter than the crop's growth cycle, from sowing to full maturity, there is loss of yield. Awoisika*et al.* (2013) observed that global warming would likely affect agricultural productivity due to the changes in the long period. They observed that the length of the growing period would increase by 10 %. Loss of yield can also occur when the length of the growing period is much longer than the length of the growing cycles (Awoisika*et al.,* 2013). Patterns of rainfall variability are not necessarily harmful, and the problem arises from extreme events and uncertainties, which derives from the difficulty of predicting the weather beyond a week (FAO, 2014). An increase in technology through a better weather forecast and farmers enlightenment can help reduce rainfall variability (World Meteorology Organization, 2010). Therefore, countries with high inter- annual variability (typically symptomatic of ENSO or longer-term climate shifts) can be expected to lag in economic development. Furthermore, the affected countries typically lack the most common response to hydrologic variability (Brown, 2016). Farmers can be more concerned with minimizing the damage to crops during periods where rainfall exceeds potential or below expectation and when rainfall distribution does not cover the length of the growing season.Therefore, it is difficult to ensure high skill in forecasting planting dates, but, when agro- meteorological information about the about the rainy season's behaviour is available, crop losses should be minimized (Silvakumar, 1999).

(Brown, 2016) carried out a study on precipitation indices in Northern Nigeria. They used six indices of precipitation cessation, onset, length of rainy season, hydrology ration, seasonality index, and occurrence of pentad spells. The analysis results showed that the rains now start late but end early,the length of the rainy season is decreasing. Therefore, the northern part of Nigeria is becoming drier as the rainy season is now spread within fewer months. Therefore, this study adopted the method used by Brown, (2016) in examining precipitation effectiveness.

2.2.11 Farmers perception and adaptation of rainfall variability effects on agriculture Smallholder farmers are sensitive to fluctuations and uncertainties of climatic conditions because of their sole dependency on rain as a key determinant of their livelihood. In sub-Saharan Africa (SSA), rainfall is the most important climatic parameter for smallholder farmers given that their farming activities are pre-dominantly rain-fed (Oloukoi*et al.*, 2016). Anuforom (2015) explain the amount of rainfall that matters and its temporal and spatial distribution that influence the planning and operations at the farm level. Stern andOloukoi*et al.* (2016) explain that mean annual rainfall determines the types of crops grown and livestock kept while rainfall variability determines the effective onset of the cropseason, the timing, length and severity of dry spells during the growing season of cultivated crops. Even with the climate change phenomenon, the average annual amount of rain in most countries in SSA remains adequate for agricultural production but most worrying is its distribution in the growing season (Anuforom, 2015). In Uganda, for example, the average annual rainfall amount is about 1,318 mm, which is adequate to support agricultural activities (Marengo*et al.,* 2017). However, the onset, cessation and distribution of rains during seasons have become unpredictable (Marengo*et al.,* 2017; Ngetich*et al.,* 2014; Mandal*et al.,* 2015). For example, the commencement of the first season in Uganda has frequently tended to shift from early March to late March or early April (Ngetich*et al.*, 2014).

Similarly, the frequency and severity of extreme rainfall related events such as droughts, heavy Studies on rainfall variability and its impacts commonly apply crop-model simulations to recommend appropriate adaptation strategies (Mandal*et al.,* 2015). However, strategies may not be properly situated in the farmers' perceptions. To cope with unpredictable rainfall patterns, farmers need to adapt their farming practices to sustain their production (Anuforom, 2015). Mandal*et al.* (2015), contends that farmers can only adapt to rainfall variability if they perceive it as a problem and an opportunity. Other studies (Mandal*et al.,* 2015;Eludoyin*et al.,* 2017) have considered farmers' perceptions about rainfall variability for comparison with meteorological data as a check on the validity of farmer perceptions. The study explores farmers' perceptions of rainfall variability as far as it affects their agricultural production. Understanding these perceptions informs farmers decision making on adaptation measures and is also the core foundation for designing acceptable interventions to adapt to rainfall uncertainty (Eludoyin*et al.,* 2017). Farmer's ability to adapt to the problem of climate variability lies to a large extent in their perception of risk and vulnerability.Ruttan (2014) noted that, the perception of climate risk and the potential benefits of taking action is an important determinant of adopting agricultural technologies. Knowing that climatic patterns are changing and poses a great deal of threat to farming, especially rain- fed farming, is the foundation of better adaptation. Ruttan (2014) stated that it is expected that improved knowledge and farming experience will positively influence farmer's perception and decision to take up adaptation measures.

2.2.12 Some major crops in Benue State

Cassava (*Manihot esculenta crantz*) is grown in many tropical countries of Africa, Asia and Latin America For chips, broken dried roots, meal, flour and tapioca starch, dried cassava roots and meal which are used as raw materials for compounding animal feeds, while cassava starch is used for industrial purposes; and grocery tapioca is used solely for human consumption (Yahaya, 2011).In Nigeria, cassava is grown in all the ecological zones. It is planted all year round, depending on theavailability of moisture. The peak of the planting period is April to May. A mixed cropping system is the mostpractised method of cassava production. It is important not as a food crop but as a majorsource of income for rural households. Nigeria is theworld's largest exporting country of dried cassava, with 77%of world export in 2005 (FAO, 2014). In Benue State, cassava production records show that the total number of farm families involved in the production is 413159 (FAO, 2014). The area of land devoted to the production of this crop is 268.11 ('000 Ha), and a total output of 3533.69 ('000 metric tones) (BNARDA, 2013). By zone, the North Central Zone produces over 7million tons of cassava and yam a year, south –South produced over 6million tons of cassava a year, while the South West and South East produce less than 6million tons a year. The North West and North East produce less than 4million tons a year, respectively (Bello, 1998).Benue, Kwara,Kaduna and Kogi states in the North Central zone are the largest producers of tuber crops(BNARDA, 2013).

Yam (*Dioscorea*spp.) is also a staple food crop in Nigeria. It is cultivated mostly in the Derived and Southern Guinea Savanna of the country. Nigeria is by far the world's largest producer of yams, accounting for over 70–76 percent of the world production. Although it is grown widely in Nigeria, the area where it is grown most is the Benue State (land area of 802,295 km^2), one of the states in Benue valley of Nigeria where the labour-intensive practices are still the norm, and the land holdings are small. In this state, especially among Tiv people, the size of the yam farm or the tonnage of yams produced becomes the social status of that farmer (BNARDA, 2013).Because of a high level of yam production in the State of Benue, Benue State is crowned as the ‘Nigerian Bread Basket’. Yams are planted on mounds rather than flat slopes depending on the soils’ hydromorphic nature, which are generally of loose soil suitable to grow roots and tuber crops(BNARDA, 2013). While yam production issues have been stressed on agronomical practices, a research study carried out on the economic efficiency of this crop grown in this region with small farm holdings, which is labour-intensive, reveals that land, labour and material (fertilizers and chemicals), credit and extension services inputs have a significant bearing on the yield of yam in the region. Yam is in the class of roots and tubers that are a staple of the Nigerian and West African diet, which provides some 200 calories of energy per capita daily (Ojo, 2015). In Nigeria, in many yam-producing areas, it is said that "yam is food and food is yam". However, yam production in Nigeria is substantially short and cannot meet the growing demand at its present level of use. It also has an important social status in gatherings and religious functions, assessed by the size of yam holdings one possesses. Yam is grown on free- draining, sandy and fertile soil, after clearing the first fallow. The land is prepared in the form of a mound or ridge or heap of one-metre height.

The tuber is the main part of the yam plant, which has highcarbohydrate content (low in fat and protein) and provides a good energy source. Unpeeled yam has vitamin C, sweet in flavour, is consumed as boiled yam (as a cooked vegetable) or fufu or fried in oil and then consumed. It is often pounded into a thick paste after boiling and is consumed with soup. It is also processed into flour for use in the preparation of the paste. Its medicinal use as a heart stimulant is attributed to its chemical composition, which consists of alkaloids of saponin and sapogenin. Its use as an industrial starch has also been established as the quality of some species can provide as much starch as in cereals (Yahaya, 2011).

Rice (*Oryza sativa*) is an increasingly important crop in Nigeria. It is consumed more than half of the world's population. Rice is the world`s second most popular crop after maize. The position acquired by rice is attended by great demand on the Nigerian market. The agriculture sector is the third- best valuable business in the world. Technology and Oil and Gas Industry cannot feed the population, while crops can do that. Therefore, rice production in Nigeria, one of the most popular products in the country, promises to be successful.Statistically, Nigeria is the highest importer of rice globally and the largest producer in West Africa (IRRI, 2011).

The main rice- producing states in Nigeria is; Benue, Ebonyi, Kaduna, Kano, Niger, Taraba and Borno. Others states includes Enugu and Cross River (FAOSTAT, 2012). It is a staple food in the country and the most widely consumed, it is 3rd highest global food production, after sugarcane and maize. It is a cereal grain that grows in swampy areas, in regions with high rainfall but can still be grown in areas with little rainfall through the use of water-controlling terrace systems; it's sensitive and requires a lot of care and attention to grow well.Rice cultivation can be done by transplanting or direct seeding; the seeds are sprayed onto the soil after which it is ploughed into the soil by using a plough before cultivation, therice seeds is soaked in water for 34 hours and allow drying for 24 hours after which it is ready for cultivationOkorie (2014).It takes about 120-200days after planting, depending on the areas and other factors for the grains to get ready for harvest; when it is ready, the grains falls off upon the stalk changing from green to golden-yellow.The water contained in the rice paddies is allowed to dry and evaporate before harvesting properly and let the rice ripen well.The rice is then harvested by cutting the stalk directly beneath the heads and the grains separated from the stalk by a mechanized thresher.Rice is one of carbohydrate- rich foods source in Nigeria and most African countries as well, and can be cooked in various ways and still be appetizing and nutritious, some of the delicacies include jollof rice, fried rice, coconut rice, ofada rice with stew, soup or sauce and in few cases as a rice pudding.

Maize (*Zea mays*) (also known as 'corn' in some countries) is one of the Nigeria's most common and important food crop. It is widely eaten in various forms, and Maize farming is a high-potential opportunity for Nigeria and its people, especially those who are willing to learn how to turn a business idea like this to wealth (BNARDA, 2013). Maize is perhaps the most common food crop in Nigeria, and also the most important as it is eaten in various dishes and forms the basis for most of the meals prepared by the average Nigerian family. Corn is a crop cheaper than rice and wheat, two of the other most consumed cereals, and this affordability makes maize hugely popular. The savvy agribusiness investor stands to make a sizeable amount of money through commercial maize farming. Maize, also known as corn, is one of the farm produce that gives an incredible return on investment, as one seed of planted maize could return more than 500 kernels of corn come harvest season. A little monetary investment in corn farming can therefore yield a sizeable level of income and profit after a little while.

Maize matures very fast. Between planting and harvest time, a farmer needs to wait only between 3 or 4 months. Therefore cultivating just 5000 kernels of corn, a farmer can harvest not less than 2.5 million kernels of the same maize in less than 120 days. Maize is a hardy plant and is one of the few crops that can grow on a vast array of soils and survive in different climatic conditions. It needs sunlight to prosper, and Nigeria is a country blessed with abundant sunlight; maize can therefore be grown successfully in almost every state of the country.

Maize remains a key food crop in Africa, Latin America and Asia. It is primarily used as human food; in developed countries, maize is one of the most important raw materials for animal feed production and biofuels. Maize also forms the basis for the production of most animal feeds in Nigeria. Without it, the livestock farmerwill probably be unable to rear his livestock. The production of meat, eggsanddairy products (like milk and yoghurt) would be difficult without maize, which is a hugely important ingredient in animal feed.To begin any planting of maize, a farmer first has to find suitable and arable land. While it is a hardy plant grown almost anywhere, corn grows best in rich loamy or sandy-loamy soil. Such soil also has to be a well-drained area and situated on a fairly flat landscape.Maize does not do well in waterlogged areas, so if a farmer has to use a piece of land that is not well- drained, there is a need to make ridges or mounds to protect the crops from waterlogging.There are three major markets for maize and its allied products in Nigeria, Corn for Human Consumption**,**Corn for animal feed and corn for Industrial Consumption (BNARDA, 2013).

Soybean (*Glycine max*) is an important source of high quality and inexpensive protein and oil. It is a cheap protein-rich grain that contains 42.8% high- quality protein, 22.8% edible vegetable oil, 33% carbohydrate and a good balance of amino acids (IITA, 2012). In addition,soybean oil is 85% unsaturated and cholesterol- free compared with other legumes and other animal sources. This indicates that the crop has a tremendous potential to improve the families of resource- poor farmers (Adesina, 2014). Soybean is also medicinal and is extremely useful for the treatment of malnutrition, particularly among children, and in the fight against diseases such as heart disease, cancer, diabetes, high blood pressure, stroke, ulcer as well as the loss of body mass among people living with HIV/AIDS (Fabiyi, 2013). The promotion of soybeans is valuable in countries such as Nigeria, where high-quality protein sources are too expensive, and the purchasing power of a large percentage of the population is low. Nigeria is Africa's leader in soybean production (IITA, 2012). Benue State is the largest producer of soybeans in Nigeria, accounting for 175000 metric tons of the estimated national production of 437000 metric tons in 2007 (IITA, 2012). Soybeans are used for human consumption as well as animal feed. It is also used in the industries as an anti-corrosion agent, core oil, and bio-fuel due to less or no nitrogen element in the oil, and as a disinfectant, in pesticides, printing inks, paints, adhesives, antibiotics and cosmetics (Ngalamu, 2012).

Groundnut or Peanut (*Arachis hypogaea*) is a major crop grown in Nigeria's arid and semi-arid zone. It is either grown for its nut, oil or its vegetative residue (haulms). Recently, groundnut meal is becoming more recognized as a dietary supplement for children on protein poor cereals-based diets and as an effective treatment for children with protein related malnutrition. It is the 13th most important food crop globally and the 4th most important source of edible oil. Its seeds contain high- quality edible oil (50 %), easily digestible protein (25 %) and carbohydrates (20 %) (FAO, 2014). The crop is mainly grown in the northern part of Nigeria. Over 85 % of the groundnuts produced in the country are from Kano, Kaduna, Taraba, Benue, Bauchi, Borno, and Adamawa states (Ngalamu, 2012).The long-term mean climate state strongly influencesthe nature of the farming system in any particular location, the experience the infrastructure of local farming communities aregenerally appropriate to particular types of farming practices and to a particular group of crops known to be productive under the current climate.

Changes in the mean climate away from current states may require adjustments to current practices in order to maintain productivity, and in some cases, the optimum type of farming system may change. According to Fakoredeet *al.* (2016), water availability is the most critical factor for sustaining crop productivity in rain-fed agriculture. Even if a drought-tolerant trait is introduced, water is not available to crops when there is no water in the soil. Rainfall patternfrom season to season greatly affects soil water availability to crops and poses crop production risks. Fakorede(2016) noted that crop cultivations should be situated in areas with high rainfall with low variability; however, subsistence farming can be found in a wide range of environmental conditions from very suitable to marginal lands. The pattern in seasonal rainfall (the accumulated amount of rainfall from the planting to the harvest of a crop) is higher in the smaller rainfall areas. Overall, about 37% of maize-growing areas in the Sub-Saharan Africa (SSA) region are located in areas with the coefficient of variation (C.V) of seasonal rainfall higher than 0.2 (Fakorede, 2016).

Different crop yields keep decreasing worldwide, and climate variability, especially rainfall, is considered a major cause. Govinda (2013) observed that rice yield in the northern Darchula district of Nepal decrease with a decrease in rainfall amount. Vaidah (2015) observed that yield is projected to decrease across Africa due to climate change, especially sugar cane, sweet potato, maize, rice, and cassava production in terms of crops. International Plant Protection Convention Project stated that without appropriate adaptation, Africa could witness up to a 40 % decrease in cereal production by 2050. Ayanlande (2012) noted that inter- annual rainfall pattern had been the key climatic element that determines the success of agriculture in Guinea Savannah’s ecological zone of

Nigeria. Climate variability has been the most important determinant of crop yields in Nigeria and other parts of West Africa (Awoisika et al., 2013).

2.3 Empirical Studies

Hence it becomes important to have an in-depth knowledge of the effect of rainfall variability on crop yields in Benue State, which will help in agriculture decision making and meeting the food needs.Different studies for individual countries and on the global scale also found that recent trends have decreased different crops as observed among the top three rice and wheat- producing nations, witnessing very low yield growth rates (Gleeson, 2012). China, India and Indonesia are witnessing rice yield increases of only 0.7 %, 1.0%, and 0.4 % improvement per year. China, India, and the U. S., the top three wheat producers, similarly witness yield increases by 1.7 %, 1.1%, and 0.8 % per year, respectively. At these rates (Gleeson, 2012) found that yield driven production growth in India and China could result in nearly unchanged per capita rice harvests, but decline steeply in Indonesia. Gleeson (2012) also noted that maize, rice, or wheat yield improvement rates are below the 2.4 % doubling rate in many smaller crop producing nations. Unfortunately, a high percentage of total calories consumed in these countries are from these four crops. This is particularly true for maize throughout much of Africa (especially in Kenya, Zambia, Zimbabwe), Central America (especially in Guatemala, Nicaragua, Panama), and parts of Asia (Nepal, Georgia).

Anuforom (2015) observed that despite great advances made in the understanding and dealing with the problem of rainfall variability impact on crop yield at the international level, awareness and concern for the problem at the national and local levels remain poor or, in some cases, non- existent. Without knowledge and awareness of climate variability and its possible effects on agriculture, there will be little or no adaptation strategies to cope with the challenge. Akpenpuun (2013), in his study of the impact of crop yield in Kwara State showed that variation in the tuber crop yields in the State could be attributed to climate variation.Emmanuel and Fanan (2013) also found out that rainfall is highly variable in Makurdi and maize yield. They reviewed further that changes in onset and cessation are the main reason for maize yield decline in Makurdi.Oruonye*et al.* (2016) were able to show by experiment that yield is proportional to transpiration under the steady condition when water is a limiting factor. He concluded that crop yields depend on agro – climatological factors the state of crop and technology. This finding was supported by Fatuase and Ajibefun (2013). They emphasized that the variability in crops yield from year to year for different areas suggests that climate partly controls yields.World Meteorology Organization (2010) pointed out that the relationship between rainfall and crop yields are complex. The organization emphasized that rainfall (of whatever degree) is important, but its influence at one period depends on moisture conditions.

Traore *et al.* (2013) noted that rice provides 19 % of dietary energy globally. Rice provides a higher percentage of total calories consumed in countries like the Dominican Republic, Costa Rica, Haiti, Sierra Leone, Nigeria, and North Korea. Yet yields are declining from −0.1 % to −3.2 % per year. In some of the worlds top rice producers, such as India and China, the per capita production may remain nearly unchanged. In numerous smaller rice producers across the world where rice is an important significant provider of daily dietary energy such as in Peru, Ecuador, Bolivia, Benin, Togo, Myanmar, Philippines, Malaysia, South Korea, Nepal, and in Sri Lanka, the per capita production may also remain unchanged.

Motzke (2012) noted that wheat provides 19 % of global dietary energy. Wheat comprises an even larger portion of the diet in some countries where yields are declining due to climate change, particularly in Eastern European countries of Bulgaria, Hungary, Czech Republic, Moldova, Romania, Slovakia, and Ukraine. In many countries, such as Bolivia, Peru, Paraguay, Afghanistan, and Iraq, wheat yield increases are too low to maintain their current per capita harvests. Clearly, the global crop yield trend is affected by climate change; hence the world faces a looming and growing agricultural crisis. Yields are not improving fast enough to keep up with projected demands in 2050 (Huybers*et al*., 2016). Zampieri *et al.* (2017) found that a linear correlation between total global wheat production and globally averaged explained 42 % of the total variability in wheat production. Variability in national crop yields was strongly associated with heat anomalies in Central Europe, Russia, Argentina and Southern Canada. Yield anomalies in the Mediterranean region and Central Asia were strongly associated with drought, while water excess was more relevant for Northern and Western Europe and humid tropical regions. Furthermore, the authors found that the effects of heat are comparable or even larger than the effects of water stress for most countries.Barlow *et al.* (2015) observed that approximation of heat and water stress effects on crop yield by a single combined stress indicator is a strong simplification of reality. The range of the optimum, and sub-optimum and critical high and low temperatures, varies considerably both between processes and crop development phases of wheat. Relatively warm conditions are required for germination, followed by low temperatures in the vegetative development with increasing temperature optima in subsequent development phases. The impact of temperature anomalies in a specific year on wheat yield also depends on how well the long-term mean conditions in the analysed region fit the optimum ranges. While a relatively good agreement between long-term climate and optimum conditions can be expected in highly productive regions like Western Europe, poor agreement in regions with marginal production can result in a higher sensitivity to climate anomalies in specific development phases.

Additionally, the sensitivity of crop yield to temperature and moisture anomalies also depends on the specific processes and yield components affected. Suboptimal or critical conditions tend to have large impacts on crop yield in the period around anthesis (Rezaei *et al.*, 2015). Suboptimal conditions in early development stages can be partially or completely compensated by many different mechanisms when the growing conditions in subsequent development phases are favourable.Webber (2017) used theprocess based crop models method to quantify the effect of climate variability on crop yields by applying process- based crop models. These models are usually based on known causal relationships between model input data such as climate and processes affecting output variables such as crop yield. The representation of the effect of extreme temperatures on crop growth and yield remains challenging particularly for models applied at a large scale. Interestingly, a recent study on the impact of weather on yield anomalies in wheat and maize- based on gridded crop models at the global scale found that water limitation is a major driver of the observed variations in most countries *(*Dinesh, *et al.*,2015*).* This contradicts the results obtained by Zampieri *et al.* (2017)suggesting that heat stress is often the most important predictor, generally as important as drought. Results of studies based on the use of empirical, statistical models and process- based crop models should therefore be compared systematically to initiate a learning process, reduce uncertainties and improve the respective approaches.

Bekele *et al.* (2017) noted that indigenous perception is the basis for local- level decision making in many rural areas. It has value not only for the culture in which it evolves, but also for scientists and planners striving to improve the condition in rural localities. Farmer's methods and perception of climate variability will be a great input to solving the puzzle of adaptation which is usually top-bottom approach despite the significant role played by the indigenous perception in different areas of climate change still traditional perception is usually neglected in academic, policy and public dialogue (Challinor*et al*. 2011).Bekele *et al.* (2017), in theirstudy used the participatory approaches to assess vulnerability to climate variability and adaptation should be looked at from the view of farmers. This is the same approach adopted for this study. All through time, it is the indigenous knowledge that has helped farmers kept hope in a changing climate.

According to Bekele *et al.* (2017) indigenous knowledge has, over time immemorial, played a significant role in solving problems related to climate variability. Local farmers may not understand the science of climate variability, but they lightly observe and feel its effects. Bekele *et al.* (2017) noted that some farmers responses demonstrate appreciable knowledge of global climate changes.Based on climate-crop modelling over Nigeria has employed different approaches. Some studies (Ajetomobi, 2010) used statistical modelling techniques to investigate the relationship between crop yields and climate (rainfall and temperature) variability over the country. Ayanlande (2012) applied a Geographical Information System (GIS) and remote-sensing approach to study the inter-annual changes in (tuber) crops in response to rainfall and temperature variability between 1970 and 2000 over the Guinea Savanna ecological zone of Nigeria.

Adejuwon (2011) adopted erosion productivity impact calculator (EPIC) to forecast present-day and future crop yields of some staple food crops over Nigeria as a case study for sub-Saharan West Africa. However, while statistical models and GIS approaches are suitable for operational purposes, they cannot adapt to different conditions over time and space, hence not suitable for research purposes. On the other hand, EPIC requires too much complex input data that are difficult to obtain for operational purposes over Nigeria (Adejuwon, 2011). Therefore, the present study applies a crop model (General Large Area Model, hereafter GLAM) suitable for both operational and research purposes in Nigeria, because GLAM uses relatively low input data to estimate crop yields over large areas (Challinor *et al.*, 2011).

RezaeI *et al.* (2015) observed that *significant* climate conditions such as temperature, precipitation, sunshine and wind could influence and quicken their distribution.Their increase can lead to a serious decline to crop yields.IPCC (2014) suggests that crop production worldwide, especially in the Sahel region is expected to be badly affected byclimate change i.e. rise in temperature, droughts and erratic rainfall. Global warming and consequently, unexpected weather variability can be harmful to the agriculture sector through its negative impact on plant growth and development.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Preamble

The quantitative evaluation of rainfall variability and selected crop yields in Benue State Nigeria wereobtained from different data types. The data weresourced through different methods, to achieve the objectives of this research work; the data was subjected to the appropriate statistical analysis.

3.2 Sources and Types of Data

Data were obtained from both primary and secondary sources.

3.2.1 Primary data

The primary data were obtained through the administration of questionnaires to farmers in the study areas. Twelve of the Local Government Areas in the State were selected (Ushongo, Kwande, Gboko, Tarka, Makurdi, Ohimini, Ukum, Ado, Gwer-East, Gwer-West, Vandeikya and Otukpo) two from each Zone where agricultural activities is at maximum. The zones include the EasternZone (Ushongo, Vandeikya, Ukum and Kwande), Northern zone (Gboko, Makurdi, Gwer-West and Tarka) and Southern Zone (Ado, Ohimini, Gwer-East and Otukpo), respectively.

Twelve out of the twenty- three (23) Local Government Areas were selected based on theyields of the crops under study (Appendix b-g). Four LGAs each from each of the Agricultural Zone of the State where the crops under study have been produced commercially; that is, Eastern Zone (Ushongo, Vandeikya, Ukum and Kwande), Northern

Zone (Gboko, Makurdi, Gwer-West and Tarka) and Southern Zone (Ohimini, Ado, Gwer-East and Otukpo) respectively.

Each LGA was further divided into six (6) extension blocks (districts in each LGA) where selected crop yields under study are maximum, which makes 36 extension blocks. Four (4) farming communities were randomly selected from each extension blocks,making 72 communities. For each farming community, with the assistance of BNARDA local extension workers, a compilation of list of crop farmers was also be required, and ten (10) crop farmers were randomly selected, which resulted in a sample size of seven hundred and twenty (720) food crop farmers.

3.2.2 Method of questionnaire administration

A total of 240 questionnaires were administered each zone and 60 in each LGA making a total of 720. These structured questionnaires were used to generate data in the study area. The information gathered were on the socio- economic characteristics of the respondentsand the adaptation strategies adopted. The data was collected with the assistance of three extension workers from BNARDA.

3.2.3 Secondary data

On the other hand, the crop data were obtained from the institutions that are responsible of keeping records of rainfall and crop yield. The yield and rainfall data from 1988 to 2017 of Benue State were used in the study. The data on crop yields were obtained from the Benue State Agricultural and Rural Development Agency (BNARDA). The thirty (30) years data was obtained from the annual collation of data base on agricultural production from different Local Government Areas of Benue State through Benue State Agricultural and Rural Development Agency. The data comprised of the total area cultivated in a year, the total yield in metric tons in a year and the total yield by the area cultivated.

The rainfall data was based on CMAP data from 1988 to 2017 across the twelve LGAs under study. CMAP data were downloaded from the Mirador website (http:/mirador.gsfc.nasa.gov/). The rainfall time series for the study areas were extracted using GrADS (Grid Analysis and Display System) software. The datasets can also be accessed through File Transfer Protocol (ftp:cmapopen.gsfc.nasa.gov/pub/merged).Grid rainfall from CMAP data with a spatial resolution of 0.25^0 and over regions between 50^0 N and 50^0S.The data on crop yields were obtained from the Benue State Agricultural and Rural Development Agency (BNARDA). The thirty (30) years data were obtained from the annual collation of data base on agricultural production from different Local Government Areas of Benue State through Benue State Agricultural and Rural Development Agency. The data comprise the total area cultivated in a year, the total yield in metric tons in a year and the total yield by the area cultivated.

3.3 Methods of Data Analysis

3.3.1 Examination of rainfallvariability in different LGA of Benue State.

To examine rainfall variability in different LGA of Benue State, the following indices were used.

i. Coefficient of Variation (CV): Measure of relative variabilitythatcomprises mean and standard deviation were used to determine the rainfall variability. The rainfall variability was examined using the Coefficient of Variation CV which is given as.

$$\mathrm{CV} = \left[\frac{SD}{\overline{RF}}\right] \times 100\% \qquad 3.1$$

Standard deviation (sd) is defined by

$$\mathrm{SD} = \frac{(RF - \overline{RF})}{N}$$

where RF = the annual rainfall for a given period

$\overline{RF}$= the average annual

N= number of variable

ii. Precipitation Variability index (PVI)

This model (Precipitation Variability index) is a modification of the precipitation periodicity index (PPI) developed by Hassan (2013).It can be expressed as:

$$\mathrm{PVI} = \left(\frac{A}{Y} - \frac{B}{Y}\right) 100\% = \frac{Hd}{M} - \frac{Ld}{My} \qquad 3.2$$

Where PVI is Precipitation Variation Index

Hd= highest daily rainfall in a given month

Ld= lowest daily rainfall in a given month

M= Total monthly rainfall

My= Total monthly rainfall* Total annual rainfall

PVI is an improved version of the Precipitation Periodicity Index (PPI) developed by Hassan (2013). This model can explain the tendency of drought in a given rainy season. It has three threshold levels that explain the region's variability in dryness and vulnerability to drought. That is

Table 3.1 Precipitation Periodicity Index (PPI)

S/No	Precipitation periodicity Index	Implication
1	≤ 20%	Least variability
2	≥20% but ≤30%	Moderate variability
3	≥30%	High variability

Source: Adapted from Hassan (2013)

1. is a normal distribution rainfall with adequate moisture for the cropping period
2. is a moderate rainfall distribution with enough moisture but may require some measure of moisture supplement during the cropping season
3. It is prone to dry spells during the cropping season,requiring some form of irrigation to compliment the rain waters.

3.3.2 Assessment of the trend of some selected crops.

To establish trends analysis of the selected crops yield which are; cereal (maize and rice), root and tuber (cassava and yam), and legume (groundnut, soyabeans) in the study area, the Mann-Kendall test(Mann, 1945; Kendall, 1975) model modified by Yue (2014), was usedin conducting a trends in time- series data to determine trend analysis. According to Yue (2014) test, the trend line will show the basic long- term underlying pattern.

Let $x_1, x_2 \ldots x_n$represent n data points where $x_j$represents the data point at time j. Then the Mann-Kendall statistic (S) is given by

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sign(x_{j-} x_k) \qquad 3.3$$

$$\text{VAS (S)} = \frac{[n(n-1)(2n+5) - \sum_i^m = 1 \; ti(ti-)(2ti+5)]}{18} \qquad 3.4$$

Where:

n = the number of data points

ti = the number of ties for the i value

m = the number of tied values (a tied group is a set of sample data having the same value)

$$Z = \begin{cases} \frac{S-1}{\sqrt{VAR(s)}} = ifs > 0 \\ 0 \qquad = ifs = 0 \\ \frac{S+1}{\sqrt{VAR\ (s)}} = ifs < 0 \end{cases} \qquad 3.5$$

The test statistic Z\were also used to measure the significance of the trend. This test statistic can be used to test the null hypothesis, H0. If | Z| is greater than Zs/2, where α represents thechosensignificance level (example: 5% with Z 0.025 = 1.96) then the null hypothesis is invalid the trend is significant.The trend is decreasingif Z is negative and the computed probability is greater than the significance level. The trend is **i**ncreasingif the Z is positive and the computed probability is greater than the significance level. If the computed probability is less than the level of significance, there is no trend.

3.3.3 Assessment of the effects of rainfall characteristics on some selectedcrop yields

To analyse the indices of rainfall (onset, cessation and length of rainy season) Olaniran (2001). This can be expressed as

$$OD = \frac{D(50.8-F)}{R} \qquad 3.6$$

Where OD is the onset date

D= number of days in the first month with effective rainfall

F = the accumulated rainfall totals of the previous month

R= the total rainfall in the month with effective rain

The same formula was applied calculate the rainfall cessation, but the monthly rainfall value is accumulated from December backward. The month that has accumulated rainfall totals equal to or exceeds 50.8 mm then becomes the end of the rainy season.

Partial Correlation $$r_{xy.z} = \frac{r_{xy} - (r_{xy}\, r_{yz})}{\sqrt{(1-r_{xy}^2)(1-r_{yz}^2)}} \qquad 3.7$$

Where $r_{xy}.z$ indicates the correlation coefficient for x and y controlling for z

With the use of the Statistical Package for Social Sciences, SPSS Partial correlation analysis was used to determine the effects of onset and cessation on crop yield in Benue; hence the effect of other variables is controlled. The significance of the partial correlation coefficient is determined in the same manner as for bivariate correlation. The only difference is that with three variables, the degree of freedom V = (n-3). For four variables it would be (n-4).

3.3.4 Delineation ofproper agro-climatic zones in the study area.

In order to delineate the zones into proper agro-climate areas, the Precipitation Variability Index PVI was used. The index was obtained from the lowest monthly, the highest monthly and the total annual rainfall data in percentage. This index is computed using:

$$\text{PVI} = \left(\frac{A}{Y} - \frac{B}{Y}\right) 100\% = \frac{Hd}{M} - \frac{Ld}{My} \qquad 3.8$$

The total precipitation variability index in each of the zones was computed to derive the means of the PVI for each of the zones. The derive means were utilized to acquire the total means of the zones for climatic zoning of the study area. This index is used to determine the magnitude of zonal rainfall variability (Hassan, 2013) and has the following threshold classes:

i. PVI ≤ 20% = Least Variability

ii. PVI ≥20% ≤ 30% = Moderate Variability

iii. PVI ≥30% = High variability

The quality or state of being periodic is the recurrence at regular intervals of variation in precipitation. The measure of periodicity is the frequency at which drought can occur which is called Hydrological Drought.

3.3.4.1 *Climatic and crop zone map.*

In creating a climatic zone map of the study area and crop zone, the calculated means of the zone of the study were imported to Arcmap 10.2 through linking of spatial and non- spatial data tool in the Arc tool box. In order to carry out this activity, the shapefile of the study and zone area was added through the arc-catalogue toolset. The data were reclassified into three zones as least variability, moderate variability, high variability, and the map were customized along with exportation for analysis. In other words, the crop of interest in the study area are yam, maize, soyabean, rice, groundnut, and cassava, were linked with spatial data on Arcmap 10.2. to create a crop zone map.

3.3.5 Adaptation strategies for optimum crop yield in the study area.

The number of farmers included in the study (participants) was determined using Yamani (2016) formula. This formula is concerned with applying a normal approximation with a confidence level of 95% and a limit of tolerance level (error level) of 3.5%.

To this extent the sample size were determined by $n = \frac{N}{1+Ne^2}$ 3.9

Where:

n = the sample size

N = population

e = the limit of tolerance (0.035)

$$\text{Therefore, } n = \frac{6600}{1+6600(0.035)^2} = \frac{6600}{1+6600(0.001225)} = \frac{6600}{1+8.085} = \frac{6600}{9.085}$$

n = 726 respondent.

The study respondents were 726, and simple random sampling was used to distribute the respondents' questionnaires. Random sampling was used to select the sample for this study reducing bias or human interference. The reason was to select cases that are informative and assumed to be familiar with some fundamental issues concerning the socio- economic impacts of the study areas. Seven hundred and twenty questionnaires were returned, and the analysis was carried out based on these returned questionnaires. Descriptive statistics were used to analyse the data obtained from questionnaires and surveys of farmers. The data was presented using frequency, tables, percentages, charts, and figures.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSIONS

This chapter presents the results and discusses the various findings in the study. Among issues presented are:

4.1 Precipitation Variability Index (PVI)

Following objective one, Precipitation Variability Index for each Local Government in Benue State for the three zones was calculated, and the results are presented in thefigures below. For clearer understanding and ease of interpretation, PVI distributions are presented in months for each Local Government Area. This indicates months with a high or low tendency of moisture stress or drought. The PVI is presented in percentage of drought tendency in the study area. It gives more insight into water moisture requirements for agriculture more than the monthly total, mean annual precipitation. The precipitation variability index deals with daily rainfall in relationship with the monthly total and annual mean. This allows us to understand tiny details that could otherwise be lump up in sum and means of precipitation. It is a known fact that the average annual or seasonal rainfall at a place does not give sufficient information regarding its capacity to support crop production. Daily, monthly and Seasonal rainfall pattern does.

4.1.1 Precipitation variability indexes in northern zone of Benue State

The Northern Zone covers four LGA’s under study which includes Makurdi, Gwer-West, Tarka and Gboko

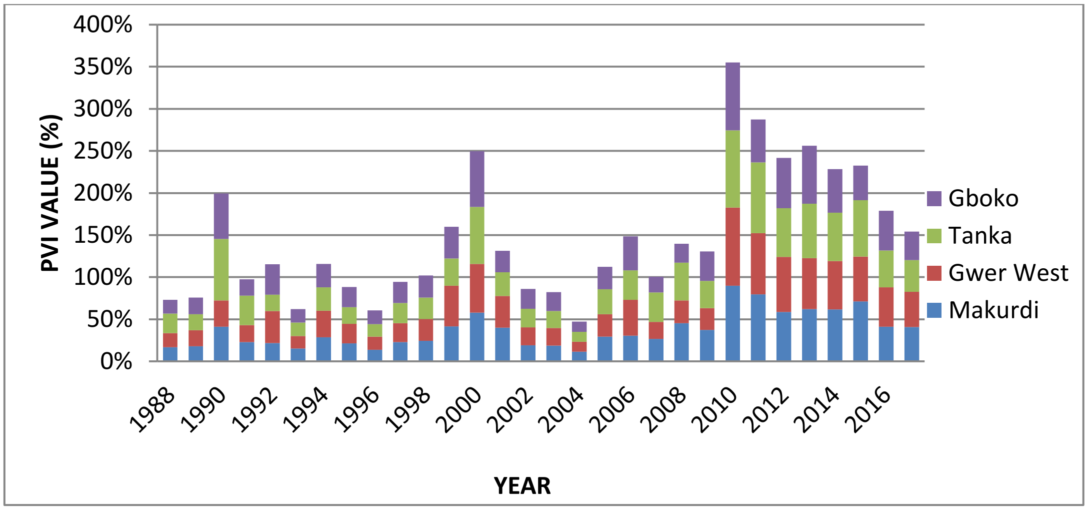

Figure 4.1 PVI for April in Makurdi, Gwer-West, Tarka and Gboko L.G.A (Northern Zone)

It was revealed from figure 4.1 that the Precipitation Variability Index of April for the years 1988-2017 shows only a few years of 1988, 1989, 1992, 1993, 1994, 1995, 1996 1997, 1998, 1999, 2001, 2002, 2003 and 2004 in Makurdi, Gwer-West, Tarka and Gboko L.G.A have PVI of less than 30 %, this is an indication of moderate PVI with a tendency of dry spells. All other years have PVI of more than 30 % in Makurdi, Gwer-West, Tarka, and Gboko L.G.A, especially, 1990, 2000, 2005, 2010, 2011, 2012, 2013, 2014, 2015, 2016 and 2017, which is an indication of insufficient moisture content which may not favour farming activities.

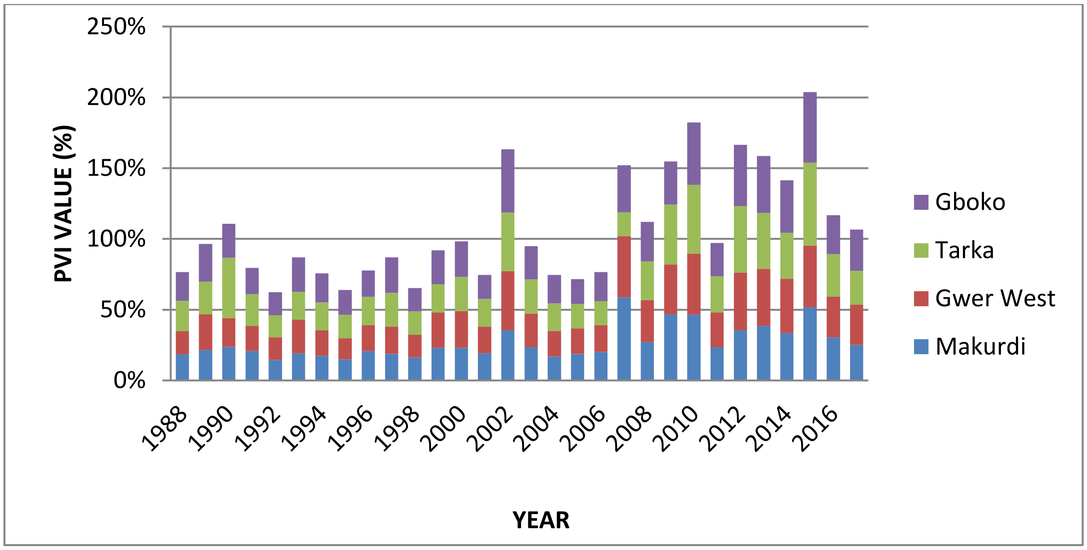

Figure 4.2 PVI for May in Makurdi, Gwer-West, Tarka and Gboko L.G.A (Northern Zone)

It was observed from Figure 4.2 that the Precipitation Variability Index of May for the years 1988-2017 showsthe month of May shows the distribution of moisture content with a high tendency of drought in Tarka in 1990, 2002, 2009, 2010, 2012, 2015, and in Makurdi, Gwer- West, Gboko in 2007, 2008, 2009, 2010, 2012, 2013, 2014 with PVI of above 30 %..The year 1988, 1989, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, and 2001 have PVI values ofbetween 10 % -20 % for all the four LGA. This shows that the drought index in May is quite low; thus, farming activities enjoyed moisture content

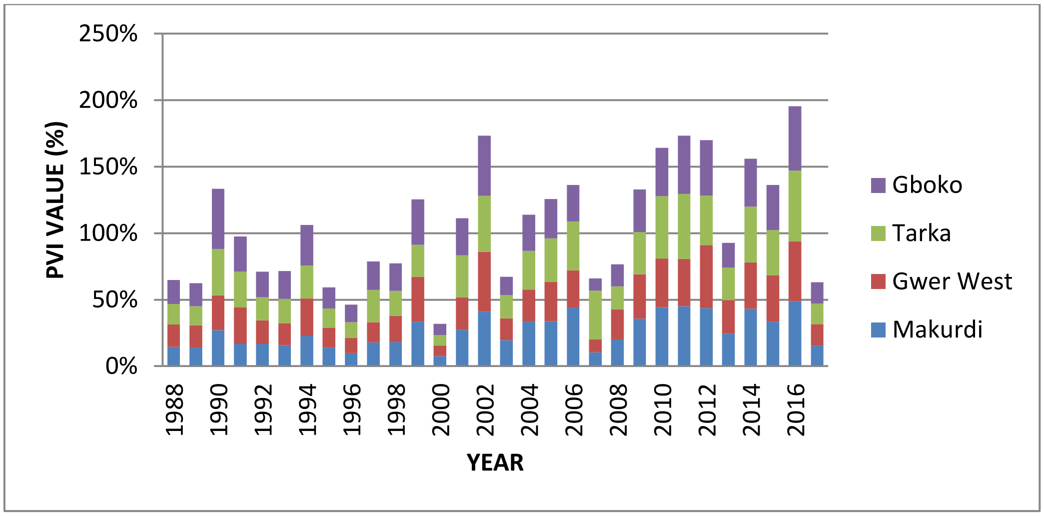

Figure 4.3 PVI for June in Makurdi, Gwer-West, Tarka and Gboko L.G.A (Northern Zone)

It was observed in Figure 4.3 that Precipitation Variability Index values for June in Makurdi, Gwer-West, Tarka, and Gboko from 1988- 2017 showthe year 1988, 1989, 1991, 1992, 1993, 1995, and 1996 are the only years with PVI below 20 % in all the four LGAs in the Northern Zone.This means that these years had the least variable moisture. While the years 1990, 1994, 2001, 2004, 2006 and 2008 for Gwer- West had PVI of more than 20 % but less than 30%, indicating moderate variability of moisture content. While the year 1990, 1999, 2002, 2005, 2009, 2010, 2011, 2012, 2014, 2015, and 2016 for Makurdi, Gwer-West, Tarka, and Gboko have PVI above 30 %, which signifies the month with high moisture variability

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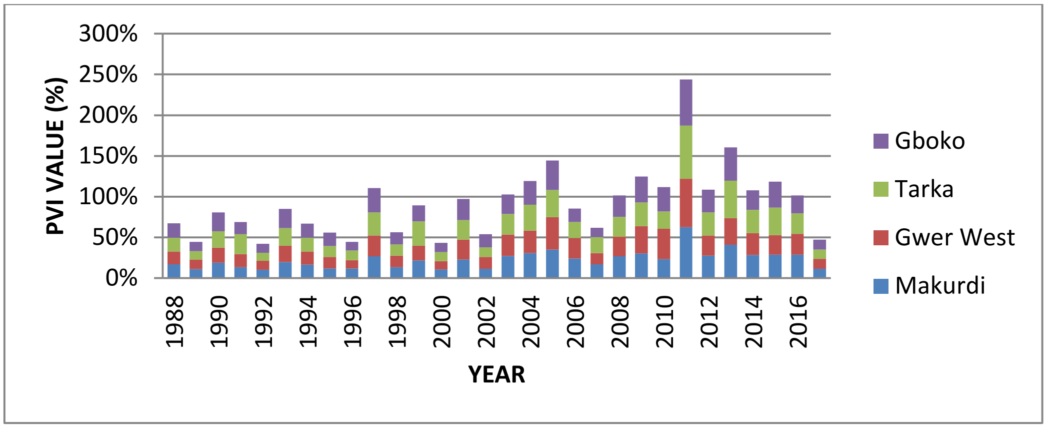

Figure 4.4 PVI for July in Makurdi, Gwer-West, Tarka and Gboko L.G.A (Northern Zone)

It was observed in Figure 4.4 that Precipitation Variability Index values for June in Makurdi, Gwer-West, Tarka, and Gboko from 1988- 2017 showthe year 1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995 1996, 1997, 1998 1999, 2000, 2001, 2002, 2003, 2004, 2006, 2007, 2009, and 2012 for all the four LGAs and year 2014, 2015, 2016 and 2017 for Makurdi, Gwer-West, Tarka shows PVI values of below 30 % which indicates there was adequate moisture content. While the year 2005, 2011, and 2013 for Makurdi, Gwer-West, Tarka and Gboko have PVI to which indicates high dry spells.

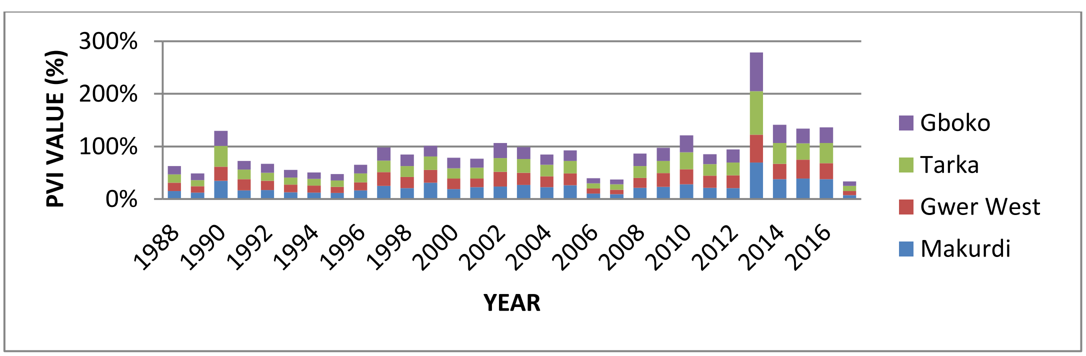

Figure 4.5 PVI for August in Makurdi, Gwer-West, Tarka and Gboko L.G.A (Northern Zone)

It was observed from figure 4.5 that Precipitation Variability Index values for August in Makurdi, Gwer-West, Tarka and Gboko from 1988- 2017 shows that all the years have normal moisture, which is good for farming activities because they have a PVI of less than 30 %. Only a few years of 1990 and 2013 of Makurdi, Gwer-West, Tarka, and Gboko L.G.A (Northern Zone) have PVI above 30 %. This signifies averagely that the PVI for the month of August can be said to be normal.

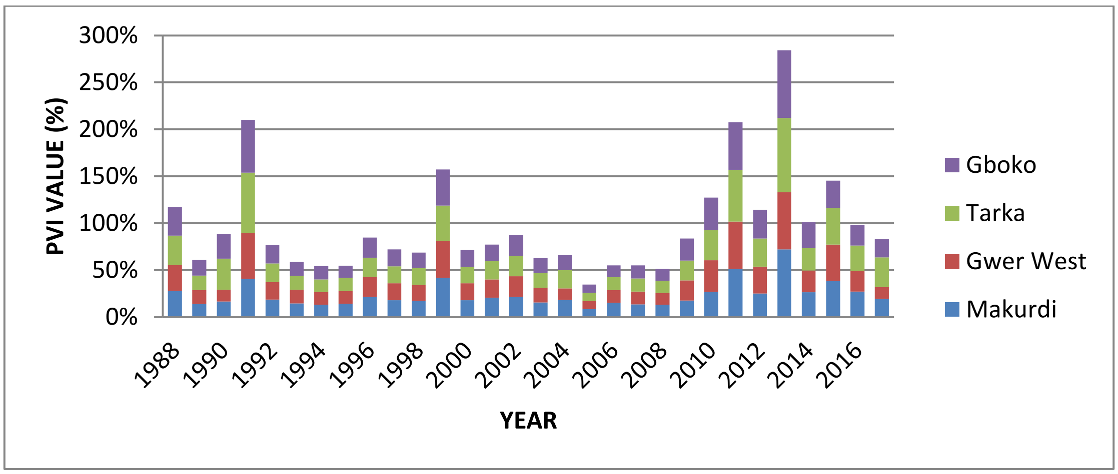

Figure 4.6 PVI for September in Makurdi, Gwer-West, Tarka and Gboko L.G.A (Northern Zone)

It was revealed from figure 4.6that Precipitation Variability Index values for September in Makurdi, Gwer-West, Tarka and Gboko from 1988- 2017 showthe years 1991, 1999, 2011, 2013, and 2015 have PVI of above 30 % which indicates that the months has no moisture to support farming activities. While in the years 1988, 1996, 2002 and 2016,the Precipitation Variability Indexes were of above 20 % but less than 30 % which means that the monthos September has moderate moisture, which can be good for farming activities. Other years 1989, 1992, 1993, 1994, 1995 1997, 1998, 2003, 2004, 2005, 2006, 2007 and 2008 has PVI of less than 20 % indicating that the month ofSeptember had excess moisture that can support farming in the stated years.

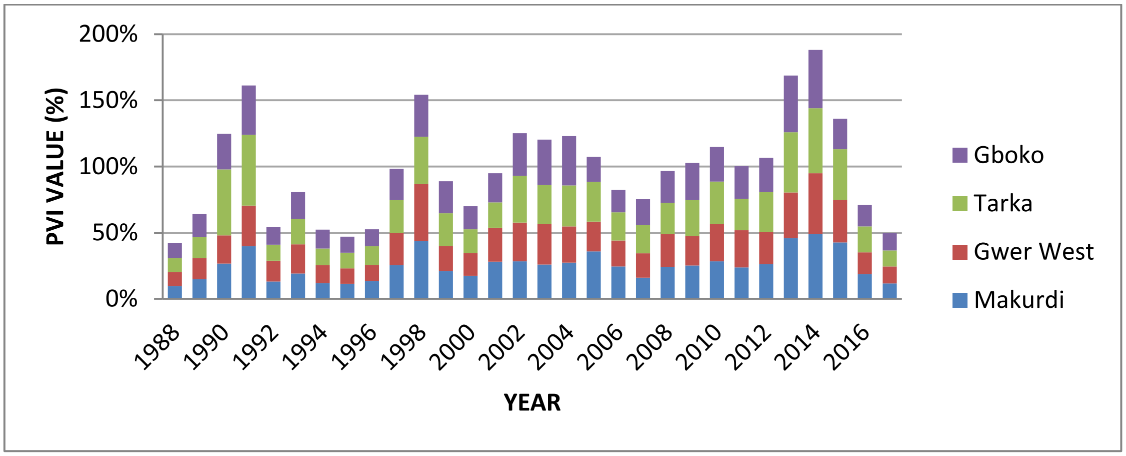

Figure 4.7 PVI for October in Makurdi, Gwer-West, Tarka and Gboko L.G.A (Northern Zone)

It was observed from figure 4.7 that Precipitation Variability Index values for October in Makurdi, Gwer-West, Tarka, and Gboko from 1988- 2017 shows that only in 1988, 1992, 1993, 1994, 1995, 1996, 2000, 2005, 2006, 2007, and 2008that PVI was below 20 %, which means the months of October in these years was well moistured. While, the years 2003, 2009, 2010, 2011 and 2012 had PVI above 20 % but less than 30 %,the moisture for those months was average but still needed little irrigation support. The years 1991, 1998, 2013 and 2014 had PVI of above 30 % indicating the presence of dry spells and drought occurrence.

4.1.2 Precipitation variability index in southern zone of Benue State

The Southern Zone covers four LGAs under study which includes Otukpo, Ado, Ohimini and Gwer-East

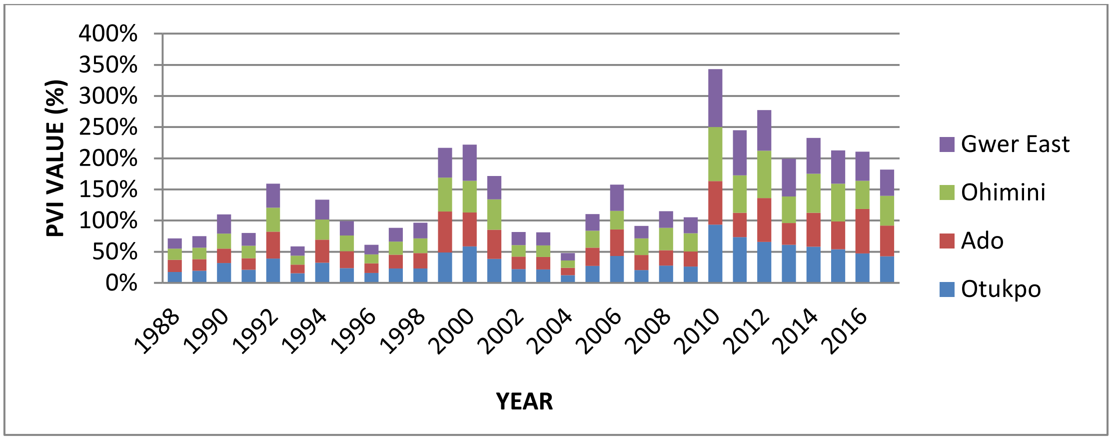

Figure 4.8 PVI for April in Otukpo, Ado, Ohimini and Gwer-East L.G.A. (Southern Zone)

It was revealed fromFigure 4.8that the Precipitation Variability Index in April for the years 1988-2017 for Otukpo, Ado, Ohimini, and Gwer-East LGA show a high tendency of drought hence apart from the years 1988, 1991, 1993, 1994, 1995, 1996, 1997, 2002, 2003, 2004 and 2009 which have PVI that is below 30 % for all the study areas in Southern Zone, all the remaining years are above 30 % an indication dry spells and moisture stress.

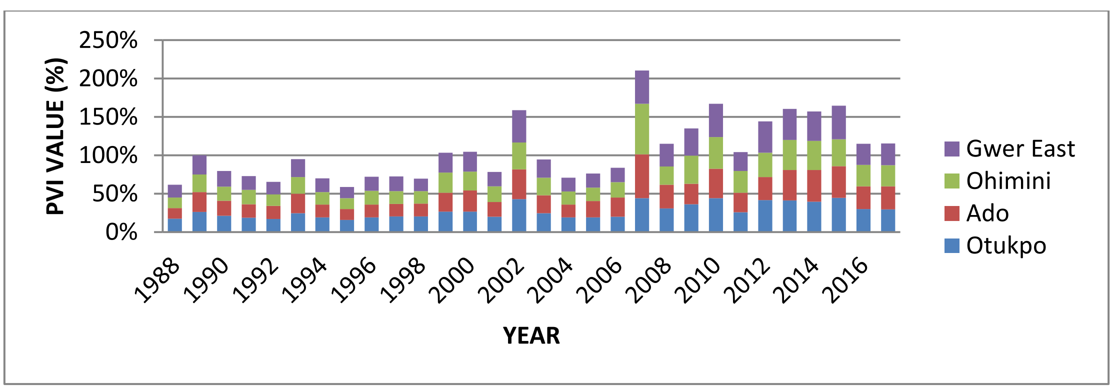

Figure 4.9 PVI for May in Otukpo, Ado, Ohimini and Gwer-East L.G.A. (Southern Zone)

It was observed from Figure 4.9that Precipitation Variability Index in May for the years 1988-2017 for Otukpo, Ado, Ohimini, and Gwer-Eastshows low variability, since most of the years 1988, 1990, 1991, 1992, 1993, 1994, 1995 1996, 1997, 1998, 1999, 2000, 2003, 2004, 2005, 2009, 2016, and 2017 have PVI of less than 30 % in all the study areas within the Southern Zone. Only in 2002, 2007, 2010, 2012, 2013, and 2014 do we have PVI of greater than 30 %, a clear indication that farming activities probably suffer and in most of the years for lack of enough moisture.

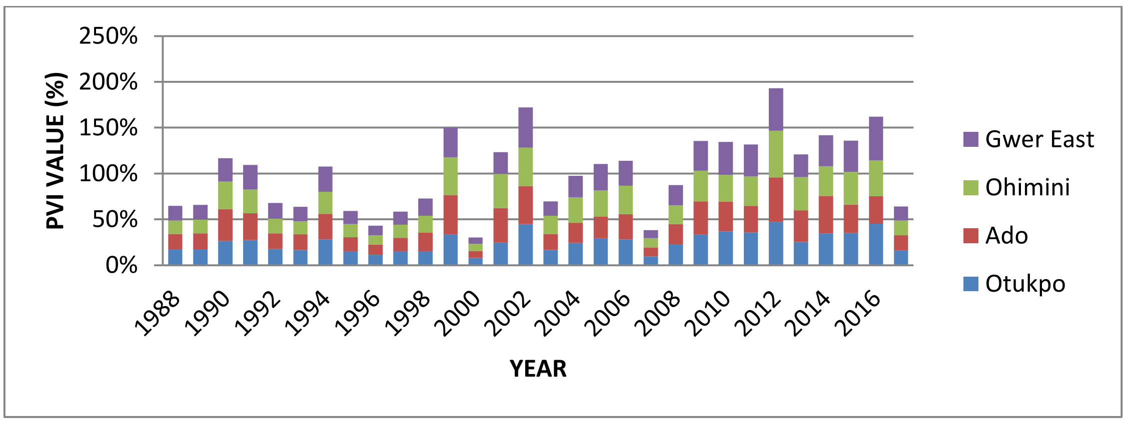

Figure 4.10 PVI for June in Otukpo, Ado, Ohimini and Gwer-East L.G.A. (Southern Zone)

It was noted in Figure 4.10that Precipitation Variability Index in June for the years 1988-2017 for Otukpo, Ado, Ohimini, and Gwer-Eas that year 1988, 1989, 1992, 1993, 1995, 1996, 1997, 2000, 2003, 2007 and 2017 show PVI of less than 20 % which is an indication of low variability where farming activities have uniform water stress in those years, while in 1990, 1994, 2004 and 2005, the PVI was moderate which signifies a tendency for good moisture condition but might need anadditional source of water. Also, in 1999, 2002, 2012, 2015, and 2016, the PVI was above 30 %, signifying the condition of drought.

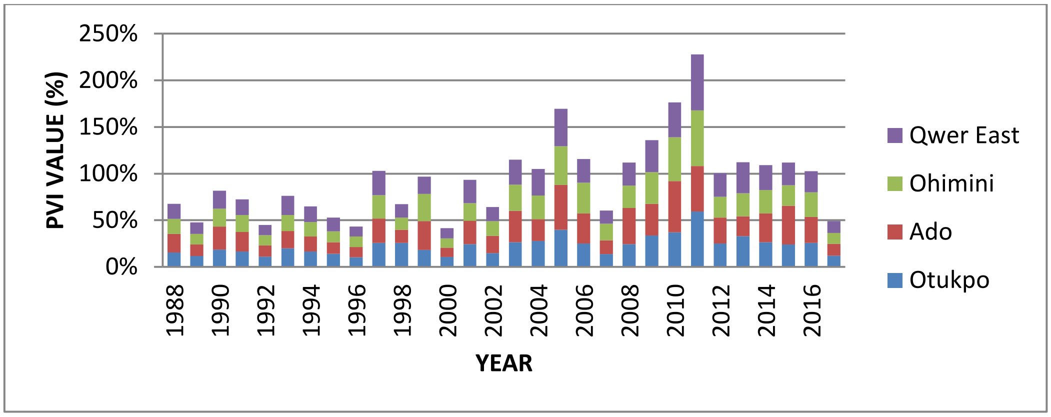

Figure 4.11 PVI for July in Otukpo, Ado, Ohimini and Gwer-East L.G.A. (Southern Zone)

It was observed in Figure 4.11that Precipitation Variability Index in July for the years 1988-2017 for Otukpo, Ado, Ohimini, and Gwer-East reveals that from 1988-2002 shows low moisture variability. Only a few years of 2005, 2009 and 2010 are above 30 % in all the LGA under study within the northern zone, which shows high moisture variability

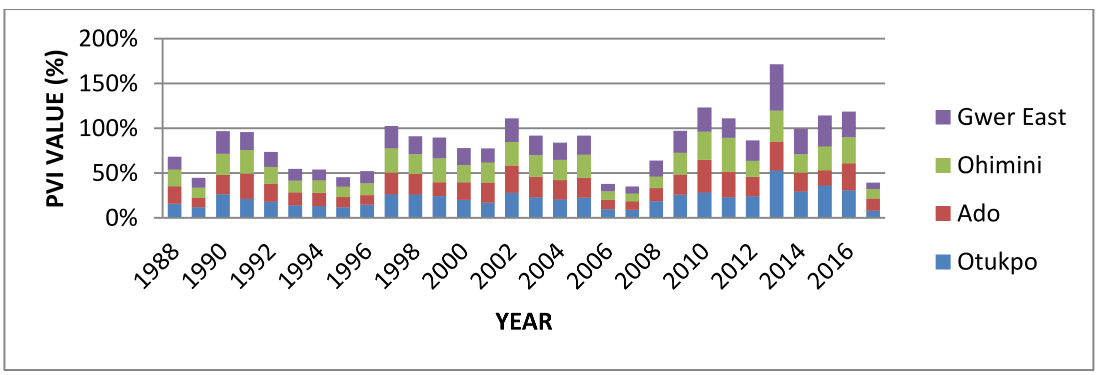

Figure 4.12 PVI for August in Otukpo, Ado, Ohimini and Gwer-East L.G.A. (Southern Zone)

It was revealed from Figure 4.12 that the Precipitation Variability Index in the month of August for the years 1988-2017 for Otukpo, Ado, Ohimini, and Gwer-East shows almost all the years with least variability of moisture distribution, hence from 1988-2009 falls between10 % and 30 % except 2010, 2012, 2013, and 2014, which have high variability of moisture distribution. This month, in general, supports farming activities.

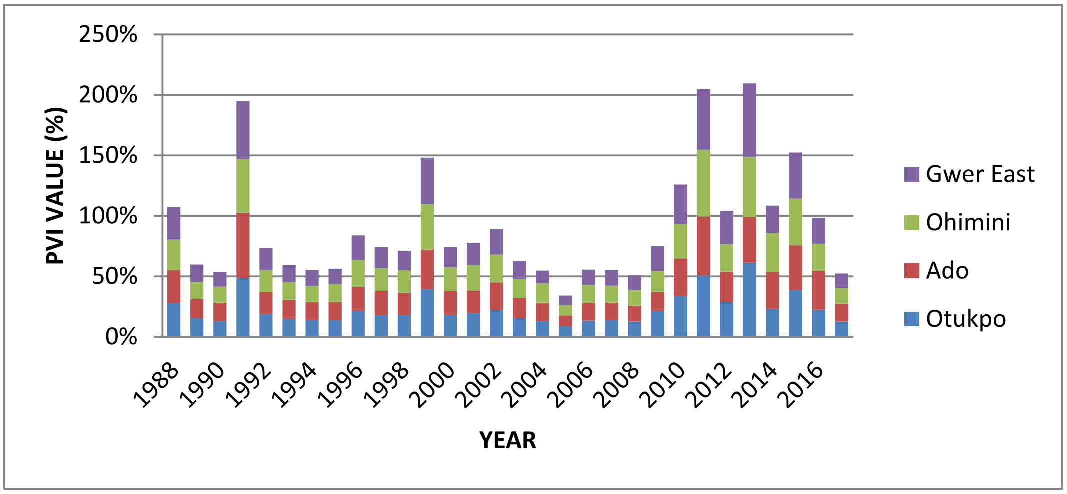

Figure 4.13 PVI for September in Otukpo, Ado, Ohimini and Gwer-East L.G.A. (Southern Zone)

It was observed from Figure 4.13 that Precipitation Variability Index in September for the years 1988-2017 for Otukpo, Ado, Ohimini, and Gwer-East shows that only 1991, 1999, 2011, 2013 and 2015 that have PVI greater than 39 %. While 1988, 1996 and 2002 have PVI above 20 % but less than 30 %. The remaining years have a PVI of below 20 % indicating that t September is well moisture and encourages agricultural production.

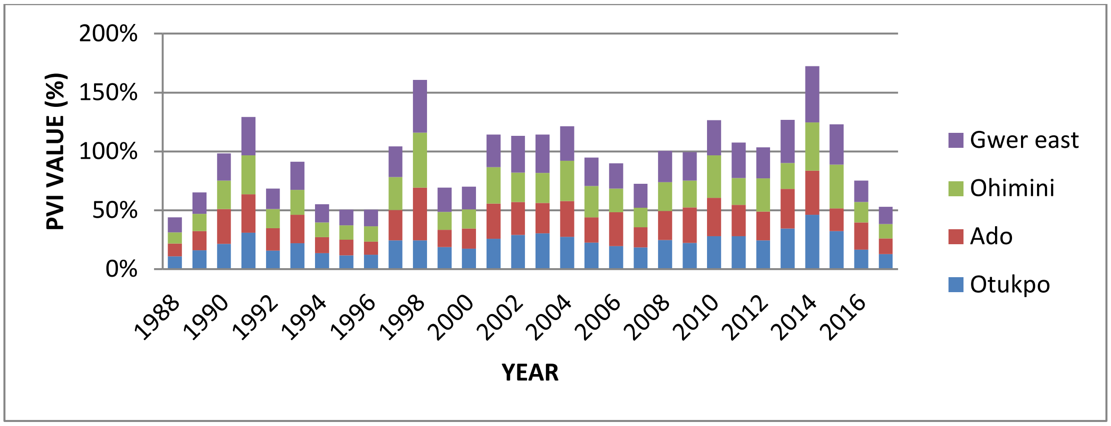

Figure 4.14 PVI for October in Otukpo, Ado, Ohimini and Gwer-East L.G.A. (Southern Zone)

It was revealed from Figure 4.14that the Precipitation Variability Index in October for the years 1988-2017 for Otukpo, Ado, Ohimini, and Gwer-East show the only year 1988, 1989, 1992, 1994, 1995, 1996, 1999, 2000, 2007, 2016, and 2017 have PVI below 20 %, which indicates that October in those years is well moisture. While the years 1990, 1993, 1997, 2010, 2011, and 2012 have PVI greater than 20 % but less than 30 %, the moisture variability for those months is moderate and may be supported with little irrigation. Hence the remaining years of 1991, 1998, 2013, 2014, and 2015 have a PVI of above 30 %, which implies years with a dry spell.

4.1.3 Precipitation variability indexes in eastern zone of Benue State

The Eastern Zone covers four LGA's under study, which includes Kwande, Vandeikya, Ukum, and Ushongo

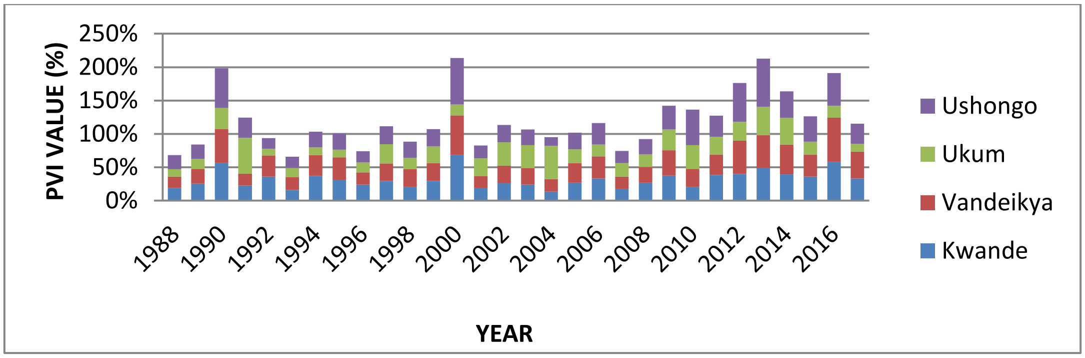

Figure 4.15 PVI for April in Kwande, Vandeikya, Ukum and Ushongo L.G.A (Eastern Zone)

It was observed from Figure 4.15 that the Precipitation Variability Index of April for the years 1988-2017 shows that Vandeikya, Ushongo, and Kwande have PVI above 30 % in most of the years including 1990, 1992, 2009, 2013, 2014, 2016, and 2017. While Ukum, on the other hand has a PVI of less than 30 % in 1988, 1989, 1992, 1994, 1995, 1998,2000, 2006, 2008, 2011, 2012, 2016, and 2017 except in 1990, 2001, 2002, 2004, and 2013 which have PVI of above 30 %. This indicates that farming suffers lack of moisture in this month in Vandeikya, Ushongo, Ukum, and Kwande

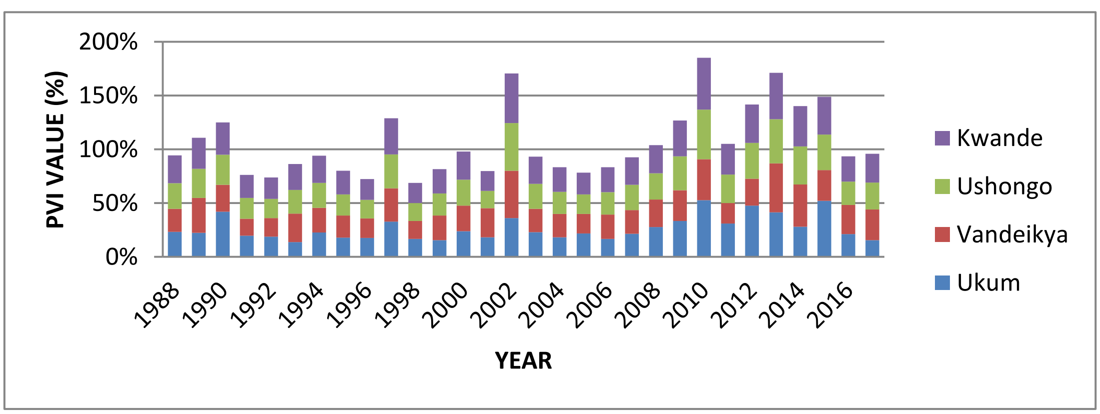

Figure 4.16 PVI for May in Kwande, Vandeikya, Ukum and Ushongo L.G.A (Eastern Zone)

It was observed from figure 4.16 that the Precipitation Variability Index of May for the years 1988-2017 for Kwande, Vandeikya, Ukum, and Ushongo show the month with moderate moisture distribution because 1991, 1992, 1993, 1995, 1996, 2003, 2004, 2005, 2006, and 2007 have PVI below 20 %. While 1996, 1997, 2002, 2010, 2013, 2014, and 2015 have PVI above 30 %. On the other hand, the remaining years are less than 30 % but more than 20 % which implies that May is moisture sufficient for rain-fed agriculture.

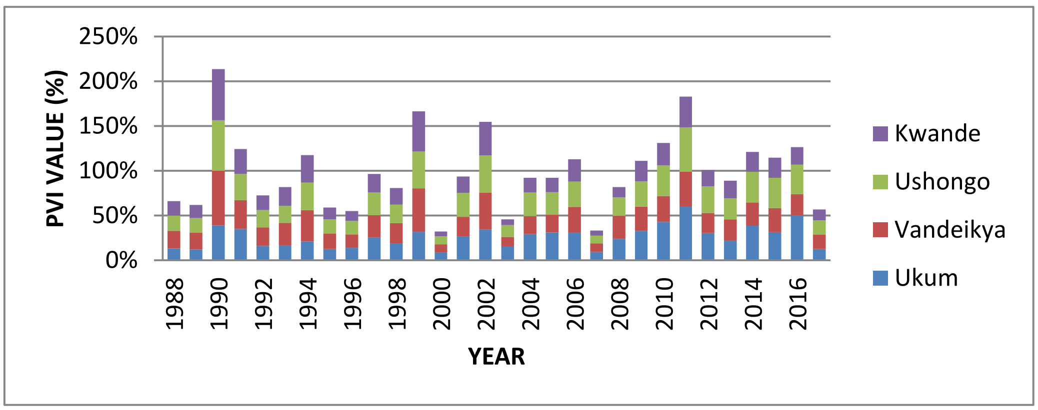

Figure 4.17 PVI for June in Kwande, Vandeikya, Ukum and Ushongo L.G.A (Eastern Zone)

It was observed from figure 4.17 that the Precipitation Variability Index of June for the years 1988-2017 for Kwande, Vandeikya, Ukum, and Ushongo show a moderate moisture distribution for almost all the years except 1990, 1994, 1999, 2002, 2011, 2014, and 2015 which have PVI of above 30 %., There is an indication of low variability and perhaps wetter ground for most of the years in June.

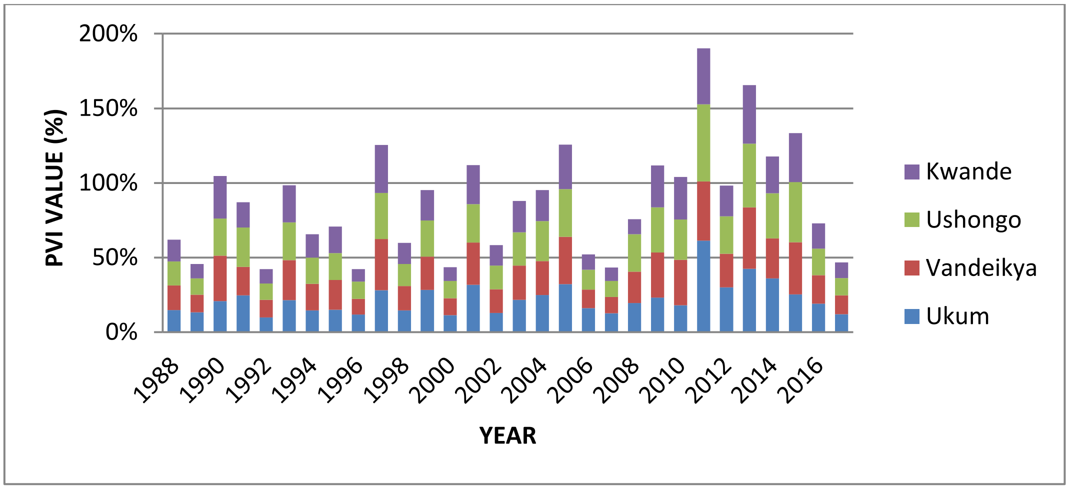

Figure 4.18 PVI for July in Kwande, Vandeikya, Ukum and Ushongo L.G.A (Eastern Zone)

It was observed from Figure 4.18 that the Precipitation Variability Index of July for the years 1988-2017 for Kwande, Vandeikya, Ukum, and Ushongo which show that, apart from the year 1990, 1997, 2005, 2011, 2013, and 2015 which have PVI that is greater than 30 %, the remaining years have PVI between 9 % - 25 %. This implies that July for Kwande, Vandeikya, Ukum, and Ushongo has moderate moisture distribution, hence July is considered a drought-free month.

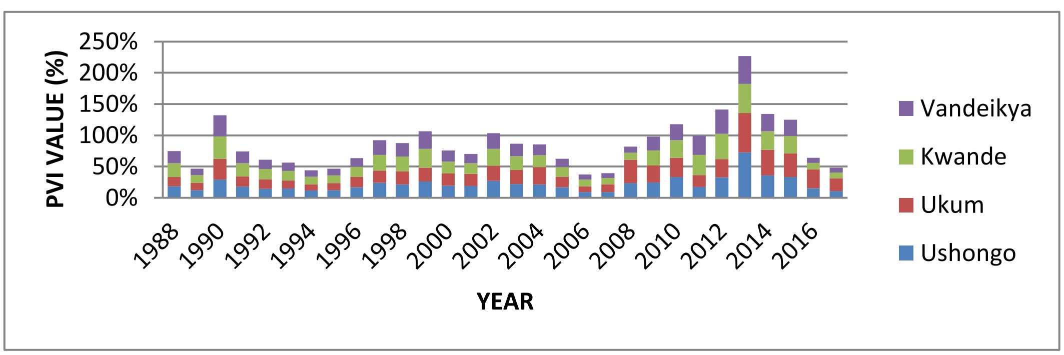

Figure 4.19 PVI for August in Kwande, Vandeikya, Ukum and Ushongo L.G.A (Eastern Zone)

It was noted from Figure 4.19 that the Precipitation Variability Index of August for the years 1988-2017 for Kwande, Vandeikya, Ukum, and Ushongo shows that only the year 1990 and 2013 have a PVI greater than 30 %, the remaining years for Kwande, Vandeikya, Ukum and Ushongo are in between 7 % and 23 %. This indicates that the distribution of moisture is normal and has no tendency for dry spell or drought.

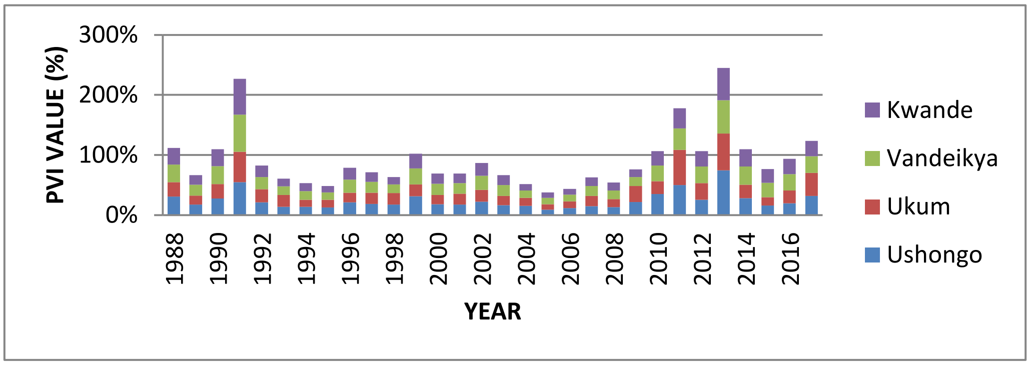

Figure 4.20 PVI for September in Kwande, Vandeikya, Ukum and Ushongo L.G.A (Eastern Zone)

It was observed in Figure 4.20 that the Precipitation Variability Index of September for the years 1988-2017 for Kwande, Vandeikya, Ukum, and Ushongo show the distribution of moisture is moderate, only the years 1991, 2011, and 2013 had a PVI above 30 %, and in the remaining years, the PVI is between 7 % - 24 %, which is an indication of sufficient moisture distribution.

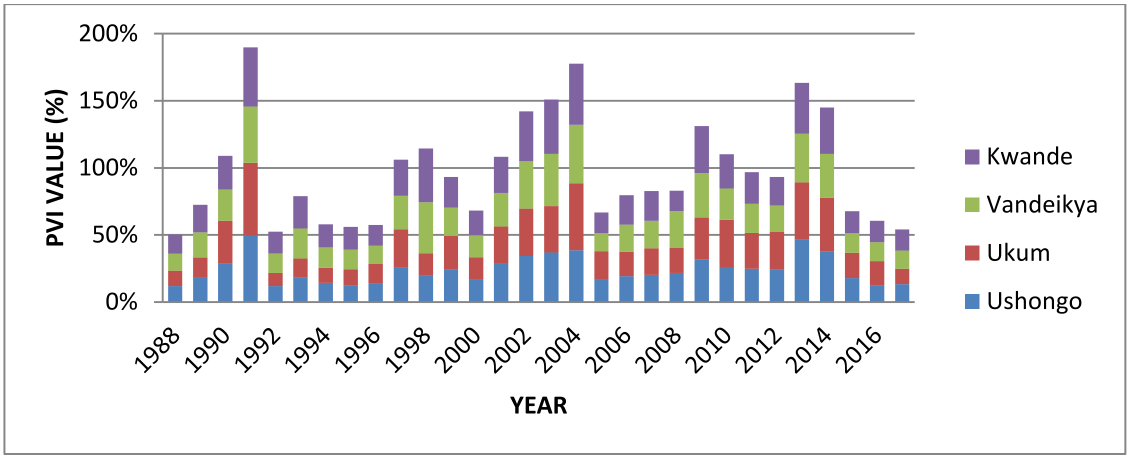

Figure 4.21 PVI for October in Kwande, Vandeikya, Ukum and Ushongo L.G.A (Eastern Zone)

It was observed from Figure 4.21 that the Precipitation Variability Index of October for the years 1988-2017 for Kwande, Vandeikya, Ukum, and Ushongo shows moderate moisture variability, hence, most years in this month for Kwande, Vandeikya, Ukum and Ushongo have PVI of less than 30 %, except for the year 1990, 1998, 2002, 2003, 2009, and 2014 that have PVI of above 30 %. This implies that this month has sufficient moisture distribution for all the Local Government Areas within this zone.

Table 4.1 is the summary of PVI in the Northern, Western, and Southern Zone of Benue State. The Northern zone is categorized into four selected LGAs including, Makurdi, Gwer-West, Tarka, and Gboko. The mean precipitation index in this zone indicates that April, May, and October in all the LGAs show PVI of 30 % and above, which implies high variability, the rain-fed agricultural activities may be subjected to drought except an alternative means of moisture to support rainfall could be put in place to have maximum yield.

Gwer-West, Makurdi, Tarka, and Gboko LGA have 4 months with moderate variability from June – September, which is good for farming activities and perhaps encourages high crop yield. This indicates that rain- fed agricultural activities in Gwer- West, Makurdi, Tarka and Gboko LGA may not suffer water stressas most of the months have PVI of greater than 25 %. Averagely, the Grand Mean of PVI in the Northern Zone indicates high variability of 30 %. On the other hand, the southern zone has the following LGAs; Otukpo, Ado, Ohimini, and Gwer- East. The mean PVI shows that only Otukpo from (May- October) has moderate moisture variability, with a PVI is greater than 20 % but less than 30 %. The month of April for all the LGAs has a PVI of high moisture variability of greater than 30 %.

Otukpo, Gwer –East, and OhiminiLGAshave six months (May- October) with moderate variability, while Ado has five months of moderate variability in May, June, July, September andOctober. This shows that for adequate farming activities to succeed, and another alternative source is needed in this zone; hence most of the months have a moderate moisture index which will be subjected to little drought and may affect the growing season. Averagely, the Grand Mean of PVI in this zone is 26.16 %, which is an indication of moderate variability.

The EasternZone has the following LGAs, Kwande, Vandeikya, Ukum, and Ushongo. The month of April is considered as the dry month within the zone except in Vandeikya and Ushongo Local Government Areas with PVI of 22.68 % and 20.12 % which indicates moderate variability of moisture. Ushongo LGA has five months of least variability,while Kwande and Ukum LGAs have four months of least variability. The highest PVI recorded in this zone is in Ukum LGA in April with 34.55 %. This implies low variability of moisture in almost all the LGAs in the zone;this will enhance rain- fed farming activities to do very well. In this zone, planting should be done during April, especially in Vandeikya and Ushongo,while in Kwande and Ukum, planting can be effective in May. Averagely, the Grand Mean of PVI in this zone is 19.40 % which indicatesminor variability.

In summary, considering the Precipitation variability Index in all the LGAs within all the Zones, Kwande LGA in the Eastern Zone has a PVI of 17.41 % in August which is an indication of the least variability of moisture with high rainfall intensity, this implies that, in all the zones in Benue State agricultural activities should be carried out specifically towards the end of April in Southern and Eastern zone while the month of May should be considered in the Northern zone, hence the Precipitation Variability Index is highly variable in the months of April. This agree with the researchcarried out in Nasarawa State which is located in the Northern part of Benue State (Agidi, 2017), which reviewed that most of the LGAs considered indicated high and moderate variability. While the current research reviewed that in all the LGAs considered high, moderate, and least variability were experienced in the State.

Table 4.1 Mean Summary of PVI (%) in the Three Zones of Benue State

NorthernZone	April	May	June	July	August	September	October	**Mean**
Makurdi	37.23	36.76	26.40	22.48	23.19	30.55	32.98	29.94
Gwer-West	39.32	33.46	29.40	26.47	28.56	28.43	36.34	31.71
Tarka	39.24	32.34	27.64	27.60	26.62	26.02	30.88	30.05
Gboko	35.23	29.92	26.51	22.85	21.86	35.45	34.73	29.51
Mean Total								**30.30**
SouthernZone								
Otukpo	36.85	27.44	25.25	22.87	21.70	23.01	22.69	25.69
Ado	35.35	26.23	25.77	25.3	34.21	22.81	24.12	28.03
Ohimini	36.09	25.68	25.55	22.86	21.07	22.65	23.54	25.35
Gwer east	36.28	26.46	24.70	22.86	20.31	22.18	26.30	25.58
Mean Total								**26.16**
EasternZone								
Kwande	33.22	20.12	19.01	18.04	17.41	19.37	20.09	19.61
Vandeikya	22.68	20.92	18.42	17.63	19.51	20.07	21.73	20.14
Ukum	34.55	22.25	18.09	19.21	18.99	19.59	22.55	20.60
Ushongo	20.12	19.82	19.23	18.04	18.16	20.98	19.46	19.40
Mean Total								**19.94**

4.2 Trendsof Selected Crops in the Study Area

Following objective two, the trend of annual cassava yield (Appendix B) in the study area is shown in Table 4.2. The table shows a significant positive increasing trend in the study area. A significant increasing trend at the alpha value of 0.001 was found in the Northern and Southern zones, while a significant increase at the alpha value of 0.01 was found in the Eastern zone of the study area. Finding from the study implies that cassava yield increases with decreasing coefficient of variation in climatic variables. The study established a magnitude of increase in the yield of cassava of 3.514 tones and 3.263 tones in North and East, while the highest yield is recorded in the South which is 4.934 tones.

Table 4.2 Trend of Annual Cassava Yield in the Study Area

Station	First Year	Last Year	No. of Years	Test-Z	Q-value
North	1988	2017	30	3.59***	3.514
East	1988	2017	30	2.68**	3.263
South	1988	2017	30	3.71***	4.934

****Trend is significant at α=0.001=99.9%, **Trend is significant at α=0.01 = 99%, *Trend is significant at α=0.05= 95%, +Trend is significant at α=0.1= 90% confidence level*

The trend of annual Maize yield (Appendix C) in the study area is shown in table 4.3. The table shows a significant increasing trend in the bulk of the zones. Asignificant increasing trend at the alpha value of 0.05 was detected for North and South, while East shows positive change but no significant increasing trend. The trend of maize implies that the yield of maize is increasing in the study area from 1988-2017. This may be because of the suitability of almost all the agricultural zones in the State to maize production and the relatively short length of growing season for maize which might not be affected by rainfall variability. This agrees with IITA, which stated that maize is high- yielding, easy to process, readily digested and costs less than other cereals. It is also a versatile crop, allowing it to grow across a range of agro- ecological zones. The crop cycle is relatively shorter, making it the first crop to harvest for food during the hunger period in Nigeria. Large arable land available in almost all zones and the relatively short cycle of growth is an additional motivation to cultivate maize, hence lead to high yield. The presence of extension workers from BNARDA and the introduction of high- yielding maize seed to farmers is a panacea for high maize yield in Benue state.

Table 4.3 Trend of Annual Maize Yield in the Study Area

Station	First Year	Last Year	No. of Years	Test-Z	Q-value
North	1988	2017	30	2.07*	0.019
East	1988	2017	30	1.59	0.012
South	1988	2017	30	2.36*	0.040

****Trend is significant at α=0.001=99.9%, **Trend is significant at α=0.01 = 99%, *Trend is significant at α=0.05= 95%, +Trend is significant at α=0.1= 90% confidence level*

The trend of annual rice (Appendix D) yield in the study area is shown in table 4.4. The table shows a significant reduction in the trend of rice. A significant decline trend at an alpha value of 0.001 was detected for North, East and South of the study area. Rice cultivation is usually done in swampy areas close to the river.With population explosion and urbanization, more swampy areas that are supposed to be used for rice farming will be taking up other activities, which will lead to inadequate land for rice cultivation and the possible cause of the decline in rice yield in Benue State. This is supported by Salau *et al*., (2016) which noted that rice is cultivated in virtually all the agro-ecological zones in Nigeria. Despite this, the area cultivated to rice appears small. In 2000, out of about 25 million hectares of land cultivated to various food crops, only about 6.37 % was cultivated to rice. High dependence on imported rice also leads to a decline in rice yield as farmers will have no value to their product, competing with better and well-polished foreign rice; this can lead to a lack of zeal in rice farming.

Table 4.4 Trend of Annual Rice Yield in the Study Area

Station	First Year	Last Year	No. of Years	Test-Z	Q-value
North	1988	2017	30	-3.02**	-0.038
East	1988	2017	30	-3.04**	-0.036
South	1988	2017	30	-3.20**	-0.028

****Trend is significant at α=0.001=99.9%, **Trend is significant at α=0.01 = 99%, *Trend is significant at α=0.05= 95%, +Trend is significant at α=0.1= 90% confidence level*

The trend of annual Yam yield (Appendix E) in the study area is shown in table 4.5. The table shows a significant positive increasing trend in the study area. A significant increasing trend at alpha the value of 99 % was found in the Southern zone, while a significance increase at the alpha value of 90 % was found in the Northern zone of the study area. The Eastern zone shows positive change but no significant increasing trend. This increase might result from deliberate efforts by government to export yam from the State which makes it a good source of foreign income. The entire agriculture zone in the State support yam cultivation, this implies that there are more land for yam farming and hence the reason for the high yield across the State. Yam grows in areas of annual rainfall around 1200mm, the mean annual rainfall across Benue state is above 1000mm; this shows that yam farming is boosted with abundant rainfall, hence the increased in yield.

Table 4.5 Trend of Annual Yam Yield in the Study Area

Station	First Year	Last Year	No. of Years	Test-Z	Q-value
North	1988	2017	30	1.82+	2.038
East	1988	2017	30	1.29	1.071
South	1988	2017	30	3.00**	3.545

****Trend is significant at α=0.001=99.9%, **Trend is significant at α=0.01 = 99%,*

**Trend is significant at α=0.05= 95%, +Trend is significant at α=0.1= 90% confidence level*

The trend of annual groundnut yield (Appendix F) in the study area is shown in table 4.6. The table shows a significant increasing trend in all the zones across the study area. A significant increasing trend at an alpha value of 99 % was detected for Eastern, Northern and Southern zone. The magnitude of change of 0.057 tones occurs highest in the Northern zone, while the lowest magnitude of change of 0.050 tones occurs in the southern zone. The result affirms that there is a significant positive increase in groundnut production across the State.

Table 4.6 Trend of Annual Groundnut Yield in the Study Area

Station	First Year	Last Year	No. of Years	Test-Z	Q-value
North	1988	2017	30	4.93***	0.057
East	1988	2017	30	4.67***	0.056
South	1988	2017	30	4.98***	0.050

****Trend is significant at α=0.001=99.9%, **Trend is significant at α=0.01 = 99%, *Trend is significant at α=0.05= 95%, +Trend is significant at α=0.1= 90% confidence level*

The trend of annual soyabean yield (Appendix G) in the study area is shown in table 4.7. The table shows a significant increasing trend in all the zones across the study area. Asignificant increasing trend at an alpha value of 95 % was detected for the Eastern, Northern, and Southern zone. The magnitude of change of 0.106 tones occurs highest in the Eastern zone, while the lowest magnitude of change of 0.101 tones occurs in the Southern zone. The result implies that there is a significant positive increase in soybean production across the State.

Table 4.7 Trend of Annual Soyabeans Yield in the Study Area

Station	First Year	Last Year	No. of Years	Test-Z	Q-value
North	1988	2017	30	5.60***	0.102
East	1988	2017	30	6.12***	0.106
South	1988	2017	30	5.55***	0.101

****Trend is significant at α=0.001=199.9%, **Trend is significant at α=0.01 = 99%, *Trend is significant at α=0.05= 95%, +Trend is significant at α=0.1= 90% confidence level*

Conclusively, this current result on trend agrees with the research carried out by Agidi (2017) in Nasarawa State where the trend analysis on different crop yields showed an increasing trendwhile that of rice showed a decreasing trend.

4.3 Analysis of Rainfall Characteristics (Onset, Cessation and the Length of Rainy Season)

These features are very important to be considered for effective farming in the tropics. The reason is that onset, cessation and length of the rainy season forms a very important component of moisture resources status for determining the production of various crops (Chima, 2015). These three components (onset, cessation, and length of rainy season) are presented together for each Local Government Area. The Onset is the date on the first point of maximum- inflexion on the pentad calendar, while the cessation is the last point of maximum inflexion on the pentad calendar. The length of the rainy season is the difference between the Onset and cessation.

4.3.1 Onset, Cessation and the Length of the rainy season in Eastern Zone

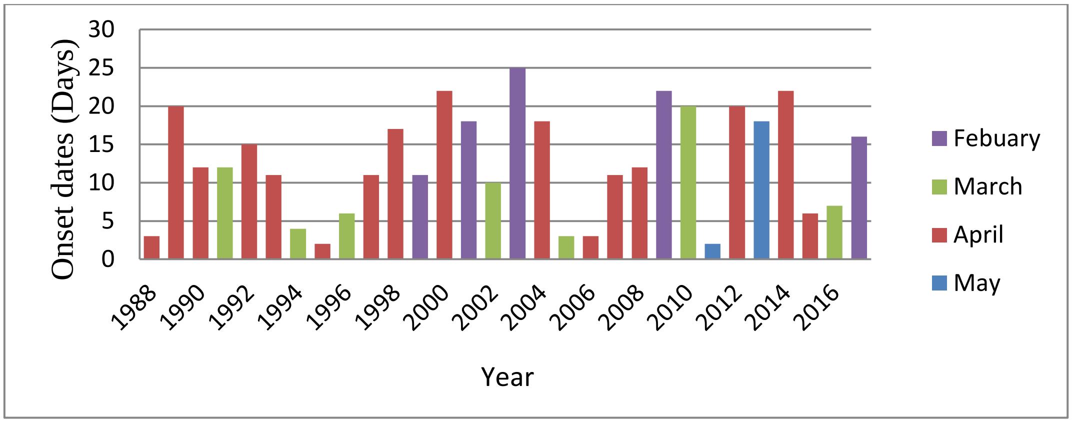

Figure 4.22 Onset of Rainfall Dates in Vandeikya

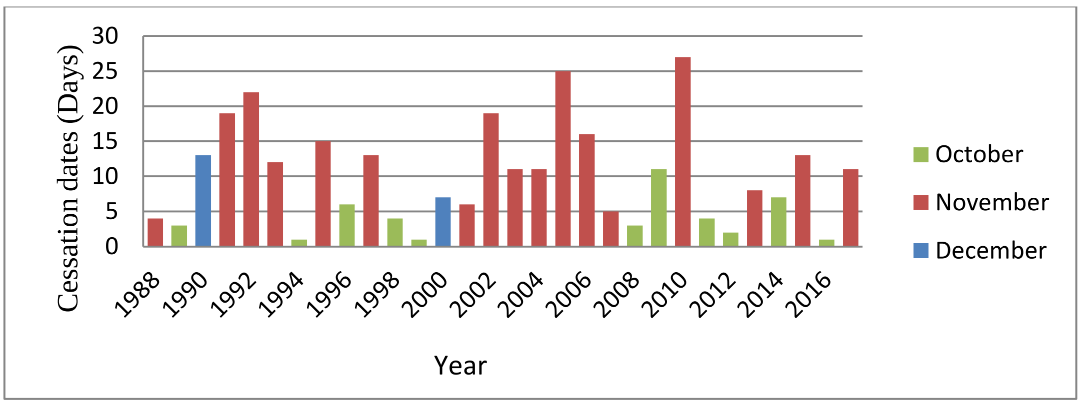

Figure 4.23 Cessation of Rainfall Dates in Vandeikya

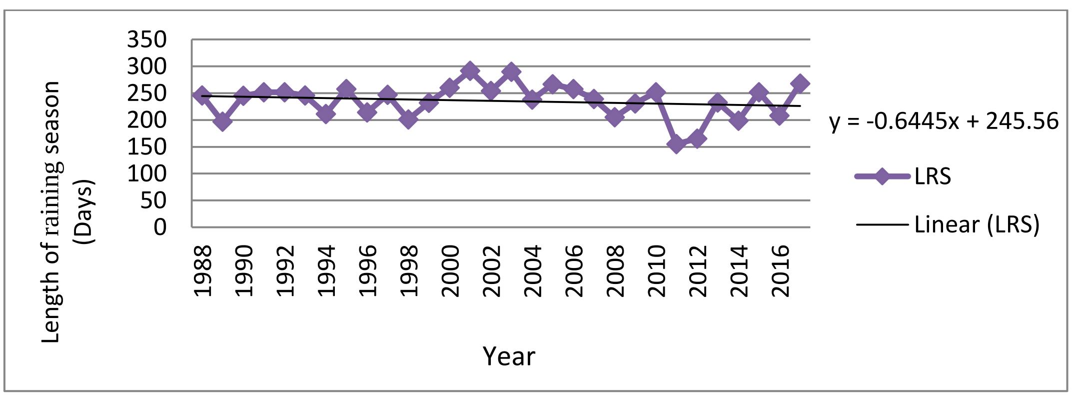

Figure 4.24 Length of the Rainy Season in Vandeikya

It was revealed from figure 4.22 to 4.24 the onset dates, cessation dates, and length of the rainy season in Vandeikya Local Government Area showthat April month dominates with rains in Vandeikya dominate in April. The earlier onset date occurs on February 25th, 2003, while the late- onset occurs on 2nd May, 2011. This reveals that planting of crops such as legumes, cereals, and tubers crops is feasible after 12th April, averagely in Vandeikya Local Government Area.Cessation, on the other hand occurs mostly in November and late cessation occurs in December. The length of rainy season shows anincrease in the length of rainy season around Vandeikya Local Government Area with an average of 235 days.

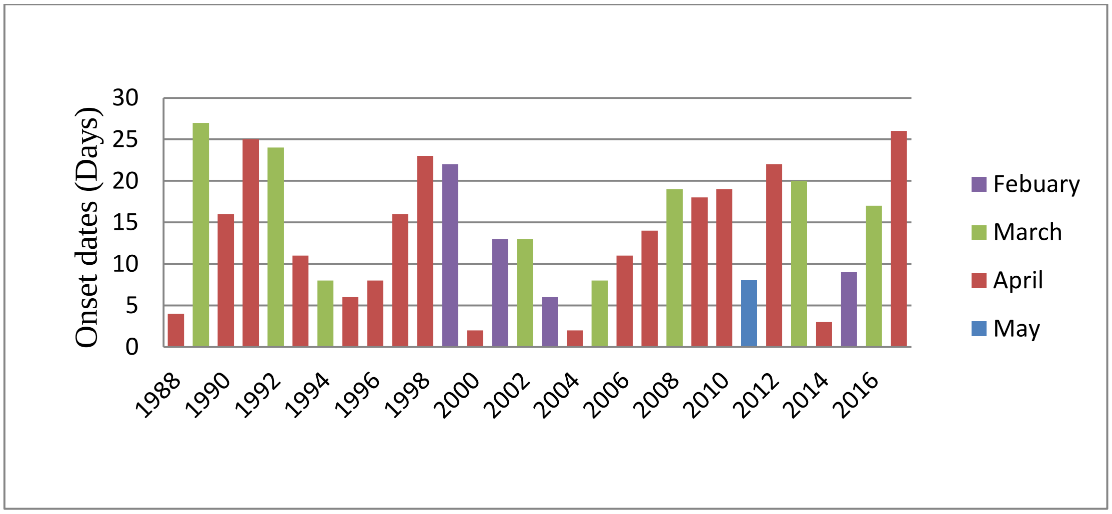

Figure 4.25 Onset of Rainfall Dates in Ushongo

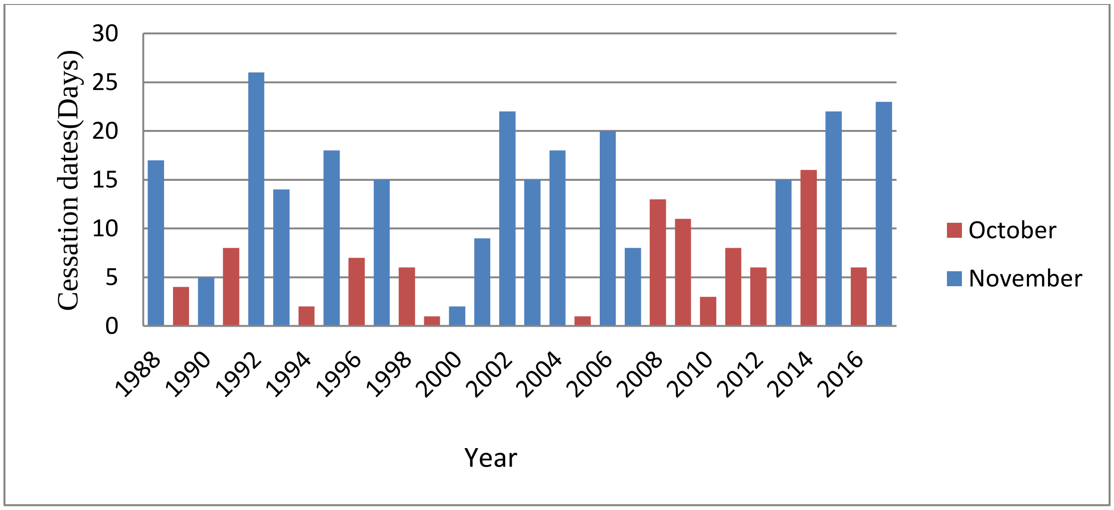

Figure 4.26 Cessation of Rainfall Dates in Ushongo

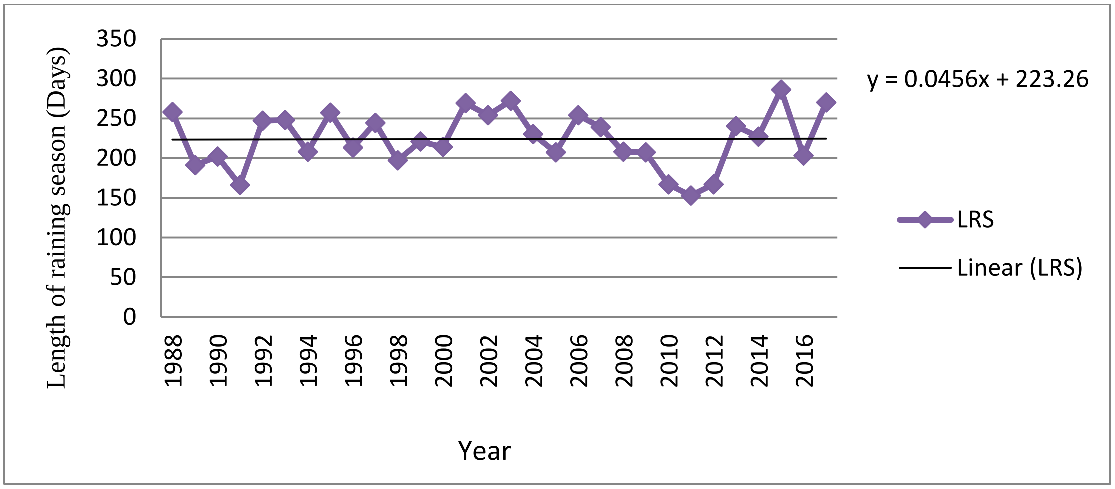

Figure 4.27 Length of the Rainy Season in Ushongo

It was observed from Figure 4.25 to 4.27 the onset date, cessation, and length of the rainy season, which falls in theUshongo Local Government Area, the result reveals that the early onset date occurs on 8th February but seems to be very scanty. The rain onset is at maximum averagely from 14th April, which is always a good time for farmers; hence planting of crops will kick-off by the middle of April. Cessation in Ushongo reveals that the cessation occurs only in October and November. The result further reveals that the late cessation occurs around 26th November while the early cessation occurs on the 2nd of October. This means that, on the average, there are early cessation dates in Ushongo Local Government Area. The length of rainy seasonin Ushongo LGA has an average of 223days which means there is areduction in the length of the rainy season in theUshongo Local Government Area.

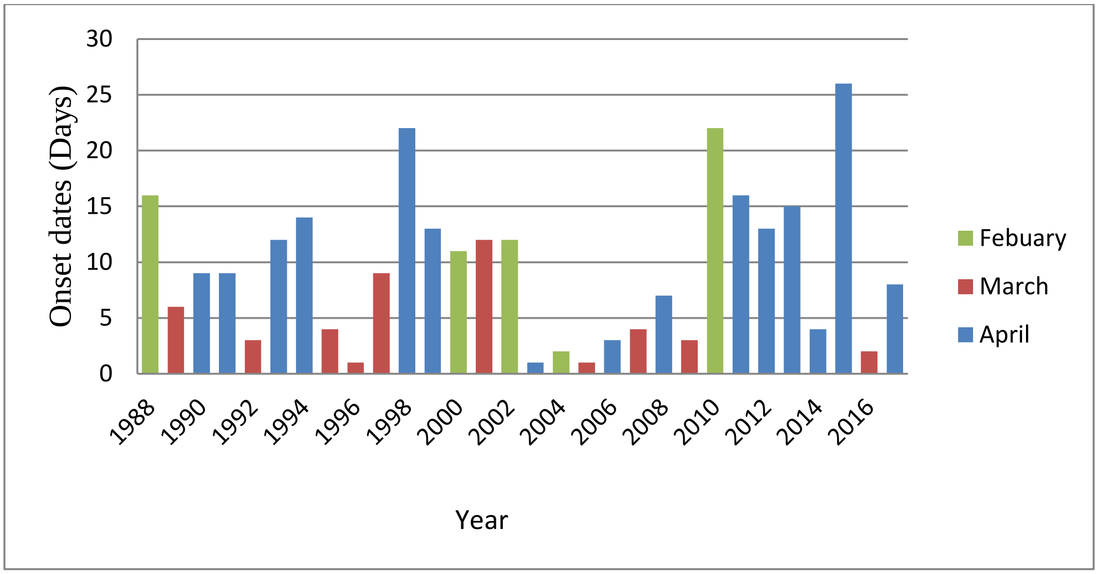

Figure 4.28 Onset of Rainfall Dates in Kwande

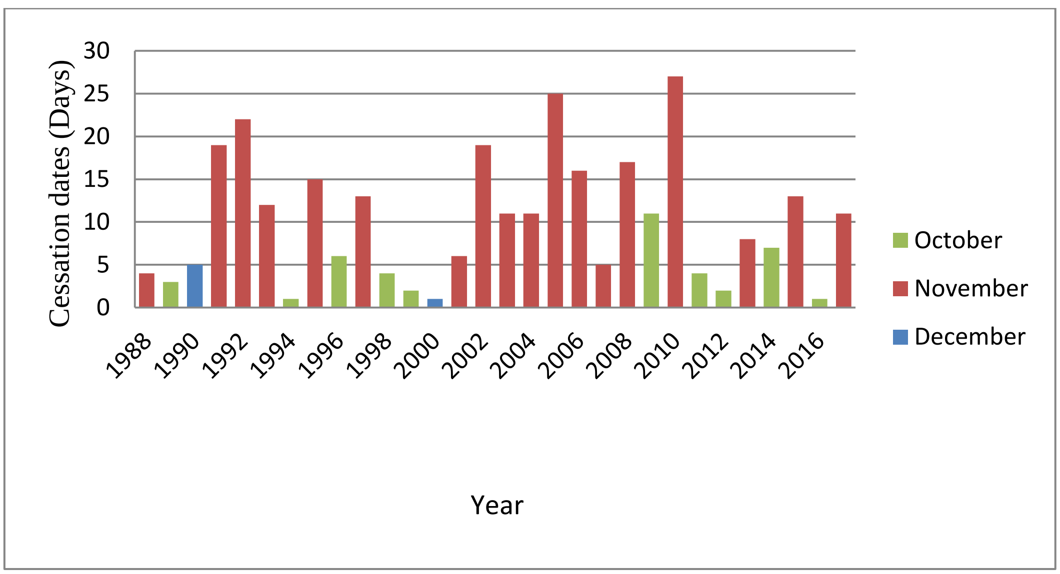

Figure 4.29 Cessation of Rainfall Dates in Kwande

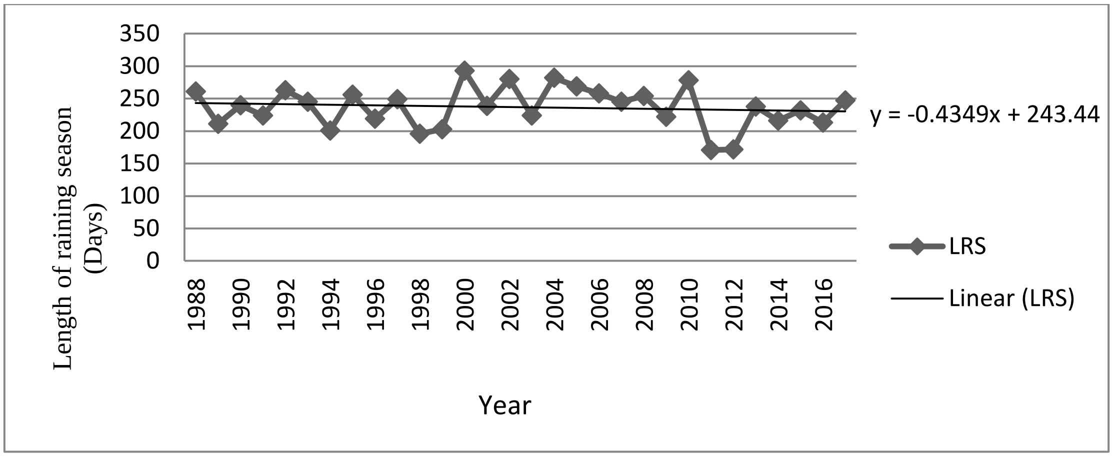

Figure 4.30 Length of the Rainy Season in Kwande

It was revealed from Figure 4.28 to 4.30 the distribution of onset of rainfall, cessation of rainfall and length of the rainy season, respectively, in Kwande LGA,it reveals that the onset of rains in this LGA is prevalent by April. The average onset in Kwande LGA is 6th April, which implies that agricultural activities shall be carried out towards the middle of April; hence the soil must have been sufficient with water. Cessation, on the other hand, shows that November is the most prevalent cessation date in Kwande LGA. This means the cessation of rains in Kwande LGA shall be reduced from the average date of 9th November, which implies the early cessation of rains. While the length of rainy season indicates an increased length of the rainy season in Kwande LGA which has an average of 236 days,this marks the highest in the zone..

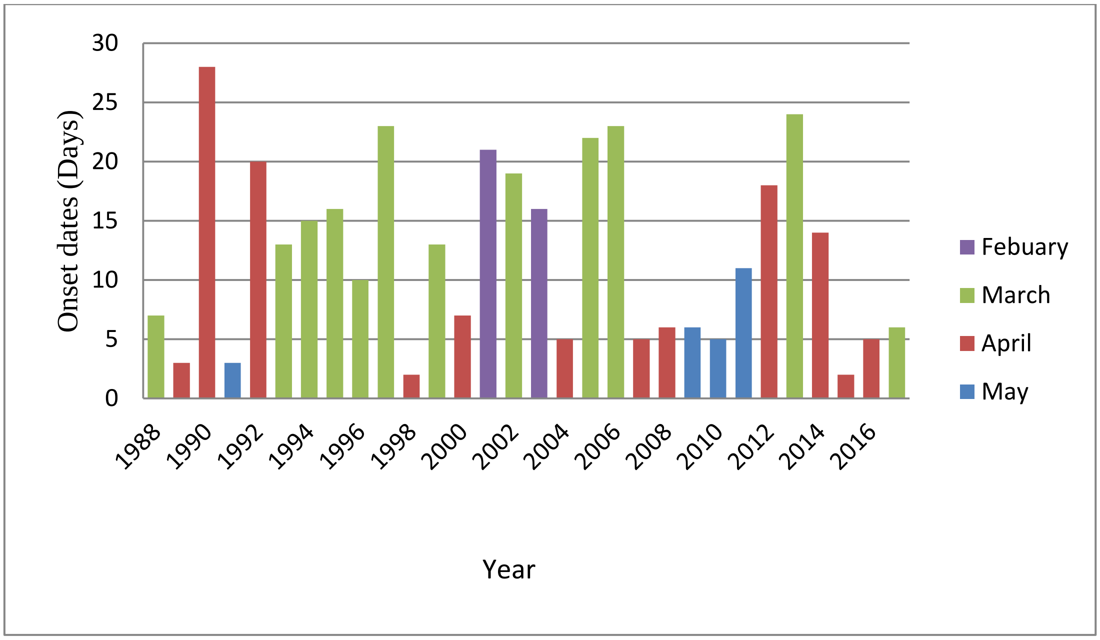

Figure 4.31 Onset of Rainfall Dates in Ukum

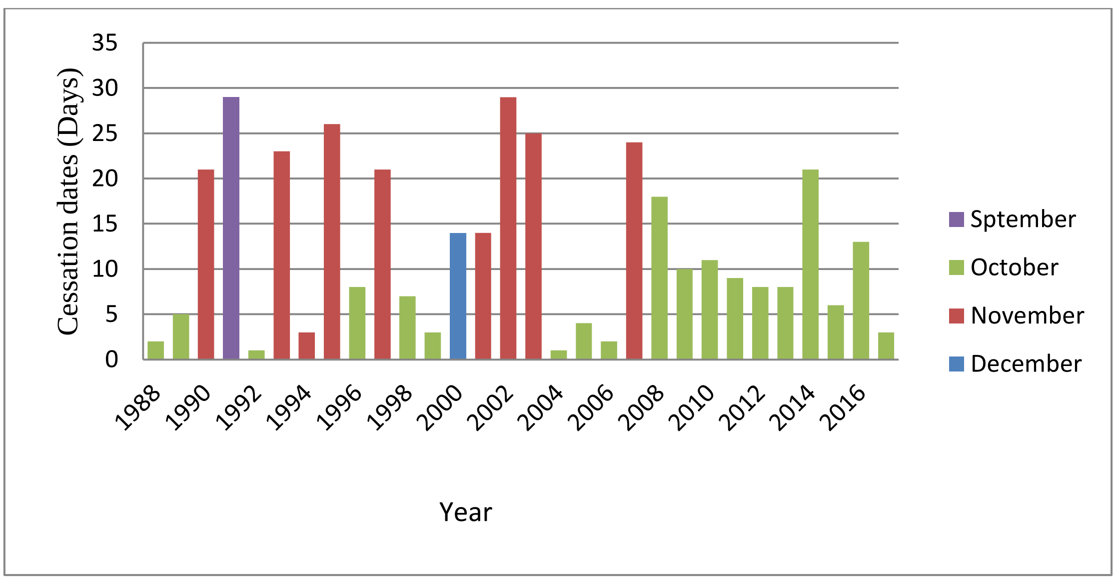

Figure 4.32 Cessation of Rainfall Dates in Ukum

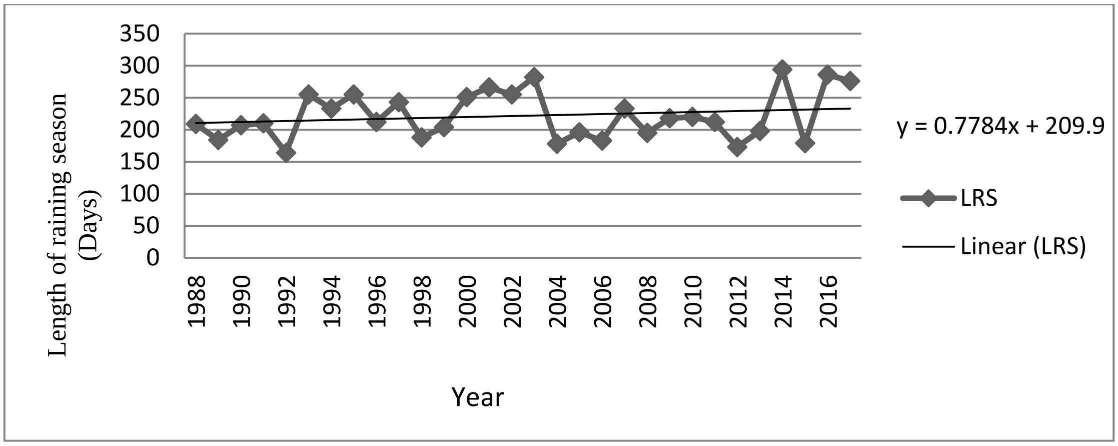

Figure 4.33 Length of the Rainy Season in Ukum

Figure 4.31 to 4.33shows the onset, cessation, and length of rainy season in Ukum LGA. It reveals that the onset of rains occurs in February, March, April, and May, but mostly occurs in March and April. The onset date in Ukum LGA is from 3rd April. The onset begins by April; this explains while tuber crop such as yam is produced on a very large scale in Ukum hence there is early onset which is good for the planting of yam for the right time of the season. Averagely, Ukum experience an onset date of 10th April. The cessation dates for Ukum occur from September, October, November, and December. The month of October is a prevalent month that cessation dates occur in most of the years, with an average cessation date of 7th October. This indicates that there is early cessation of rains in Ukum LGA. The Length of rainy season in the Ukum LGA has an average of 221days,and this means there is an increase in the length of rainy season in the Ukum LGA.

It was revealed from table 4.8 the distribution of the onset of rainfall dates, cessation of rainfall dates, and length of rainy season in the Eastern zone of Benue State. The Eastern zone constitutes Vandeikya, Ushongo, Kwande and Ukum LGA. The Onset dates occurs inApril signifying a little bit of consistency that might not cause problems to rain- fed farmers who are used to the rainfall pattern. Cessation dates, on the other hand, occurs on the 7th of October in this zone. This implies that the cessation dates are inconsistent as well. This zone has the longest length of the rainy season as compared to the three zones. The LRS is 236 days. This shows long rainfall periodin this region and adequate moisture for rain- fed farming in the zone.

Table 4.8 Average dates of Onset, Cessation of Rains and Length of Rainy Season in the EasternZone

LGA	AOD	ACD	ALRS
Vandeikya,	12thApril	14th November	235
Ushongo	14thApril	16th November	223
Kwande,	6th April	9th November	236
Ukum	10thApril	7th October	221

4.3.2 Onset, Cessation and Length of rainy season in Southern Zone

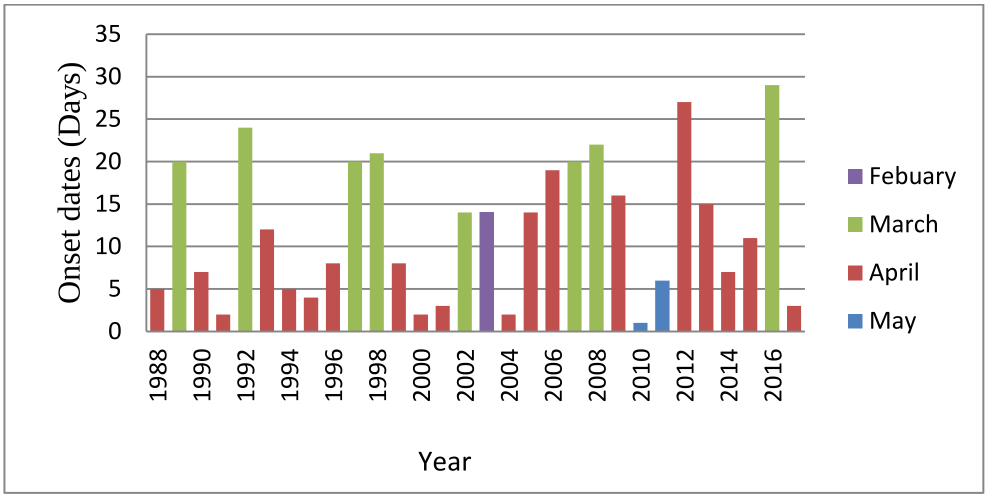

Figure 4.34 Onset of Rainfall Dates in Gwer-East

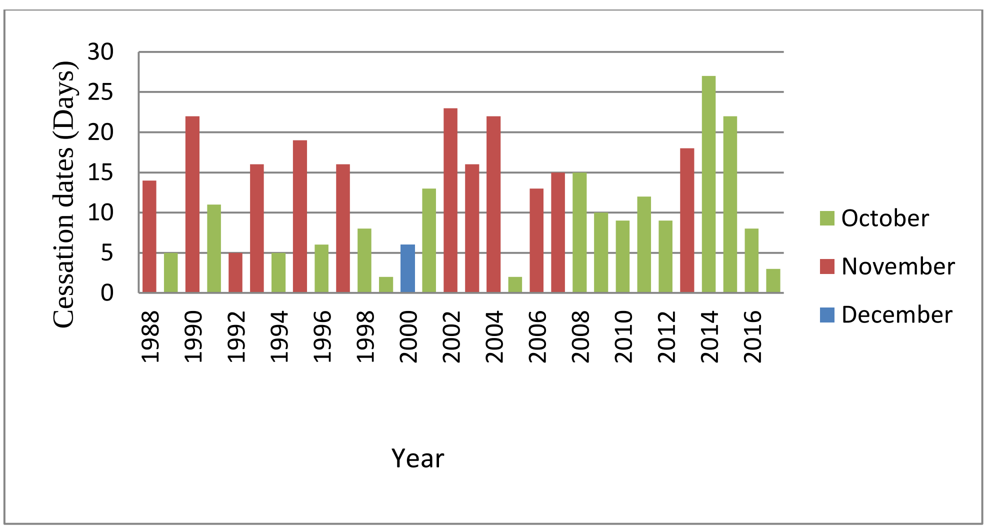

Figure 4.35 Cessation of Rainfall Dates in Gwer-East

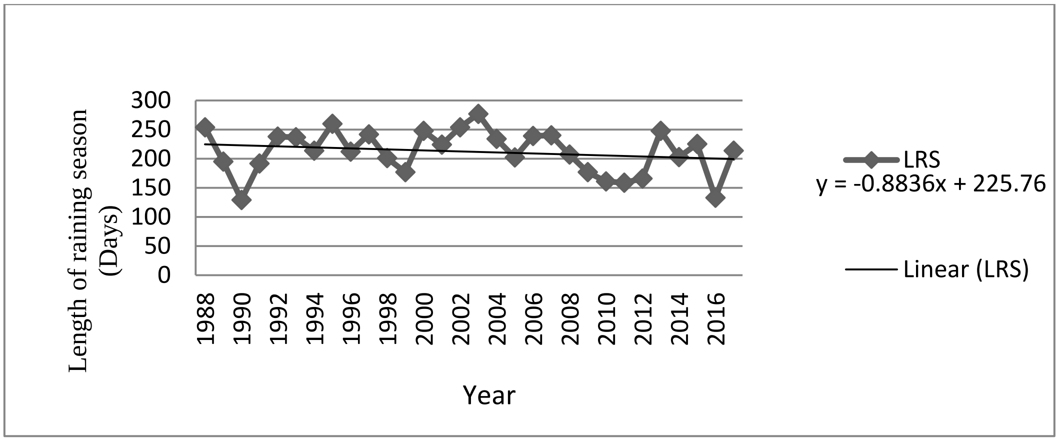

Figure 4.36 Length of Rainy Season in Gwer-East

It was observed from figure 4.34 to 4.36 the onset, cessation, and length of rainy season in Gwer- East LGA, the onset dates of rains in Gwer- East constituted the months of February, March, April, and May. The dominant month with the onset dates in most of the years in April. The average onset of Gwer- East LGA is 15th April, which implies that agricultural activities should be carried out towards the middle of April where there will be sufficient water in the soil. On the other hand, cessation occurs in October, November, and December over the years, but mostly in October and November, respectively. The average cessation date is 9th October which implies an early cessation in Gwer- East LGA. The length of the rainy season in Gwer- East indicated that the number of rainy days retrogresses as the average LRS is 212 days.

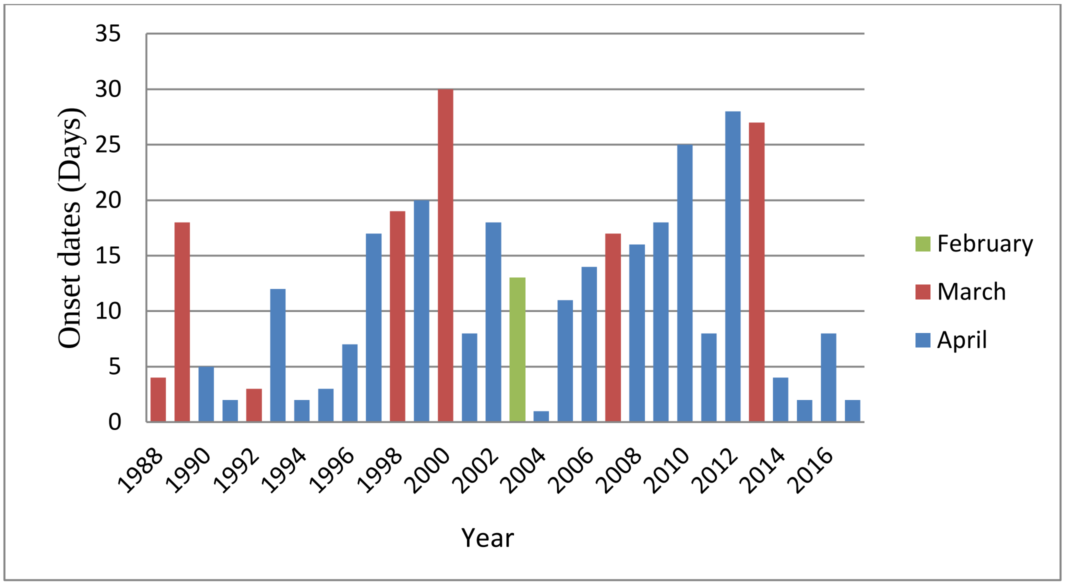

Figure 4.37 Onset of Rainfall Dates in Ado

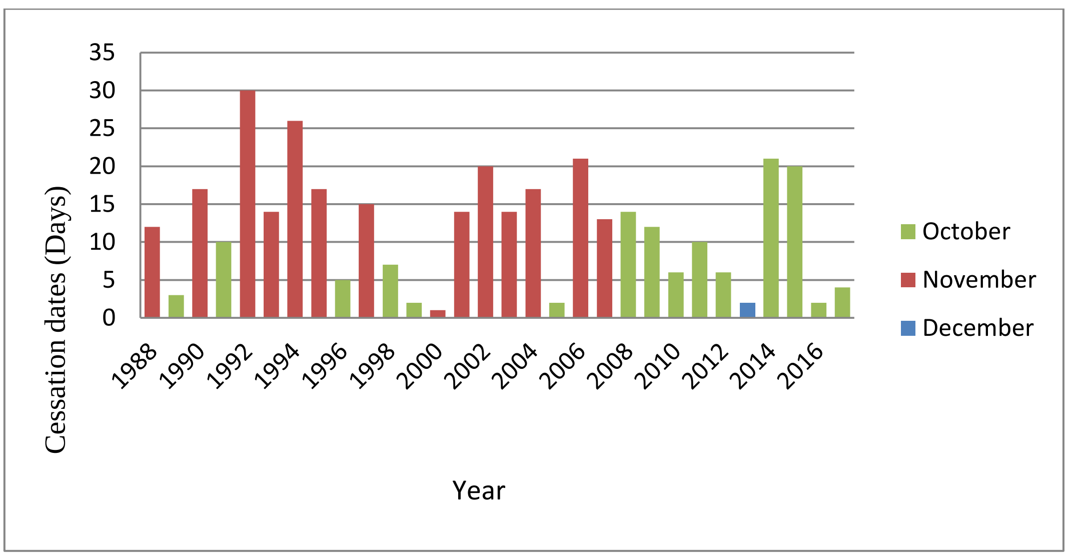

Figure 4.38 Cessation of Rainfall Dates in Ado

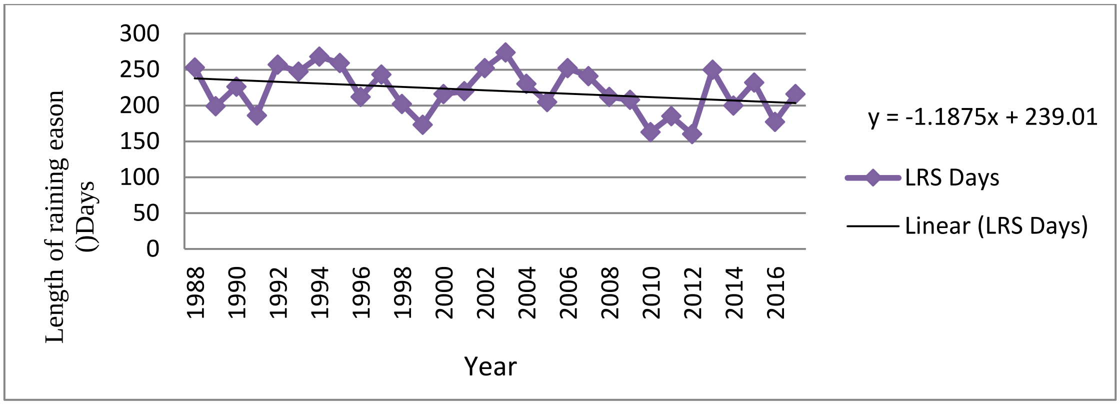

Figure 4.39 Length of Rainy Season in Ado

It was revealed from figure 4.37 to 4.39 the distribution of onset, cessation, and length of the rainy season in Ado LGA, the result reveals that the onset occurs in February, March, and April but mostly occurs in April. The average onset date is 6th April which indicates that planting crops can be effective in April. On the other hand, the cessation occurs in October, November, and December, with a highoccurrence of cessation in October, followed by November and once in December for the year 2013. The average cessation date is 17th November. This indicates that there is a late cessation in Ado LGA. The rainy season's length shows a negative trend line, which signifies a reduction in the number of rainy days of 221on averagely.

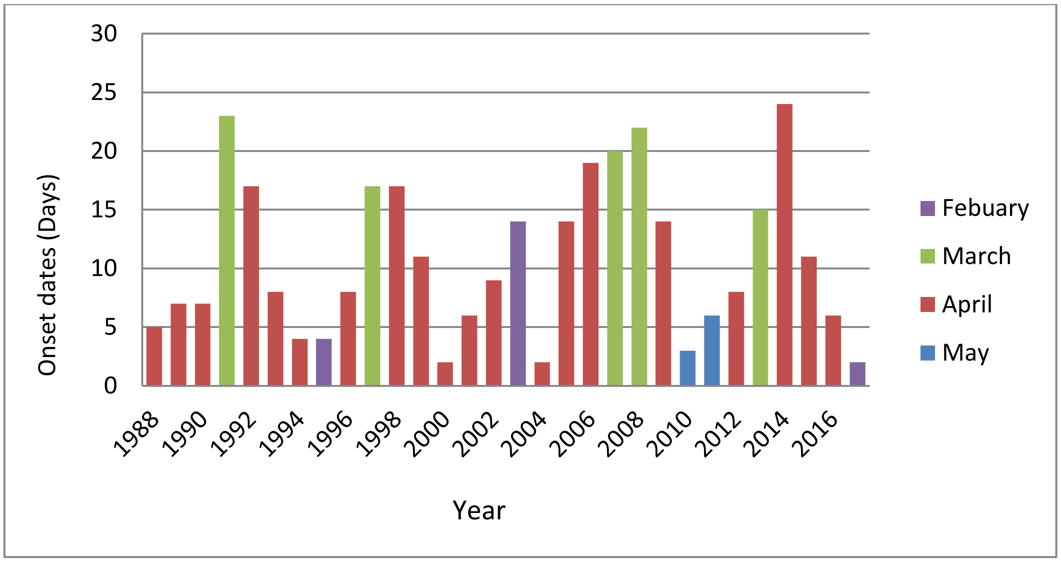

Figure 4.40 Onset of Rainfall Dates in Otukpo

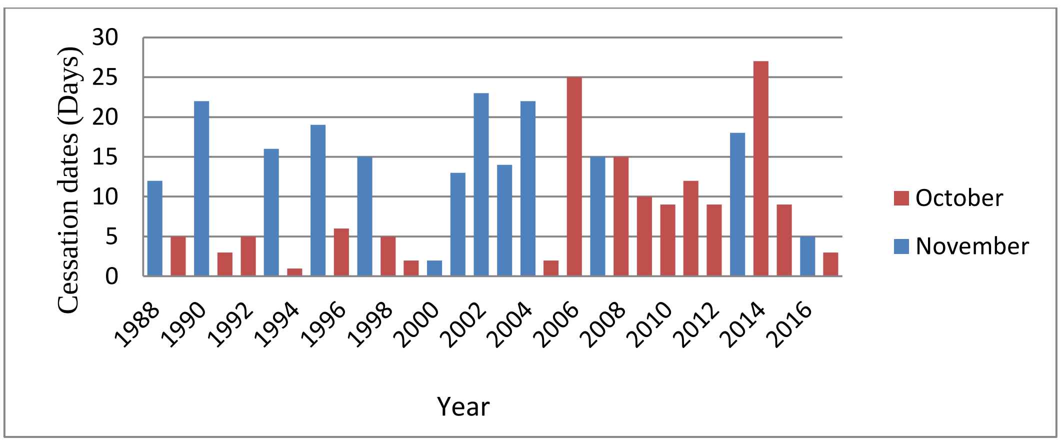

Figure 4.41 Cessation of Rainfall Dates in Otukpo

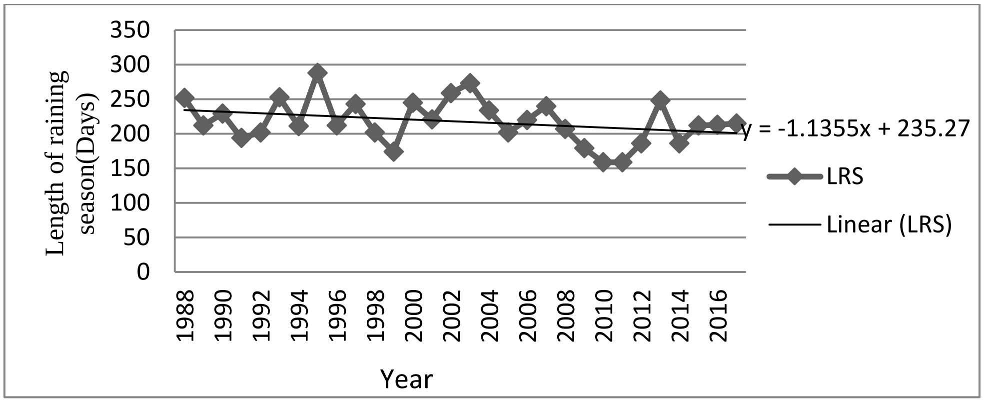

Figure 4.42 Length of Rainy Season in Otukpo

It was observed from figure 4.40 to 4.42 the onset, cessation, and length of rainy season in Otukpo, the onset date for the years reveals that April has the highest onset dates followed by March. The result also reveals that water available for planting of crops will be from 13th April on averagely; hence by this time, the soil will have sufficient water for planting. On the other hand, cessation shows that in all the years considered, the month of October is considered as the most prevalent month with a cessation date of 2nd October. The result shows that the cessation of rains in Otukpo shall be later than the average date of 6th October. While the length of rainy season in Otukpo LGA is averagely 218 days,there is a reduction in the length of rainy season around the Otukpo Local Government Area.

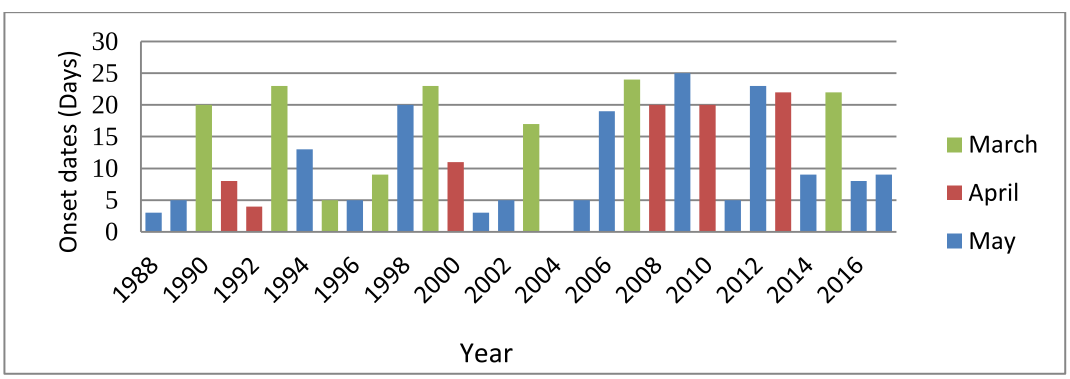

Figure 4.43 Onset of Rainfall Dates in Ohimini

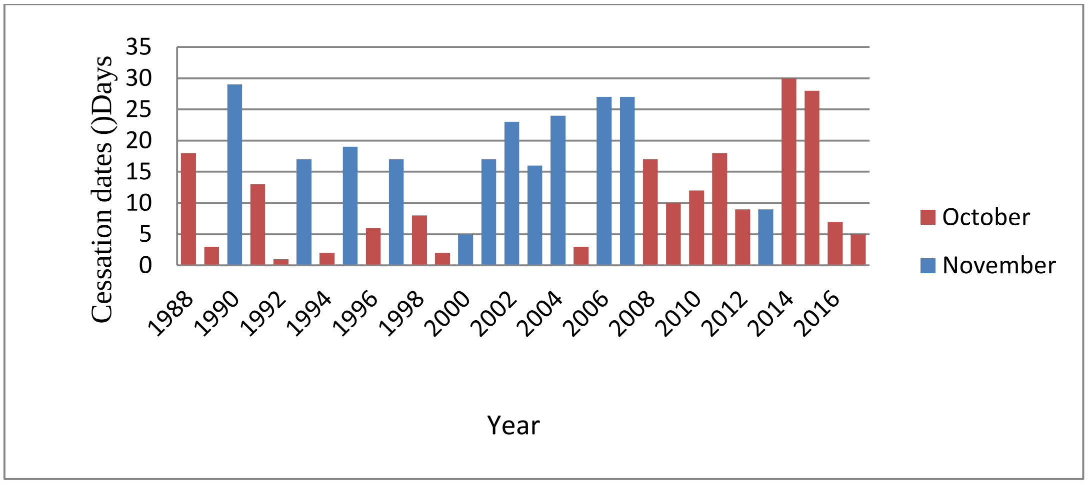

Figure4.44Cessation of Rainfall Dates in Ohimini

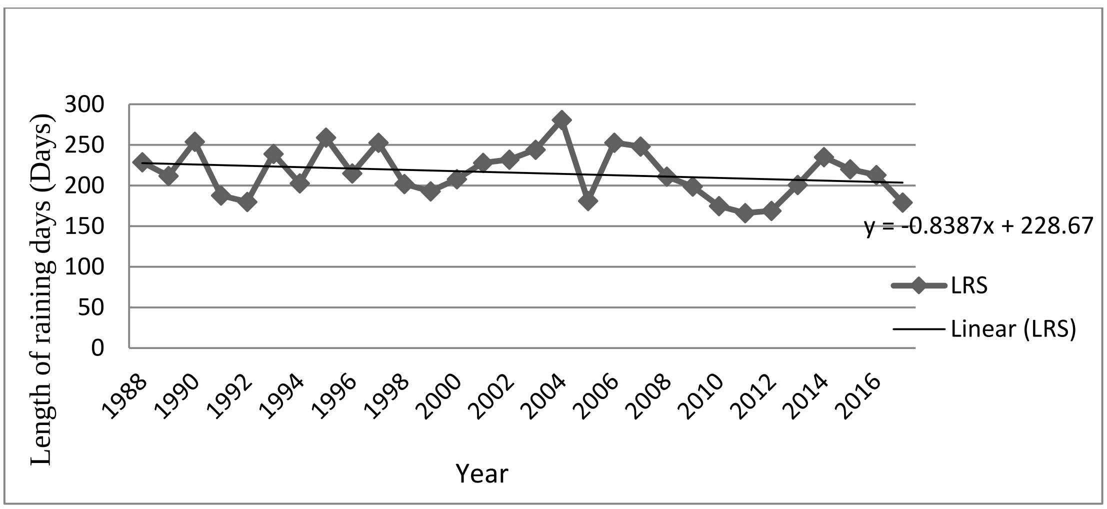

Figure4.45 Length of Rainy Season in Ohimini

It was revealed from figure 4.43 to 4.45 the onset, cessation and length of rainy season in theOhimini Local Government Area, it reveals that the onset of rains in this LGA occurs around March, April, and May; but mostly occurs in May;this implies late onset date in Ohimini as compare to any other LGA in this zone.The average onset date in Ohimini is 6th May. On the other hand, cessation dates reveal that it occurs mostly in October in most of the years. The cessation dates indicate that the rains will end earlier than 15th October. The average cessation date for Ohimini is 11th October. The Length of rainy season in Ohimini LGA reveals that the length of rainy season is decreasing from 230 days downward which is the highest in this zone.

Table 4.9 shows the distribution of average dates of onset of rainfall, cessation of rainfall and length of the rainy season. The onset dates occur from 4th, 13th, 15th April, and 6th May in theSouthern Zone. This implies that the differences in the onset dates in this zone are very wide. This signifies inconsistency which will give farmers problems in planning due to change in rainfall pattern. On the other hand,cessation dates have average dates of 6th October in Otukpo to 17th November in Ado with a wide margin average, and this will have a little difficulty on rain- fed farmers to be able to make a decision. The LRS ranges from 212days from Gwer- East.

Table 4.9Average Dates of Onset of rains, Cessation of Rains, and Length of RainySeason in the Southern Zone

LGA	AOD	ACD	ALRS
Gwer-east	15thApril	9th October	212
Ado	4thApril	17th November	221
Otukpo	13thApril	6th October	218
Ohimini	6thMay	11th October	230

4.3.3 Onset, cessation and length of rainy season in northern zone

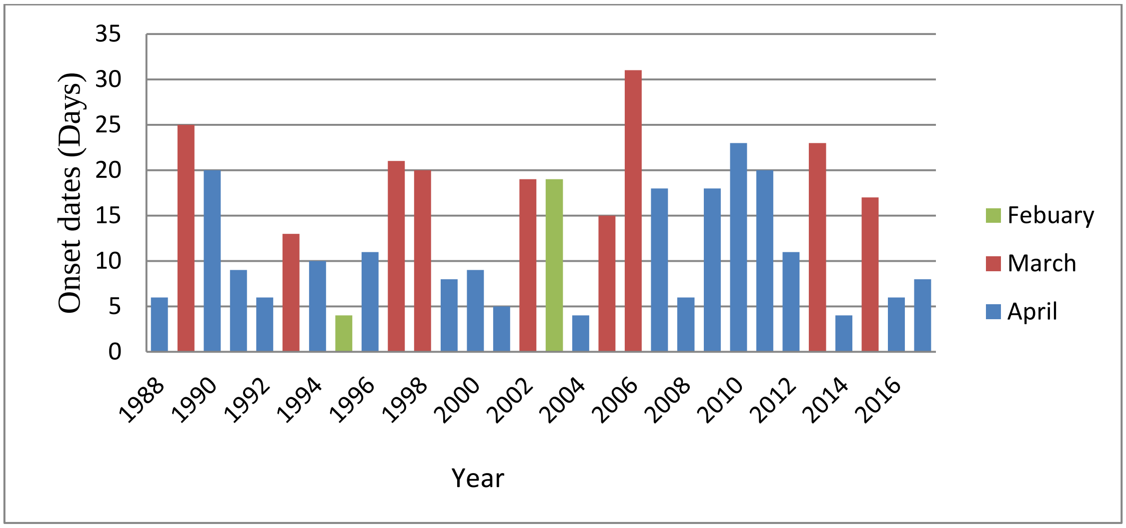

Figure 4.46 Onset of Rainfall Dates in Makurdi

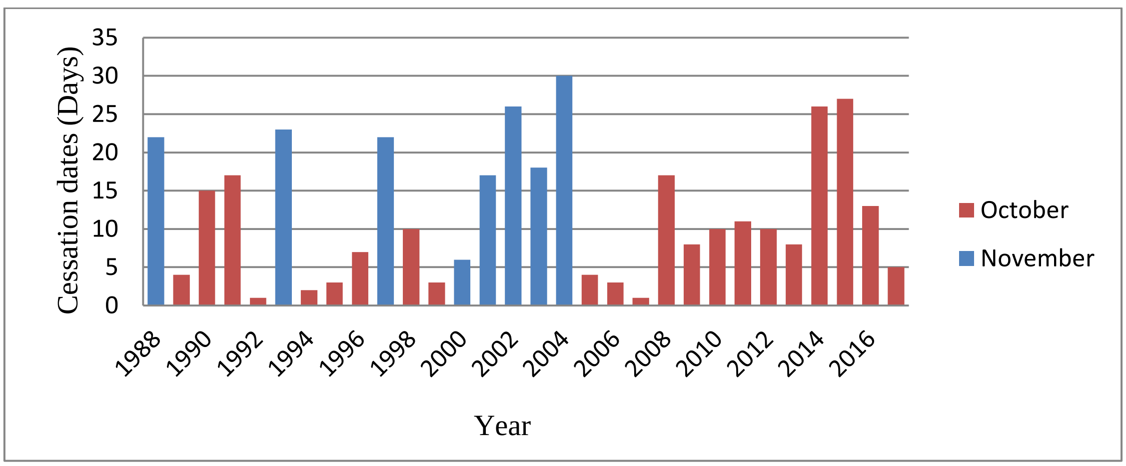

Figure 4.47 Cessation of Rainfall Dates in Makurdi

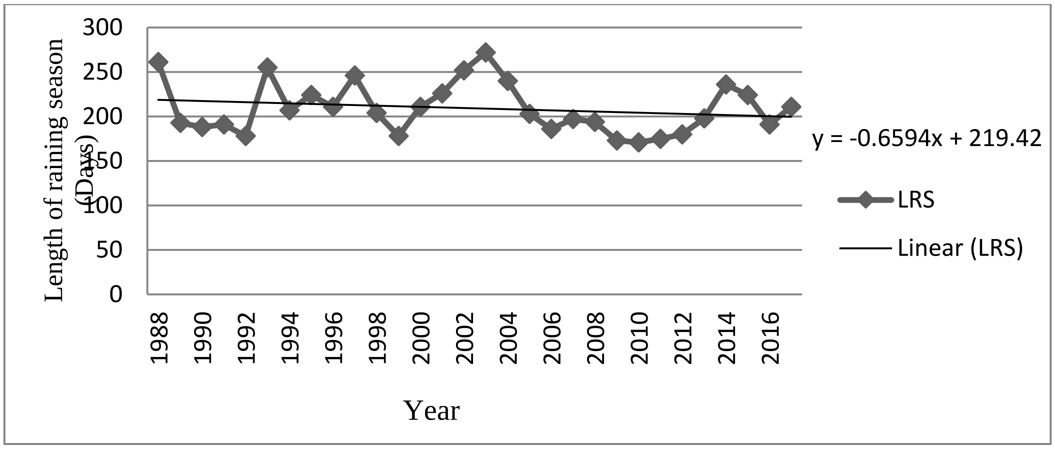

Figure 4.48 Length of Rainy Season in Makurdi

It was revealed from figure 4.46 to 4.48 the distribution of onset, cessation and length of rainy season in Makurdi LGA, it reveals that the onset of rains in Makurdi shall be earlier than the average date of 16th April. That also means there will be early onset of rains in Makurdi. The cessation of rains also indicates that there shall be a reduction from the average date of 9th October which implies early cessation of rains. While the length of rainy season has an average of 209 days which means there will be a decrease length of rainy season in Makurdi. This also means that most of the tuber crops such as yam and cassava that need water may suffer as a result of the early cessation dates.

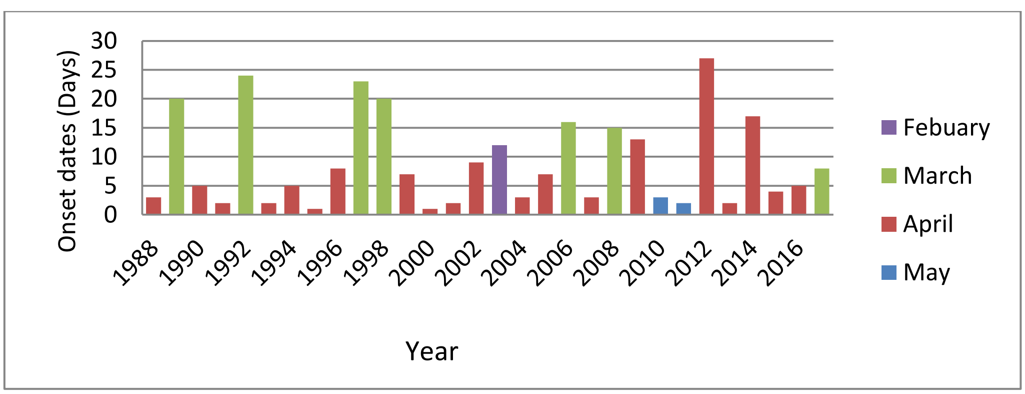

Figure 4.49 Onset of Rainfall Dates in Gwer-West

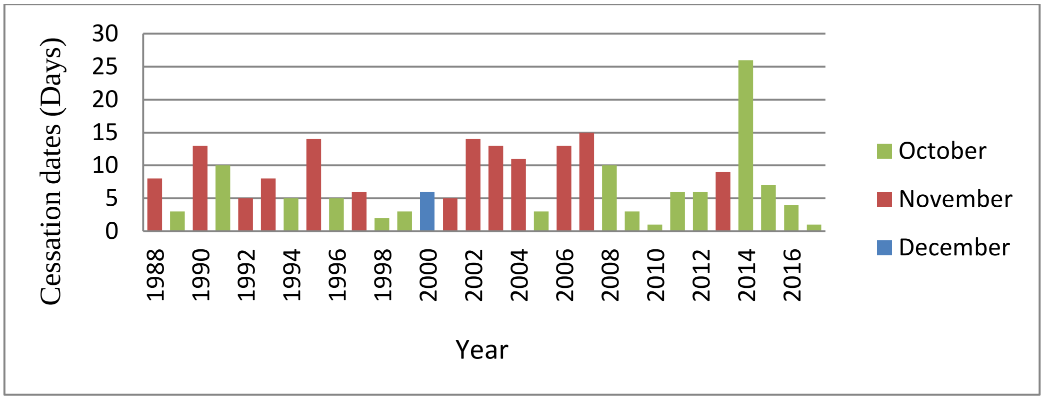

Figure 4.50 Cessation of Rainfall Dates in Gwer-West

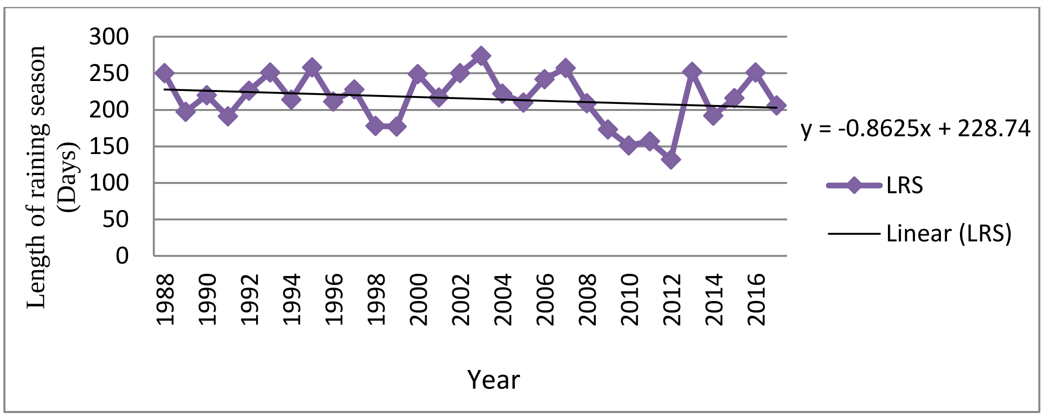

Figure 4.51 Length of Rainy Season in Gwer-West

It was observed from figure 4.49 to 4.51 the onset of rainfall, cessation of rainfall and length of the rainy season in Gwer- West Local Government Area, it reveals that the onset of rains in this LGA mostly occurs in April, followed by March, May, and February. The onset date in Gwer- West averagely occurs by 9th April which implies that, the onset shall be later than the average date of 9th April; it simply means that there will be the late onset of rains in Gwer- West. Cessation of rains in Gwer- West is prevalent in October with a date of 2nd October, which means the cessation of rains in Gwer- West shall be on the earlier date than the average date of 6th October, which implies the early cessation of rains.

The length of the rainy season in Gwer- West has an average of 215 days which means there will be a reduction in the rainy season in Gwer- West LGA.

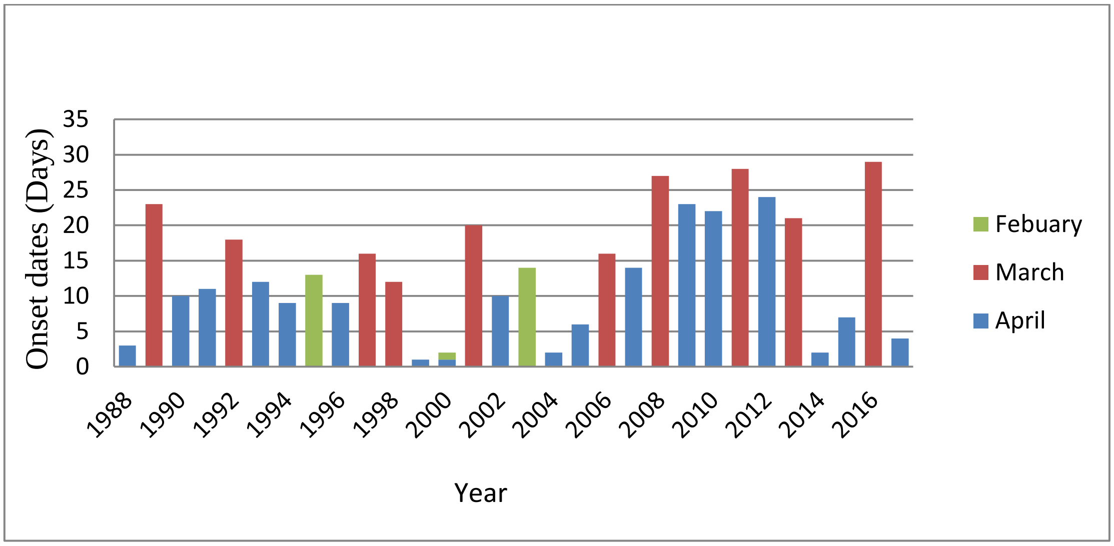

Figure 4.52 Onset of Rainfall Dates in Gboko

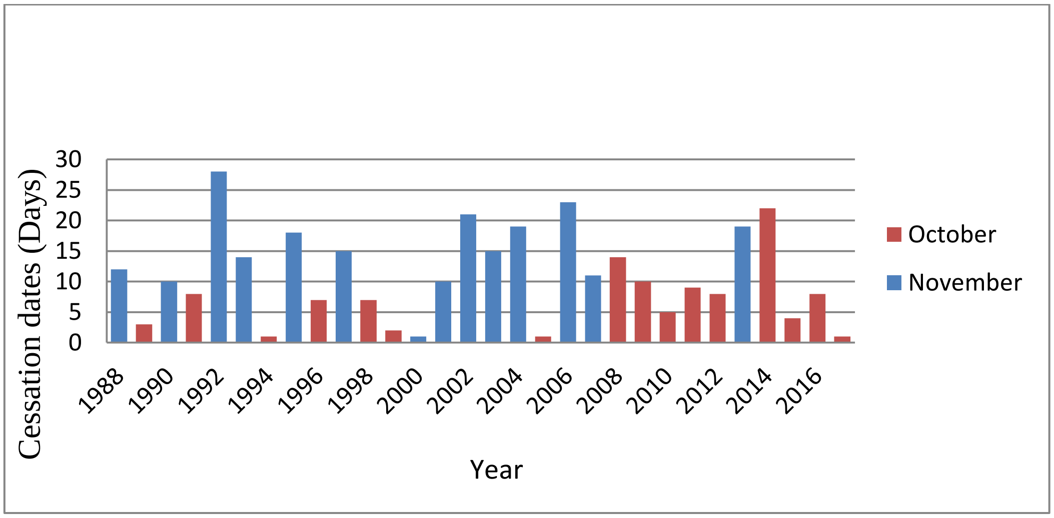

Figure 4.53 Cessation of Rainfall Dates in Gboko

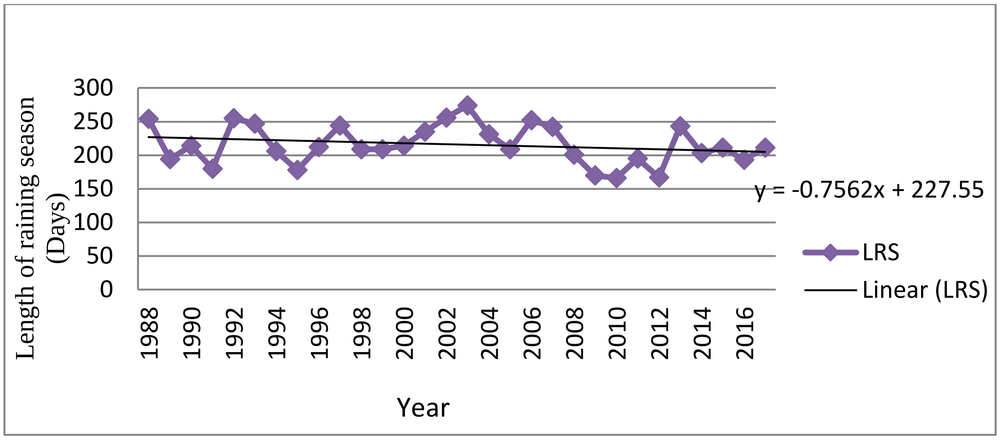

Figure 4.54 Length of Rainy Season in Gboko

It was revealed from figure 4.52 to 4.54 the onset of rainfall, cessation of rainfall, and length of the rainy season in Gboko LGA, it reveals that the onset of rains occurs mostly in April, followed by March and February. The average onset date is 14th April which implies that the onset date shall be later than the average date of 14th April. That also signifies there will be the late onset of rains in Gboko. Cessation, on the other hand, indicates that the date of cessation mostly around October and November. It reveals an average of 7th October which means there shall be earlier cessation than the average date of 7th October. This implies the early cessation of rains. In contrast, the length of raining season in Gboko LGA has decreasedby an average of 209 days.

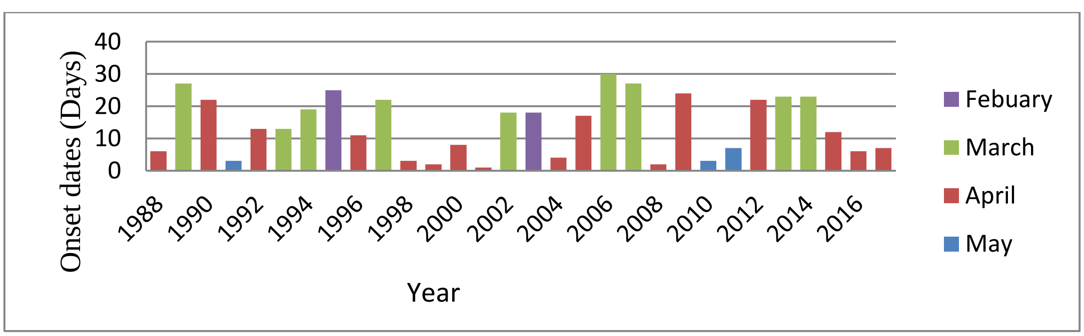

Figure 4.55 Onset of Rainfall Dates in Tarka

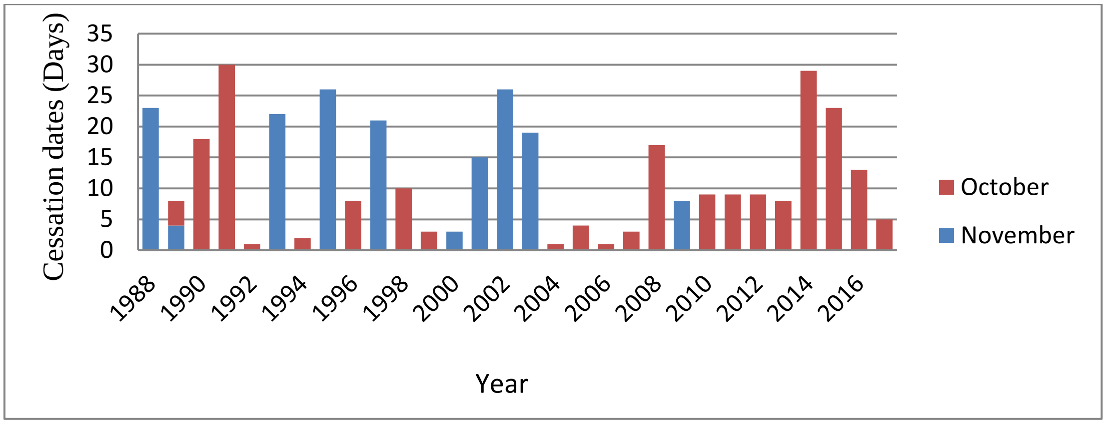

Figure 4.56 Cessation of Rainfall Dates in Tarka

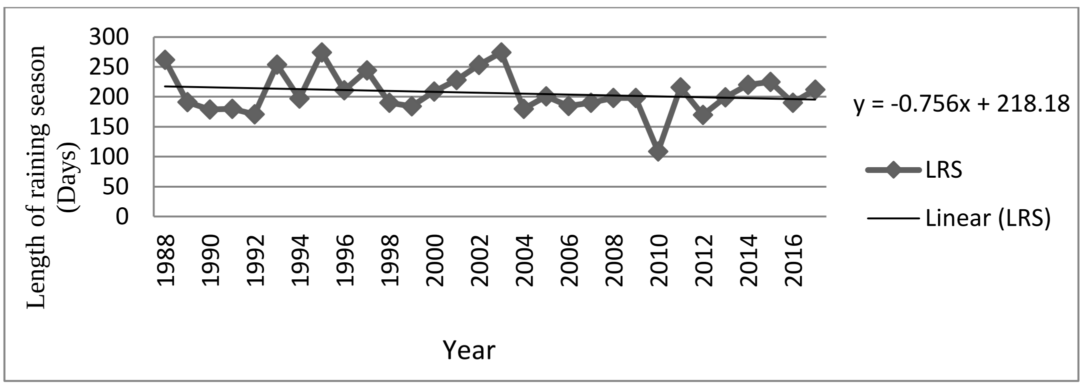

Figure 4.57 Length of Rainy Season in Tarka

It was noted from figure 4.55 to 4.57the distribution of onset date, cessation and length of the rainy season which falls in the Tarka Local Government Area, it reveals that the onset of rains mostly occurs by April in most of the years followed by March, February and May. The onset in Tarka LGA extended to May from 1991, 2010, and 2011, which implies that despite there is the onset of rains from April and March in most of the years, farmers, on the other hand, should quantify the efficiency of rains available in the soil before planting; hence the onset may extend to May. The average date of onset rains in Tarka LGA is 18th April. This indicates that there may be a late- onset date of rains in Tarka LGA.

On the other hand, the cessation dates show that October and November are the two months in all the years considered 1988-2017 that the cessation dates occur, but is more prevalent in October, which indicates that from 2010 – 2017 cessation date is between 5th to 28th October. This reveals that cessation dates will be earlier than the average date of 10th October. The length of rainy season reveals that, there may be a reduction of rainy days in Tarka LGA, with an average of 206 days which is the least in this zone.

Table 4.10 shows the average distribution of onset dates, cessation dates, and Length of rainy season in the Northern zone of Benue State, which comprises Makurdi, Gwer- West, Gboko, and Tarka Local Government Area. The onset dates in these LGAs range from 9th, 14th, 16th, and 18th April. In contrast, the cessation dates range from 6th October to 10th October. The LRS ranges from 206 days to 215 days. This result shows that, the onset days seem to be changing from one LGA to the other, the cessation date is almost constant. The LRS is not uniform, and the least is found in Tarka while the longest is found in Gwer-West.

Table 4.10 shows the average dates of Onset of rains, Cessation of Rains and Length of rainy season in the Northern zone

LGA	AOD	ACD	ALRS
Makurdi	16thApril	9th October	209
Gwer-west	9thApril	6th October	215
Gboko	14thApril	7th October	209
Tarka	18thApril	10th October	206

4.3.4 Rainfall characteristics effects on selected crops

Table 4.11 reveals the effect of onset and cessation on groundnut yield in Benue.Interestingly, regression analysis of the effect of rainfall onset and cessation revealed a value of 0.349 and -0.286, respectively, on groundnut yield. This means that, late rainfall onset results in more groundnut yields while late cessation results in poor yields. The months were represented in ascending order, with January having a value of 1 to December having a value of 12. Therefore the inverse relationship shows the lower the month, the higher the effect. This means onset in March (with a value of 3) has more effect than onset in April (with a value of 4). This is because if the trend of onset is moving from March to April or May, there will be an increase in groundnut yield. On the other hand, there is a negative regression value of rainfall cessation on groundnut yield in Benue. The length of the rainy days has increased, which has no significant effects on groundnut yield hence the crop has short lengths of the growing season of 150 days.

Table 4. 11 Shows theEffect of Onset and Cessation on Groundnut Yield in Benue

Model	Unstandardized coefficient	Standardized coefficient	T-value	sig
Rainfall onset	11.899	0.349	1.292	0.95
Rainfall cessation	-15.349	-0.286	-1.035	0.95

Table 4.12 shows the effect of onset and cessation on maize yield. Regression analysis on the effect of onset and cessation of rainfall on maize yield revealed the value of 0.065 and -0.16, respectively. This shows that the late onset of rainfall in Benue increases maize yield while late cessation reduces yield. Years with early cessation tend to have more yields.

Maize is widely cultivated in Benue. Maize yield revealed the value of 0.065 and 0.16, which implies that late rainfall onset results in more maize yields while late cessation result to poor yields. This is supported by the findings of Traore *et al*. (2013), who reported variability in crop yields due to rainfall onset and cessation in Mali. The months were represented in ascending order, with January having a value of 1 to December having a value of 12. Therefore the inverse relationship shows the lower the month, the higher the effect. This means onset in March (with a value of 3) has more effect than onset in April (with a value of 4). The implication of this is that if the trend of onset is moving from March to April or May, there will be increase in sorghum yield supported by Bekele *et al*. (2017). As maize is widely cultivated in Benue, which is the crop used by the locals to prepare soft foods such as Pap and Tuwo, this will affect the income and available food for consumption if it is affected by the changes in onset and cessation (Ngetich *et al*. 2014; Eludoyin*et al*. 2017). The length of the rainy days, on the other hand, has reduced, which has no significant effects on maize yield, hence the crop has short lengths of the growing season of 145 days or less.

Table 4. 12 Shows the Effect of Onset and Cessation on Maize Yield in Benue

Model	Unstandardized coefficient	Standardized coefficient	T-value	sig
Rainfall onset	0.665	0.065	0.226	0.95
Rainfall cessation	-2.580	-0.160	-0.562	0.95

Table 4.13 shows the effect of onset and cessation on yam yield in Benue. The regression analysis of the effect of onset and cessation of rainfall on yam yield in Benue revealed regression coefficients of -0.083 and 0.124 respectively. That means that yam yields are

higher during years of early- onset than years of late- onset. On the other hand, yam yields are higher during years of late cessation. In addition, the result of regression analysis of the effect of onset and cessation of rainfall on yam yield in Benue revealed a regression coefficient of -0.083 and 0.124, respectively. That means that yam yields are higher during years of early- onset than years of late- onset.

On the other hand, yam yields are higher during years of late cessation. This is in line with Oruonye et al. (2016), who documented that early cessation of the rainy season can result in the cutting short of the growing season of crops and consequently result in crops failing to reach their physiological maturity stage. The length of the rainy days has increased, which has positive effects on yam, hence the crop has long lengths of the growing season of 8-11 months after planting.

Table 4.13 Shows theEffect of Onset and Cessation on Yam Yield in Benue

Model	Unstandardized coefficient	Standardized coefficient	T-value	sig
Rainfall onset	-48.028	-0.083	-0.288	0.95
Rainfall cessation	113	0.124	0.443	0.95

Conclusively, this current research agrees with Agidi (2017) a research conducted in Nasarawa State where he emphasized that crop yields solely depends on the onset and cessation of rainfall, crops are mostly affected by the cessation of raining season. This demonstrates end has an awesome impact on crop yield as looked at that of onset of the drizzling season. There ought to be an arrangement for early cautioning and reacts frameworks which are essential for diminishing the danger of life and rural misfortunes in Benue postured by onset and end of the down-pouring- season

4.4 Delineation of Agro-Climatic Zones for Effective Utilization of the Limited Agricultural Lands in Benue State

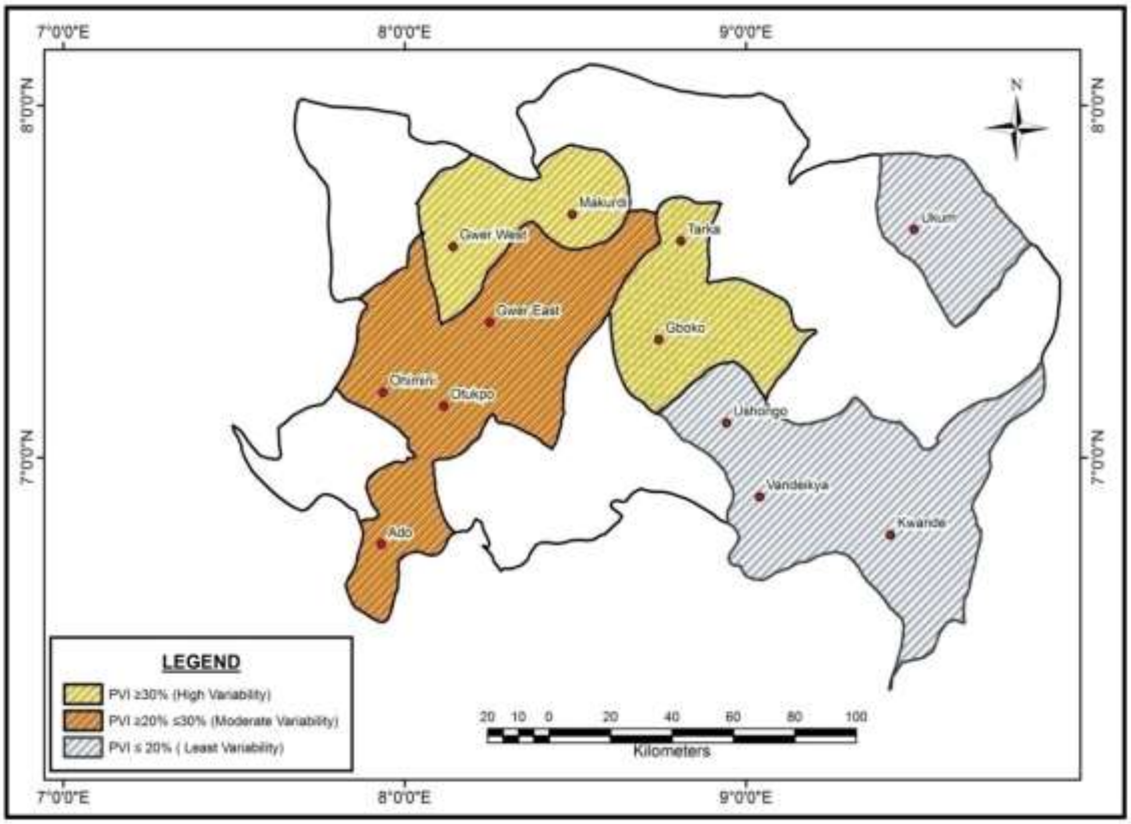

Figure 4.58Moisture Index Derived from Precipitation Variability Index (PVI)

Source: BNARDA, 2013

The three zones in Benue under Study consist of the Northern, Eastern, and Southern zone, while the crops consist of Cereals (Rice and Maize), Tubers or roots (Yam and Cassava) and Legumes (Groundnut and Soyabeans). The Eastern zone of the State comprises of Ushongo, Vandeikya, Kwande, and Ukum. The Northern zone comprises of Makurdi, Gwer-West, Tarka, and Gboko, and the Southern zone comprises Otukpo, Ado, Ohimini, and Gwer-East.This analysis that results in the determination of the moisture index forms the backbone of the discussion of the agro-ecological characterization. The spatial distribution of the moisture index in Benue State is illustrated in Figure 4.58. The measure of periodicity is frequency. That is the frequency at which a drought period can occur. This periodicity was used to unmask the salient feature of rainfall over Benue State (figure 4.58). The moisture index model was first applied on Nasarawa State (Agidi 2017) whose less than 20% periodicity in the South -Eastern Nasarawa bordered the Benue. It is also observed to have similar characteristics of rainfall (figure 4.58).

The characteristic pattern of rainfall divided the study area into three climatic zones; the zone of less variable precipitation (precipitation periodicity less than 20%), are the Eastern part, the zone of highly variable precipitation periodicity greater than 30% consists of the northern part and the zone of moderate variable precipitation periodicity of greater than 20 % but less than 30 % which occurs in the Southern zone. The zone of less variable rainfall received almost uniform rainfall during the rainy period, while the zone of highly variable rainfall has drier spell periods during the active raining months.

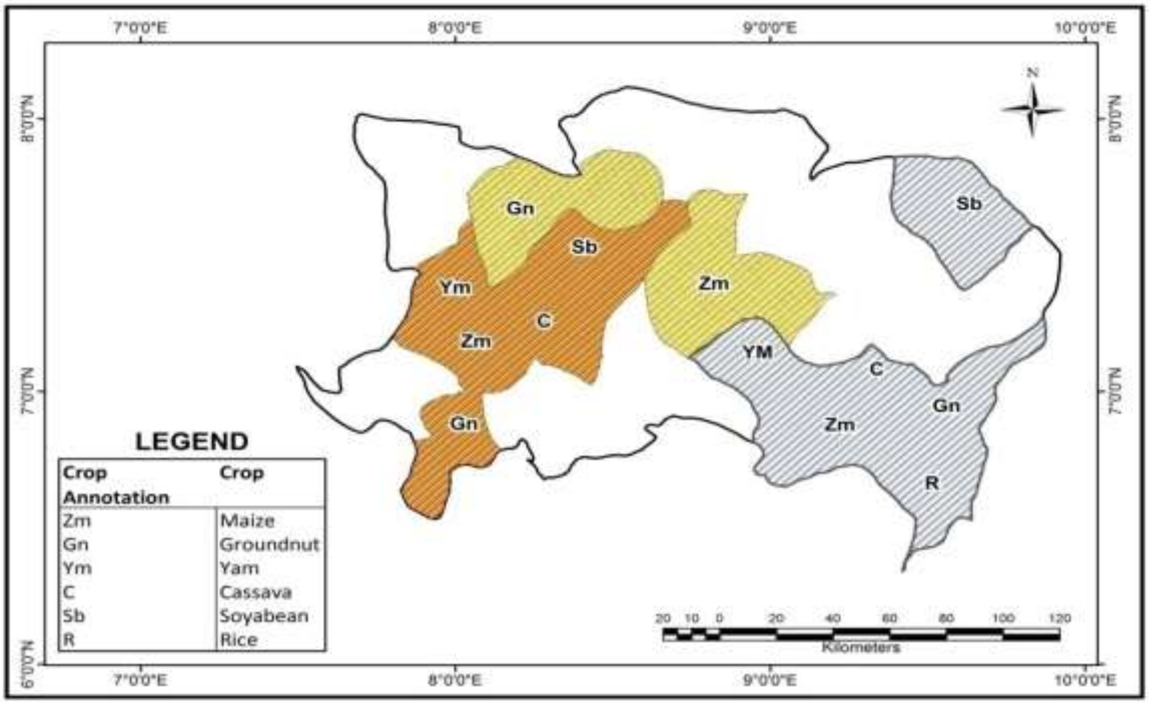

Figure 4.59Crop Zones Characterization of the Study Areas

Source: BNARDA, 2013

Climate is probably the most important factor determining what crops can be grown in any given geographic region. The most dominant climatic characteristic in this regard is precipitation, and according to Raoul (2005),agro-ecosystems are often named after their predominant crop. Owing to the pressure on the arable land of the Benue State, we cannot afford the luxury of defined crop belts if we are also concerned about sustaining the farm lands. Bearing this in mind, the researcher derived crop zones for the Benue State, as illustrated in Figure 4.59. The crops consist of Cereals (Rice and Maize), Tubers or roots (Yam and Cassava), and Legumes (Groundnut and Soyabeans). The Eastern zone of the State comprises Ushongo, Vandeikya, Kwande, and Ukum. The Northern zone comprises Makurdi, Gwer-West, Tarka, and Gboko, and the Southern zone comprises Otukpo, Ado, Ohimini, and Gwer-East.

The Eastern zone shows that tubers or root crops (yam and cassava) are mostly cultivated in this zone;for instance, yam and cassava are largely cultivated in all the Local Government Areas in the Eastern zone (Ushongo, Vandeikya, Kwande, and Ukum). Furthermore, the Eastern zone is also known for the cultivation of Legumes crops (Groundnut and Soyabeans) in a large quantity; for instance, soyabeans and groundnut are largely cultivated in all the LGAs of the Eastern zone. Also, the Eastern zone is known for the cultivation of Cereal crops (Rice and Maize) in a large quantity because of the efficient amount of rainfall present in the zone.

The Northern zone shows that, maize and groundnut are being produced in a large quantity, most especially in Tarka, Gboko, Makurdi, and Gwer- West which indicated that despite the low amount of rainfall in these LGAs it may not likely affect these crops. The Southern zone, on the other hand, shares the same characteristics of rainfall as it is in the Eastern zone, therefore, having the same crop growth such as rice, maize, groundnut, yam, cassava, and soyabean in large quantity especially in Otukpo, Ado, Ohimini and Gwer-East LGAs of Benue State.

This study agrees with the research conducted by (Hassan, 2013) in FCT Abuja, which revealed that the Eastern zone of the FCT experience much rainfall and perhaps support the growth of tuber crops, while the Northern zone of FCT experienced less amount of rainfall and support less rain-fed crops. Therefore, this current study considered different crops and where such crops grow in their respective zones in Benue State. It was concluded that the cereals, legumes, and tuber crops grow very well in the Eastern and the Southern zone,respectively, because of the abundant rainfall in the zones.In contrast, in the Northern Zone, where the rainfall is minimal, it is only groundnut and maize that grows in a large quantity.

4.5 Identification ofAdaptation Strategies for Optimum Crop Yield in the Study Area.

This section deals with the responses gotten from the administered questionnaire to the respondents across the selected LGA in Benue State. The section contains four sections; the socio-economic and farm- specific characteristics of farmers, followed by farmers' agricultural systems and crop yield then the farmer's knowledge of rainfall variability, and farmers' adaptation strategies and constraints. To a larger extent, the findings may help to understand farmers response to rainfall variability andgive insight into the constraint to their having high yield.

4.5.1 Socio-economic, institutional, and farm-specific characteristics of the respondents

Table 4.14shows the age distribution of respondents. More than 80% of respondents are between the age of 35 years and 65 years. The result shows that most of the farmers are in their average age. This is perhaps an outcome of government action to have everyone actively engaged in agriculture.

Table 4.14 Distributions of the Respondents by age

Age	Frequency	Percentage
5-20	63	8.75 %
21-35	104	14.44 %
36-50	357	49.58 %
51-65	181	25.14 %
> 65	15	2.08 %

Table 4.15 indicates that most farmers in the selected Local Government Area of Benue state are predominantly married. They make up 69.03 % of the total respondent. While singles have 23.33%, Divorce has 0.69%, and widow 6.94 %

Table 4.15 Distributions of Respondents by Marital Status

Marital Status	Frequency	Percentage
Married	497	69.03 %
Single	168	23.33 %
Divorce	05	0.69 %
Widow	50	6.94 %

Table 4.16 reveals that most of the respondents are male makingup 71 % while females are 28.89 % of the respondents. This finding agrees with the result of (Osabo, et al.,

2014),which noted that men are 74.17 % and women 25.83 % of crop farmers in the savanna region of Nigeria. Male dominance in this regards might not be unconnected to the traditional role of men as bread-winners of their homes, especially in Africa.

Table 4.16 Sex Distributions of Respondents

Sex distribution	Frequency	Percentage
Male	512	71.11 %
Female	208	28.89 %

Table 4.17 indicates the distribution of respondents by the number of the workforce engaged in their farms. 41.11 % said they have about 6-10 workers in their farms which are in the highest. This can be deduced that most of the workforce are family members, either children or relatives, it can further deduce while the lowest is about 4.03 % of respondents which said they have about 4.03 % of the workforce in their farms.

Table 4.17 Distribution of Respondents by Number of Workforces

Workforce	Frequency	Percentage
1-5	97	13.47 %
6-10	296	41.11 %
11-15	170	23.61 %
16-20	85	11.81 %
21-25	43	5.97 %
26-30	29	4.03 %

Table 4.18 shows the distribution of distance to farm by the respondents. More than 71 % of the respondents have their distance to the farm from 0-3km, and this shows that they are not far from their farm and have the opportunity for better care of the farm. By protecting their crops from pests or giving quick attention to any form of abnormality noticed. About 17% of respondents have a distance between 6km to above 10km, which is quite far from home and might need some form of transportation to get to their farms.

Table 4.18 Distributions of respondents by farm distance

Distance	Frequency	Percentage
0-1km	307	42.64 %
2-3km	205	28.47 %
4-5km	78	10.83 %
6-7km	53	7.36 %
8-9km	30	4.17 %
Above 10km	47	6.53 %

Table 4.19 shows that 80.27% of respondents do not have access to credit facilities in any form. In contrast, 19.72% do have access to credit facilities. Financial institutions give credit facilities only to clubs or cooperative societies that many farmers have not joined yet. The difficult and cumbersome process and conditions of getting credit facilities is another factor that might have influence the high number of the respondent in Benue State not having access to credit facilities.

Table 4.19 Distributions of Respondents by Access to Credit Facilities

Access to credit facilities	Frequency	Percentage
Have access	142	19.72 %
Have no access	578	80.27 %

Table 4.20reveals that 69.03 % of farmers in the study areas have no other source of income other than farming, 30.97 % engaged in activities other than farming. The high dependence on rain- fed farming by the respondents is a great risk to the economy. This is because any negative consequence of climate will render a lot jobless.

Table 4.20 Distributions of Respondents by Other Sources of Income

Other sources of income	Frequency	Percentage
Available	223	30.97 %
Not available	497	69.03 %

Table 4.21 shows the distribution of respondents according to their access to extension workers. 67.78 % of the respondents have access to extension workers, while 32.22 % said they have no access to extension workers. The high extension workers is an omen for great things because extension workers are trained and send to disseminate information further and demonstrate the use of seed hybrid and improve farming techniques to farmers.

Table 4.21 Distributions of Respondents by Access to Extension Workers

Access to Extension Workers	Frequency	Percentage
Access	488	67.78 %
No access	232	32.22 %

Table 4.22 shows the distribution of the number of times extension workers visit the farmers. 30.56 % of the respondents have 16-20 numbers of visits in a year, while 29.31 % have no visits at all. The percentage difference of visit by extension workers and no visit is not wide, which indicate quite a good numbers of farmers are still not met.

Table 4.22 Distributions of Respondents by Number of Extension Workers Visited in a year

Extension workers visited in a year	Frequency	Percentage
0-5	101	14.03 %
6-10	35	4.86 %
11-15	57	7.92 %
16-20	220	30.56 %
21-25	96	13.33 %
NON	211	29.31 %

Table 4.23 shows the distribution of the level of education of the respondents in the study areas. 39 % of the respondent has no formal education while more than 60 % of the respondents have attended at least primary, secondary and tertiary education. This reveals that most of the respondents are literate and hence were easier to understand concepts of rainfall variability and adaptation strategies for excesses of rainfall variability.

Table 4.23 Distributions of Respondents by Level of Education

Level of Education	Frequency	Percentage
Tertiary	97	13.47 %
Secondary	189	26.25 %
Primary	150	20.83 %
Non	284	39.44 %

4.5.2 Agricultural system and crop yields

Table 4.24 shows the distribution of farmers in the study area. 87.50 % revealed they are rain- fed farmers, which means they depend on rainfall for their farming activities, while 12.50 % are irrigation farmers.

Table 4.24 Distribution of Respondents by Type of Farming

Type of farming	Frequency	Percentage
Rainfed	630	87.50 %
Irrigation	90	12.50 %

Table 4.25 shows the distributions of the crops grown under study in the study areas. 37.22 % of the farmers are engaged in root and tuber crops (yam and cassava) farming. 34.58 % are into cereal crops (rice and maize) farming, while 28 % are for legume (soyabeans and groundnuts) farming. The almost uniform distribution of the percentage of types of crop grown is because of suitable conditions for the growth of the crops in all the zones. Tuber crops have higher percentage because it has short growing period and suitable in all the soil across the State. In comparison, cereal has less percentage because it is usually confirmed along with waterlogged areas and highly water- dependent.

Table 4.25 Distribution of Respondents by Type of Crops Grown

Types of crops grown	Frequency	Percentage
Yam (Dioscoresspp)	171	23.75 %
Maize (Zea mays)	116	16.11 %
Rice (Oryza Sativa)	133	18.47 %
Cassava (manihot esculenta crantz)	97	13.47 %
Soyabeans (Glycine max)	88	12.22 %
Groundnut (Arachis hypogaea)	115	15.97 %

Table 4.26 shows the distribution of the type of farming practice by the respondents. 56.81 % of the respondents are involved in mixed farming, which is rearing animals and crop farming on the same piece of land. 34.72 are mainly crop farmers, while 8.47 % are pastoralists.

Table 4.26 Distributions of Respondents by Type of FarmingCultivated

Farming Practice	Frequency	Percentage
Mixed Farming	409	56.81 %
Pastoral	61	8.47 %
Crop Farming	250	34.72 %

Table 4.27 shows the distributions of farming system practice among the respondents in the study area.50.97% of respondents are involved in multiple crop farming. 24.31% are into monoculture, while 10.14% are involved in irrigation farming.

Table 4.27 Distributions of Respondents by Type of Farming Practice

Variable	Frequency	Percentage
Farming system practice		
Multiple cropping	367	50.97 %
Irrigation	73	10.14 %
Monoculture	175	24.31 %
Others	105	14.58 %

Table 4.28 shows the distributions of yam harvested by respondents per annum. 46.39 % of respondents harvest between 100-500 tubers of yam per annum, which is the highest percentage among respondents. 11.94 % harvest between 6000 and above, which is the least.

Table 4.28 Distributions of Respondents by Total Harvest of Yam per Annum

Total harvest of yam in a year (Tubers)	Frequency	Percentage
100-500	334	46.39 %
600-1000	205	28.47 %
1000-5000	95	13.19 %
6000 and above	86	11.94 %

Table 4.29 shows the distributions of total harvest Maize per annum among respondents. 55.97 % harvest between 10-20 bags of maize per annum, which is the highest percentage among the respondent. While 10.28 % harvests between 110 and above bags which is the least percentage among the respondents.

Table 4.29 Distributions of Respondents by the Total Harvest of Maize per Annum

Total harvest of maize in a year (Bags)	Frequency	Percentage
10-20	403	55.97
30-50	147	20.42
60-100	96	13.33
110 and above	74	10.28

Table 4.30 shows the distribution of cassava harvested by respondent per annum. 45.83 % of the respondents; harvest is between less than 1000 tubers per annum which is the highest

percentage among the respondents. 3.61 % harvest is between 15000 and above, which constitutes the least percentage.

Table 4.30 Distributions of Respondents by Total Harvest of Cassava in a Year

Total harvest of Cassava in a year(Tubers)	Frequency	Percentage
less than 1000	330	45.83 %
1000-5000	204	28.33 %
6000-10000	97	13.47 %
11000- 15000	63	8.75 %
greater than 15000	26	3.61 %

Table 4.31 shows the distributions of the total harvest of rice among the respondents in the study area. 46.67 % harvest is between 1000-2000kilogrammes of rice per annum,representing the highest percentage among the respondents. In contrast, the least is 1.53 %, with a total harvest of above 11000 kilogrammes per annum.

Table 4.31 Distributions of Respondents by theTotal Harvest of Rice per Annum

Total harvest of Rice per annum (Kg)	Frequency	Percentage
less than 1000	126	17.50 %
1000-2000	336	46.67 %
3000-5000	146	20.28 %
6000-10000	101	14.03 %
11000 and above	11	1.53 %

Table 4.32 shows the distributions of the total harvest of soyabeans among the respondents in the study area. 47.22 % harvest is between 1000-2000kilogrammes of soyabeans per annum representing the highest percentage among the respondents. In contrast, the least is 1.67 % with a total harvest of above 10000kilogrammes per annum.

Table 4.32 Distribution of Respondent by theTotal Harvest of Soybeans per Annum

Total harvest of Soybeans per annum (Kg)	Frequency	Percentage
less than 1000	167	23.19 %
1000-2000	340	47.22 %
3000-5000	102	14.17 %
6000-10000	99	13.75 %
10000 and above	12	1.67 %

Table 4.33 shows the distributions of the total harvest of groundnut among the respondents in the study area. 42.64 % harvest is between 10-20 kilogrammes of groundnut per annum, representing the highest percentage among the respondents. In contrast, the least is 1.39 %, with atotal harvest of above 100 kilogrammes per annum.

Table 4.33 Distributions of Respondents by theTotal Harvest of Groundnut per Annum

Total harvest of Groundnut per annum (Bags)	Frequency	Percentage
less than 10	199	27.64 %
10-20	307	42.64 %
30-50	126	17.50 %
60-100	78	10.83 %
100 and above	10	1.39 %

Table 4.34 shows the distribution of what farmers felt are responsible for changes (increase or decrease) in crop yield.30.28 % of the respondents said the change in crop yield results from the use of improving crop species. This represents the highest percentage among the respondents. 3.75 %, which is the least choice by respondents, said that lack of funds is responsible for changes in crop yield.

Table 4.34 Distributions of Farmers Perceived Causes of theChanges in Crop Yield

What is responsible for the change?	Frequency	Percentage
Increase in farm size	72	10.00 %
Herdsmen crisis	43	5.97 %
Early planting	76	10.56 %
Used of fertilizer/pesticides	70	9.72 %
Climate change	48	6.67 %
Rain pattern	124	17.22 %
Uses of new crop species	218	30.28 %
Use of improve technology	42	5.83 %
Lack of fund	27	3.75 %

4.5.3 Knowledge of farmers on rainfall variability

Table 4.35 shows the distribution of respondents to whether they belong to a farming club. 76.39 % do not belong to any crop farmers club, while 23.61 % belong to a single farmers club. Therefore the high percentage of the respondents not belonging to any farming club, the implication is that many of them may not have access to credit facilities because banks give loans only to farming clubs and or cooperative society. Aclub can also be useful for information dissemination and easy sharing of ideas.

Table 4.35 Distributions of Respondents on Belonging to Farmers Club

Do you belong to farmers club?	Frequency	Percentage
Belong	170	23.61 %
Not belong	550	76.39 %

Table 4.36 shows the distributions on their knowledge of rainfall variability.66.94 % of the respondents do not know rainfall variability, while 33.06 % know. The more number of the respondents not knowing rainfall variability may not be unconnected because most of the respondents do not belong to any farming club and tend not to know.

Table 4.36 Distributions of Respondents on their Knowledge of Rainfall Variability

Are you aware of rainfall variability?	Frequency	Percentage
Aware	238	33.06 %
Not aware	482	66.94 %

Table 4.37 shows the distributions of the respondents on their sources of information on rainfall variability. 45.28 % of respondents relied on extension workers for their source of information and knowledge on rainfall variability, while 12.08 % got their information in

school. This shows the importance of extension in better- informing farmers on new techniques of farming and impending dangers. With a paltry 87 % of respondents getting to know about rainfall variability in schools shows that our education is not living up to the reality of the society. Such need to be taught in schools which will help in turning the fortunes of agriculture in the State.

Table 4.37 Distributions of Respondents on what is their Source of Information on Rainfall Variability

Source of information	Frequency	Percentage
School	87	12.08 %
Television	109	15.14 %
Extension workers	326	45.28 %
None	198	27.50 %

Table 4.38 shows the distribution of respondents on how rainfall variability manifests. 47.36 % indicated that rainfall manifest as decreased rainfall, while 19.03 % noted that it is manifested through an increase in rainfall. This concludes that climate change does not give uniform consequence; some places will have drought while others will have a flood. The least percentage of manifestation goes to the short growing season, which has 7.92 %.

Table 4.38 Distributions of Respondents by how Rainfall Variability Manifest

How does rainfall variability manifest in your area	Frequency	Percentage
Which variable affect yield the most for you	Frequency	Percentage
Increased rainfall	137	19.03 %
Decreased rainfall	341	47.36 %
Changes in onset/cessation dates	106	14.72 %
Low rainfall frequency	79	10.97 %
Short growing season	57	7.92 %

Table 4.39 reveals the distributions of the respondents on parameters that affect the yield of the crop the most. 49.86 % of respondents said changes in the onset and cessation dates are the main variable that affects crop yield. These variables are the most important for farmers, and the finding concurs with the result of (Tina *et al.*, 2010), which noted that the gradually changing pattern of rainfall over the years as one that is creating confusion among farmers on when to plant and when not to plant because the rains are late and usually ends early and abruptly before crops fully matured.

Table 4.39 Distributions of Respondents by the Variables that Affect the Yield of the

Extreme Temperature	67	9.31 %	C**rop**
Changes in Onset/Cessation dates	359	49.86 %	**the**M**ost**
Variation in rainfall distribution	207	28.75 %	
Early cessation	87	12.08 %	

4.5.4 Knowledge of farmers on rainfall variability adaptation

Table 4.40 shows that 73.89 % of the respondents have tried adaptation strategies to counter the consequences of rainfall variability, while 26.11 % have never tried adapting. Adaptation is an inherent process for farmers; the years put into farming activities give the farmer edge in adaptation. As noted by (Challinor*et al.*, 2011) that indigenous traditional knowledge has, over time immemorial, played a significant role in solving problems that are related to climate change and variability.

Table 4.40 Distributions of Respondents on Whether they have tried Adapting to Rainfall Variability

Have you try adapting to rainfall variability?	Frequency	Percentage
Adapted	532	73.89 %
Not adapted	188	26.11 %

Table 4.41 shows the distributions of different adaptation methods used by respondents. 55.83 % relied on changing the planting dates as adaptation strategies others, others about 33.33 %, used improved crop variety as a strategy for adaptation. The least strategy used is insurance which accounts for 0.56 %.

Table 4.41Identification of Methods of Adaptation used by Respondents

What is the adaptation strategies used?	Frequency	Percentage
Changes in planting date	402	55.83 %
Used of improved crop varieties	240	33.33 %
Switch from crop to livestock farming	7	0.97 %
Insurance	4	0.56 %
Move to new farm site	12	1.67 %
Increased water management	7	0.97 %
Increased in farm size	40	5.56 %
Used of fertilizer and insecticide	8	1.11 %

Table 4.42 shows that 69.72 % of respondents acknowledge that the strategies they used in adaptation paid off because the yield of crops increased. While 30.28 % said the strategies did not lead to an increase in crop yield. This shows the adaptation strategies by farmers using their traditional knowledge and others have a great way of dealing with the negative consequences of climate variability on crop yield.

Table 4.42 Distribution of Respondents on Whether Strategy used Works

Has the strategies increased yield?	Frequency	Percentage
Yield increased	502	69.72 %
Yield not increased	218	30.28 %

Table 4.43 shows the distributions of constraints to adaptations among the respondents. 34.44 % noted that the major constraints to adaptation are limited knowledge of the causes and effects of rainfall variability; this represents the highest factor chosen by the respondents.

Table 4.43 Distributions of Respondents on What are the Constraints to Adaptation

What are the constraints to adaptation?	Frequency	Percentage
Poverty	160	22.22 %
Lack of labourers	54	7.50 %
Low level technological know how	54	7.50 %
Poor soil	47	6.53 %
Lack of water	63	8.75 %
Shortage of land	57	7.92 %
Limited awareness	248	34.44 %
Lack of government support	37	5.14 %

Table 4.44 shows that most respondents of 49.03 % are suggesting the use of mediums to create more awareness. The least option advocated is insurance with 1.39 %.

Table 4.44 Distribution of Respondents on other Adaptation Options

Used of improved crop varieties	Frequency	Percentage
	135	18.75 %
More advocacy on Rainfall Variability	353	49.03 %
Changing of planting dates	56	7.78 %
Used of pesticides and fertilizer	87	12.08 %
Increased in farm size	26	3.61 %
Government	53	7.36 %
Insurance	10	1.39 %

4.6 Summary

This study was carried out to find the effects of rainfall variability on crop yields in Benue State. The crop yields data of cassava, yam, maize, rice, soyabeans, and groundnut yield data for 30 years (1988-2017) from the Benue State Agricultural and Rural Development Agency (BNARDA). While the rainfall data from 1988-2017 was obtained from CMAP data version, remote sensing data and covered Benue State. Questionnaires were administered to 720 farmers across 12 Local Government Areas in Benue State to get their perception towards rainfall variability and the adaptation strategies methods used. The examination of rainfall variability in Benue State was tested using Precipitation Variability Index (PVI) Model. The PVI, which investigates the moisture distribution in a place and the likelihood for drought, shows that the moisture variability in Benue State decreases from East to South and North. The Northern zone has high moisture variability from April-October; it is the zone of moisture stress requirement. With almost four months of moderate moisture and three months of high variability, rain- fed agriculture will suffer in this zone.

Farmers in this zone need to delay planting around April to avoid water stress that may affect plant growth, leading to low yield. This implies that for adequate farming activities to succeed, another alternative source is needed in this zone, hence most of the month has high moisture index, which will be subjected to drought and may affect the growing season. The southern zone PVI shows moderate variability of moisture that is PVI is greater than 20 % but less than 30 % apart from April. The month of April for all the LGA have PVI of high moisture variability. The Eastern zone PVI indicates that April,especially in Kwande and Ukum,is considered dry month within the zone, which indicates thehigh variability of moisture. This implies that planting should not be done during April, especially in Kwande, Ukum,to avoid poor growth. The Eastern zone is considered as the abundant- rain- zone; hence the PVI indicated the least variability with less than 20 % in almost all the LGAs.

Trend analysis was conducted for the crops under study, and it reveals that cassava, yam, maize soyabeans, and groundnut yield has a positive significance increase trend, which means that the yields are increasing over time. The positive significance increase of cassava, yam, maize soyabeans, and groundnut yields may be due to the suitability of climatic factors available in the entire zones to support their cultivation and thus give rise to an abundance of land to support cassava, yam, maize soyabeans, and groundnut farming. On the other hand, rice yield indicates a significance reduction, which is an indication of a decline in the crop yield. This may not be unconnected because rice water requirement is high and is mostly grown on swampy areas by rain- fed farmers, which means that such land may be limited now due to urbanization and population explosion.

The summary of the averages of onset dates, cessation dates and length of rainy season dates indicates that the onset dates of rainfall is almost equal in all the zones, with southern zone having the onset date of 4th April, followed by Eastern zone with 6th April then the Northern zone 9th April respectively. On the other hand, the cessation dates of rainfall indicates that the southern zone has average cessation dates of 17th November, while the Northern zone has the cessation date of 10th October and the Eastern zone with the cessation dates of 16th November. The finding reveals that the dates of onset are more reliable and predictable than the cessation dates. Cessation dates between October and November in the State are good because it has not moved far from the expected pattern. The Eastern zone has the highest Length of the Rainy Season with 236 days, follow by the

Southern zone with 230 days and then the Northern zone with 215 days. The rainfall characteristics on some yields indicated that the onset trend is moving from March to April or May; there will be an increase in groundnut yield, otherwise negative. Also,the length of the rainy days has increased, which has no significant effects on groundnut yield; hence the crop has short lengths of the growing season of 150 days. The maize review concluded that late onset of rainfall in Benue increases maize yield while late cessation reduces yield. Years with early cessation tend to have more yields. The result on yam reviewed that yields are higher during years of early- onset than years of late- onset. On the other hand, yam yields are higher during years of late cessation.

The summary of agro-climatic zones for effective utilization of the limited agricultural lands in Benue State. The characteristic pattern of rainfall has divided the study area into three climatic zones; the zone of less variable precipitation (precipitation periodicity less than 20 %), are the Eastern part, the zone of highly variable precipitation periodicity greater than 30 % consists of the northern part and the zone of moderate variable precipitation periodicity of greater than 20 % but less than 30 % which occurs in the Southern zone. The zone of less variable rainfall received almost uniform rainfall during the rainy period, while the zone of highly variable precipitation has drier spell periods during the active raining months. The Eastern and Southern zone reveals that tubers or root crops (yam and cassava), Legumes crops (Groundnut and Soyabeans), and Cereals crops (Rice and Maize) grows in all the LGAs within these zones. In contrast, the Northern zone shows that maize and groundnut are being produced in a large quantity, especially in Tarka, Gboko, Makurdi and Gwer- West, which indicated that despite the low amount of rainfall in these LGAs, it might not likely affect these crops.

The computation of responses from the respondents indicates that the majority of farmers in the State are male and married. The educational status of most farmers in the State shows that they have attended formal education while about 39 % have no formal education. With 61 % of them having one form of education or the other, it is easier to understand rainfall variability and ways to adapt a strategy to manage its effect. A small number of the respondents have other sources of income, while many of the respondents depend mainly on farming. This is not too good because of the excessive climatic variability, which may turn a lot into unemployed in case of any eventuality.

About 80 % of the respondents could not have access to credit facilities, while 87.50 % of the respondents are rain- fed farmers. Financial institutions give credit facilities to only farmers who belong to clubs or cooperative societies. This is because the farmers have not joined any group as such. Another reason may be the rigorous and stringent conditions attached to obtaining credit from financial institutions that discouraged them from getting it. The respondents were also enquired on their knowledge of rainfall variability, and it was observed that 33 % of the respondents are aware, and about 73 % of them have attempted adapting in one way or the other. This, to a larger extent, accounted for the positive trends most of the crops considered (cassava, yam, maize soyabeans, and groundnut).45 % of the respondents got their information about rainfall variability from extension workers. This shows that there is a positive influence of the extension officers among farmers in Benue State.47 % of the respondents perceived rainfall variability as in decreased rainfall amount while 19 % felt the opposite which is increased in rainfall. This supports manyassertions that consequences of rainfall variability are not uniform everywhere, some places experience flood while other experiences drought. 49 % of the respondents perceived changes in the onset dates and cessation dates as the major factor affecting crop yields. About 55 % of the respondents resulted to changes in planting dates as adaptation strategies while 33 % used improved seeds variety as an adaptation strategy against the negative effect of rainfall variability.Most of the respondents agreed that limited awareness is the greatest constraints to adaptation and 49 % of the respondents recommended that more advocacies on adaptation and effects of rainfall variability should be adopted as a strategy to improve crop yield.

4.7 Contribution to Knowledge

The contribution of this study to knowledge are quite enormous, the notable among them include;

1. The Agro-Climatic Zones for Benue State on Crops were been adapted.
2. The study found out that Precipitation Variability Index (PVI) in Benue State is generally moderate and the mean annual rainfall in Benue State is normal hence it is greater than 1000mmm.
3. The study found out that cassava, yam, maize soyabeans, and groundnut yields are increasing over time in Benue State;rice, on the other hand, is declining.
4. The study affirms that Onset dates of rainfall over the State are almost constant while the Cessation dates are highly variable.
5. The study found out that rainfall variability has no significant influence on cassava, yam, maize soyabeans, groundnut, and rice yields in Benue State.
6. The research found out that 73 % of farmers have tried strategies to adapt to rainfall variability.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The study focuses on rainfall variability and crop yields in Benue State. With some objectives aimed at examining the rainfall variability, the trend of selected crops, rainfall characteristics on some major crop yield, developing a comprehensive crop zonation map, and farmers adaptation strategies of rainfall variability. CMAP rainfall from 1988-2017 was used, and the crop yields (cassava, yam, maize soyabeans, groundnut, and rice) data from Benue State Agricultural and Rural Development Agency (BNARDA) were collected and analysed for the study. Data obtained from the primary sources were collected from the administration of questionnaires to 720 crop farmers across Benue State.

The distribution of moisture variability is high in the Southern zone, followed by the Eastern zone, and least in the Northern zone. Rainfall commences early in the Southern zone, followed by the East, then the Northern zone. The onset of rain is similar in all the zones. While the length of the rainy season is high in the East, followed by the South and then the North.The selected crop yields ofcassava, yam, maize, soyabeans, and groundnut show a positive trend, while rice, on the other hand, shows a negative trend over time.The perception result shows that most farmers are aware of rainfall variability, and they also noted that their crop yields are increasing as a result of using choices for adaptation.

5.2 Recommendations

The study carried out on rainfall variability and crop yields, and adaptation strategies in Benue State. The following recommendations are being suggested.

i. Other elements of climate such as temperature, relative humidity, and farm management practices should be studied to find the impact of such on crop yield.

ii. Irrigation farming should be intensified in order to curtail the uncertainty attached to rain- fed agriculture.

iii. Farmer’s adaptation measures to rainfall variability in the State should be harnessed for proper results.

iv. Looking at the threat of drought especially in the Northern zone, attention should be given to alternative water sources for farming, and the best water management idea should be utilized.

v. With the findings of the Precipitation Variability Index, crop zone classification can be done for the State.

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APPENDICES

APPENDIX A: QUESTIONNAIRE DISTRIBUTION TO THE RESPONDENTS

Department of Geography Federal University of Technology Minna

Dear Respondent,

I am a Ph.D student in the Department of Geography, Federal University of Technology Minna. I am undertaking a research on Rainfall variability on selected crops yield in Benue State. Please respond to the questions satisfactorily by ticking the correct option or filing the blank spaces provided.

The information provided by you in this survey about your family farming activities will contribute to the better understanding of the effects of rainfall variability on subsistent crop production in Benue State and some options for adaptation.

All information provided by you will be treated with absolute confidentiality as this questionnaire is solely for academic exercise.

Thanks

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SECTION A: LOCATION AND SOCIO- ECONOMIC CHARACTERISTICS OF RESPONDENT

LOCATION____

STATE____

L.G.A____

ZONE____

VILLAGE/TOWN____

SOCIO ECONOMIC, INSITUTIONAL AND FARM SPECIFIC CHARACTERISTICS OF FARMERS

1. Name____
2. Age_______________________________________Optional
3. Marital status (a) Married (b) Widow (c) Divorce (d) single. Others specify_______
4. Sex (a) Male (b) Female
5. Level of Education (a) None (b) Primary School (c) Secondary School (d) Tertiary Education
6. How many people work in your farm?_________________________________
7. What is the average distance to your farm(s) in kilometers from youhouse?_______
8. Do you have access to credit facilities? Yes/No. if yes from who__________
9. Do you have any other sources of income other than agriculture? Yes/No. if yes Specify please________________________________
10. Do you have access to extension service? Yes/No
11. If yes in 10, how many visit(s) in a cropping season

SECTION B: AGRICULTURAL SYSTEM AND CROP YIELDS

12. Agriculture type practiced (a) rain fed (b) Irrigation

13. Which of these crops do you farm? (a) Yam (b) Maize (c) Rice (d) Cassava (e) Soyabeans (f) Groundnut

14. Which of the following practiced are you doing
    (a) Crop farming
    (b) Pastoral
    (c) Mixed farming
    (d) Nomadic pastoralism
    (e)Others____

15. Which of the following farming system are you practicing?
    (a) Multiple cropping
    (b) Irrigation farming
    (c) Monoculture
    (d)Others____

16. What is your total harvest of yam per annum?
    (a) 100-500 tubers
    (b) 600-1000 tubers
    (c) 1000-5000 tubers
    (d) Others Specify____________

17. What is your total harvest of cassava per annum?
    (a) 1000-5000 tubers
    (b) 6000-10000 tubers
    (c) 10000-50000 tubers
    (d) Others Specify____________

18. What is your total harvest of maize per annum?
    (a) 10 – 20 bags
    (b) 30 – 50 bags
    (c) 60 – 100 bags
    (d) Others Specify____________

19. What is your total harvest of Rice per annum?
    (a) 10 – 20 bags
    (b) 30 – 50 bags
    (c) 60 – 100 bags
    (d) Others Specify____________

20. What is your total harvest of Soyabeans per annum?
    (a) 10 – 20 bags
    (b) 30 – 50 bags
    (c) 60 – 100 bags
    (d) Others Specify____________

21. What is your total harvest of Groundnut per annum?
    (a) 10 – 20 bags
    (b) 30 – 50 bags
    (c) 60 – 100 bags
    (d) Others Specify____________

22. Have there been any changes in crop yield over the past years?
    (a) Increase (b) decrease (c) no change
    (b)
23. What is the cause of the changes in pinion?_____________________________________

SECTION C: KNOWLEDGE OF FARMERS ON RAINFALL VARIABILITY

24. Do you belong to any civic, local or farm association(s)? Yes/No. if yes how many____

25. Are you aware of rainfall variability? Yes/No

26. If your answer in 25 is yes, in which of the way(s) does it manifest?
    (a) Late onset (b) early cessation (c) low frequency (d) short growing season (e) others specify.

27. Where did you get the information on climate variability coping strategies?
    (a) School (b) Television (c) Extension workers (d) others Specify________

28. Have you noticed long- term changes in the mean rainfall? Yes/No

29. If your answer in 25 is yes, can you tick appropriately the noticed changes;
    (a) Increase in rainfall
    (b) Decrease in rainfall
    (c) Changes in onset and cessation dates
    (e) Others Specify____________________________________

30. Which of the following climatic variable strongly affect your crop yield?
    (a) Variation in rainfall distribution
    (b) Changes in onset of the rainy season

(c) Extreme temperature
(d) Rainfall cessation
(e) Others Specify____________________________________

SECTION D: COPING STRATEGIES

31. Have you try to cope to current rainfall variation? Yes/ No
32. If yes, can you tick appropriately the coping strategies adopted so far?
    (a) Change of planting dates
    (b) Change crop varieties
    (c) Movement to different sites
    (d) Switching from crops to livestock
    (e) Increased in land area cultivated
    (f) Use of water conservation techniques
    (g) Rural- Urban migration
    (h) Religious beliefs or prayer
    (i) Change to use of chemical fertilizers, pesticides and insecticides
    (j) Use of insurance
    (k) Implementation of soil conservation techniques
    (l) Use of shades and shelters
    (m) Other coping techniques

33. Can you say that the measure adopted by you has increased your crop yield? Yes/No

34. Can you tick appropriately the problem in coping to rainfall variability?

    (a) Limited awareness or information about rainfall variability
    (b) Poverty
    (c) Low level of technology
    (d) Shortages of labour inputs
    (e) Poor soils
    (f) Lack of water
    (g) Shortages of land for cultivation
    (h) Others specify____

35. What other coping strategies option would you recommend for policy implementation?

Thank you.

APPENDIX B: CASSAVA YIELD (METRIC TONNES) IN BENUE STATE FROM 1988-2017

1	1988	154.24	254.45	217.23
2	1989	197.16	301.69	211.37
3	1990	203.38	286.27	222.86
4	1991	242.68	311.78	305.88
5	1992	287.54	351.99	305.61
6	1993	370.45	370.32	355.76
7	1994	276.97	367.86	287.23
8	1995	289.42	422.64	367.00
9	1996	325.73	399.45	312.67
10	1997	276.54	394.34	234.97
11	1998	278.86	301.34	348.87
12	1999	287.12	399.46	307.35
13	2000	297.37	356.46	307.23
14	2001	290.60	398.96	284.61
15	2002	318.37	438.48	397.33
16	2003	399.19	446.07	329.48
17	2004	361.69	391.44	332.34
18	2005	307.34	286.27	222.86
19	2006	242.68	412.48	378.82
20	2007	287.54	351.99	305.64
21	2008	368.45	378.85	385.26
22	2009	369.37	467.78	417.22
23	2010	389.42	462.18	397.04
24	2011	325.73	379.47	412.47
25	2012	296.54	386.37	294.57
26	2013	378.86	401.48	378.82
27	2014	312.12	398.43	387.56
28	2015	317.27	356.48	394.21
29	2016	330.53	396.99	376.53
30	2017	319.35	428.68	401.29

APPENDIX C: MAIZE YIELD (METRIC TONNES) IN BENUE STATE FROM 1988-2017

S/N	Year	Northern zone	Eastern zone	Southern zone
1	1988	2.23	1.35	1.24
2	1989	3.21	2.86	3.34
3	1990	3.67	3.49	2.97
4	1991	2.99	2.79	1.68
5	1992	3.87	1.95	2.07
6	1993	2.98	2.72	1.98
7	1994	3.65	3.62	3.41
8	1995	2.97	2.99	2.45
9	1996	3.62	2.65	1.65
10	1997	2.98	2.50	2.41
11	1998	2.76	2.98	2.53
12	1999	3.54	2.97	3.23
13	2000	4.52	2.24	2.79
14	2001	3.56	3.27	3.84
15	2002	3.87	2.91	3.62
16	2003	2.96	3.02	3.67
17	2004	3.13	2.92	2.34
18	2005	3.70	3.08	3.19
19	2006	3.76	1.99	2.63
20	2007	4.08	2.94	3.35
21	2008	3.61	3.46	2.93
22	2009	2.90	2.75	3.01
23	2010	3.55	2.91	2.74
24	2011	3.65	3.02	2.96
25	2012	2.98	2.67	2.89
26	2013	3.97	3.12	3.17
27	2014	3.74	2.47	2.81
28	2015	3.82	3.52	3.62
29	2016	3.97	2.99	3.90
30	2017	3.77	3.65	2.97

APPENDIX D: RICE YIELD (METRIC TONNES) IN BENUE STATE FROM 1988-2017

S/N	Year	Northern zone	Eastern zone	Southern zone
1	1988	2.81	1.85	3.27
2	1989	3.21	2.86	2.94
3	1990	3.67	3.45	3.73
4	1991	3.12	2.89	3.97
5	1992	2.99	2.76	3.17
6	1993	3.71	1.92	3.56
7	1994	2.58	2.03	2.82
8	1995	3.42	3.16	3.73
9	1996	2.84	2.62	2.67
10	1997	2.78	2.15	2.93
11	1998	2.64	2.34	3.01
12	1999	2.72	2.73	2.84
13	2000	2.79	2.86	2.97
14	2001	1.86	2.01	2.72
15	2002	2.71	1.95	2.89
16	2003	2.76	2.79	2.88
17	2004	2.73	2.78	2.87
18	2005	2.59	2.82	2.26
19	2006	2.83	2.49	2.90
20	2007	2..72	2.71	2.99
21	2008	2.88	2.85	2.94
22	2009	2.84	2.78	2.72
23	2010	3.01	3.76	3.81
24	2011	3.42	3.63	3.67
25	2012	1.89	1.84	1.99
26	2013	2.31	2.64	2.76
27	2014	1.87	1.89	1.93
28	2015	2.01	2.73	2.48
29	2016	1.72	1.93	1.97
30	2017	2.00	2.15	2.52

APPENDIX E: YAM YIELD (METRIC TONNES) IN BENUE STATE FROM 1988-2017

S/N	Year	Northern zone	Eastern zone	Southern zone
1	1988	126.24	250.42	227.17
2	1989	287.16	321.69	290.33
3	1990	205.35	276.47	232.84
4	1991	262.68	321.78	315.48
5	1992	347.51	451.99	375.66
6	1993	360.25	390.32	315.86
7	1994	356.97	397.86	367.22
8	1995	376.97	397.86	287.31
9	1996	342.94	397.86	267.42
10	1997	376.74	396.24	394.97
11	1998	278.86	401.34	388.85
12	1999	297.15	399.41	317.32
13	2000	297.37	366.48	307.46
14	2001	299.68	358.96	301.68
15	2002	328.33	428.38	367.37
16	2003	331.15	416.29	349.36
17	2004	361.29	391.48	382.31
18	2005	309.38	386.27	322.76
19	2006	262.62	312.45	278.72
20	2007	287.54	311.92	300.62
21	2008	317.43	371.85	319.26
22	2009	329.31	367.78	317.27
23	2010	329.42	442.18	347.07
24	2011	315.73	359.47	412.23
25	2012	346.54	386.38	354.52
26	2013	338.26	411.42	378.52
27	2014	318.28	399.41	377.57
28	2015	327.17	376.47	394.27
29	2016	357.53	396.92	366.52
30	2017	379.32	418.69	407.25

APPENDIX F: GROUNDNUT YIELD (METRIC TONNES) IN BENUE STATE FROM 1988-2017

S/N	Year	Northern zone	Eastern zone	Southern zone
1	1988	2.63	2.97	1.25
2	1989	3.71	3.85	2.86
3	1990	3.52	3.01	2.06
4	1991	2.98	3.13	2.19
5	1992	3.07	3.86	3.10
6	1993	3.28	3.87	3.23
7	1994	2.99	3.02	2.84
8	1995	3.98	4.06	3.29
9	1996	4.02	4.89	3.78
10	1997	3.67	4.76	3.56
11	1998	4.23	4.73	3.73
12	1999	4.57	5.37	3.89
13	2000	3.99	4.38	2.95
14	2001	3.97	4.27	3.45
15	2002	3.64	4.75	3.29
16	2003	3.78	3.99	3.03
17	2004	4.00	4.56	3.87
18	2005	3.96	4.23	3.79
19	2006	4.21	4.71	3.83
20	2007	4.37	4.74	3.59
21	2008	4.63	4.98	4.01
22	2009	4.59	4.77	3.97
23	2010	4.46	4.78	3.99
24	2011	4.81	5.11	4.02
25	2012	3.99	4.67	3.04
26	2013	4.23	4.82	3.89
27	2014	4.75	4.97	4.12
28	2015	4.38	4.86	3.79
29	2016	4.68	4.96	4.34
30	2017	4.97	5.68	4.25

APPENDIX G: SOYABEANS YIELD (METRIC TONNES) IN BENUE STATE FROM 1988-2017

S/N	Year	Northern zone	Eastern zone	Southern zone
1	1988	0.98	1.37	1.28
2	1989	1.21	1.86	1.34
3	1990	1.27	1.97	1.22
4	1991	1.31	1.74	1.61
5	1992	2.87	2.95	2.09
6	1993	2.57	2.92	2.78
7	1994	0.85	1.62	0.81
8	1995	1.97	1.99	1.45
9	1996	0.92	1.55	1.25
10	1997	1.98	1.50	1.41
11	1998	2.76	2.98	2.53
12	1999	1.54	1.97	1.23
13	2000	2.87	3.24	2.78
14	2001	2.56	3.27	2.94
15	2002	2.87	2.91	2.62
16	2003	2.96	3.42	3.00
17	2004	3.13	3.92	3.34
18	2005	3.20	3.78	3.39
19	2006	3.36	3.79	3.63
20	2007	3.08	3.94	3.32
21	2008	3.61	3.76	2.98
22	2009	3.90	3.93	3.01
23	2010	3.94	3.91	3.74
24	2011	3.65	4.02	3.96
25	2012	3.98	4.67	3.89
26	2013	3.37	3.88	3.12
27	2014	3.74	3.87	3.56
28	2015	3.92	4.52	4.05
29	2016	3.97	4.59	3.93
30	2017	3.99	4.67	3.97