ANALYSIS OF ANOMALOUS RAINFALL AND ITS EFFECTS ON CROPS YIELD IN MORO LOCAL GOVERNMENT AREA OF KWARA STATE, NIGERIA

BY

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B.Sc. Geography (UNIMAID) 2014
P15SCGS8044

A DISSERTATION SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES, AHMADU BELLO UNIVERSITY, ZARIA- NIGERIA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF SCIENCE DEGREE IN GEOGRAPHY

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MAY, 2019

DECLARATION PAGE

I declare that the work in this dissertation entitled ANALYSIS OF ANOMALOUS RAINFALL AND ITS EFFECTS ON CROPS YIELD IN MORO LOCAL GOVERNMENT AREA OF KWARA STATE, NIGERIA has been carried out by me in the Department of Geography and Environmental Management. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this dissertation was previously presented for another degree at this or any Institution.

Jamila Ahmed ABDULSALAM	Signature	Date

CERTIFICATION PAGE

This dissertation entitled ANALYSIS OF ANOMALOUS RAINFALL AND ITS EFFECTS ON CROPS YIELD IN MORO LOCAL GOVERNMENT AREA OF KWARA STATE, NIGERIA by Jamila Ahmed ABDULSALAM meets the regulations governing the award of the degree of M.Sc. Geography of the Ahmadu Bello University and is approved for its contribution to knowledge and literary presentation.

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ACKNOWLEDGEMENTS

To God, the Almighty, I cannot thank Him enough for life, providence and sustenance, and for validating the belief that I can do it only through Him.

My inestimable appreciation goes to my supervisors Professor B. A. Sawa, and Dr. B. A. Abdulkarim whose role transcends academic. They are like my parents, and mentors. I appreciate the value of their meticulous, thorough, and constructive criticisms without which the success of this work would have been a mere mirage, I cannot pay the debts.

I am very grateful to my parents, whose sacrifice cannot be quantified. To Dr. S. A. Adisa and his family, for making their home, my home during the course of this study, I am grateful. I want to appreciate all the academic and non-academic staff of the Department of Geography and Environmental Management, Ahmadu Bello University, Zaria. I am grateful to Mr. Afolabi and Mr. Ajayi, both of KWADP office Ilorin, for their assistance during the reconnaissance survey for this work. I am particularly grateful to friends like Abednego Shariason, Fabian Datong, Kolade Joel, Silas Inuwa, Lois Dodo, Zainab Jibril, Habib Muhammed, Sela Abana, Moses Pius, Zainab Sanni, Asma'u Shehu, Hajara Isah, Mahmud Abdulsalam, Asma'u Abdussalam, Abdulhamid Alkali, and Abdulkadir Sanusi, whose contributions in one way or the other has shaped this work and for their encouragement. Finally, to my siblings and the Abdulsalam Family, I say thank you for believing in me.

ABSTRACT

Distribution of crops is largely dependent on the rainfall pattern in Nigeria, which is variable in nature. This variable rainfall pattern leads to anomalies, which could pose socio-economic and developmental challenges as they threaten food security and the economy of Moro Local Government Area of Kwara state. Hence, a knowledge of the behavior of rainfall anomalies and its influence on crops yield will contribute to the well-being of the teeming population. This study analyzed the effect of anomalous rainfall on the yield of some selected crops (maize, sorghum, cassava, and yam) dominantly cultivated in the study area. The study spanned over two decades from 1991 to 2015. Anomalous rainfall was derived using Rainfall Anomaly Index (RAI). Time series analysis was employed to determine the trend of crops yield. Bivariate correlation analysis was used to determine the relationship between rainfall anomalies and crops yield after the data was harmonized to a common base using $\log_{10}$ by the means of MINITAB software. Correlation was employed to test stated hypothesis at 0.05 significance level. The variation in crops yield accounted for by rainfall anomalies and projected trend of anomalous rainfall and crop yield in ten (10) years' time to 2025 were conducted using Simple linear regression. The result showed fluctuation between wet and dry years, with more occurrence of dry years. It also showed an increasing trend in the annual yield of all the selected crops. The correlation analysis showed that rainfall anomalies has a positive relationship (r = 0.001, 0.221, 0.065) with the yield of maize, cassava, and yam, but showed a negative relationship (r = -0.194) with sorghum yield. This implies that as rainfall anomaly increases, the yield of maize, cassava and yam increased, while sorghum yield decreased. The result further showed no significant

relationship between rainfall anomalies and crops yield, as the null hypothesis was accepted. The co-efficient of determination (R^2) showed that rainfall anomalies accounts for only 0.1%, 3.8%, 4.9%, and 0.4% of variation on the yield of maize, sorghum, cassava, and yam respectively. This suggests that the yield of crops could be attributed to other climatic and non-climatic factors. Based on the predictions, result showed that rainfall anomalies will be negative from 2016 up to 2019, indicating dry years which will decrease in magnitude and will be positive from 2020 to 2025, indicating wet years which will increase in magnitude in the coming years. The crops yield (maize, sorghum, cassava, and yam) will also be on the increase in the coming years, assuming the pattern observed is maintained. It was recommended that farmers should introduce short duration maturing crop varieties and adopt mixed cropping system, that will boost high crop yield in Moro Local Government Area.

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND TO THE STUDY

Plants require a certain amount of water, warmth and sunlight to develop. However, these requirements differ across plants (Blanc, 2011). Rainfall is a key determinant of crop growth and yields in rain-fed areas. Plants assimilate water through their roots and transpire it through small pores in their leaves called stomata. Water lost via transpiration has to be replaced by water available in the soil (soil moisture) to enable plants to grow. When soil moisture is insufficient to cover the plant's water needs, water stress occurs and plant growth is hindered (Winch, 2006). Plants have different water requirements depending on their physiology, phonological stage and the climatic zone where they are grown. As small plants have smaller leaf surface area than larger plants, smaller plants transpire less and thus need less water (Cothren, Matocha and Clark, 2000). Some plants have particular water needs during critical growth stages. In hot, dry, windy and sunny areas, plants transpire more, and have higher water requirements, than in cool, humid, cloudy and windless areas (Blanc, 2011).

According to theOrganization For Economic Co-operation and Development,[OECD] (2017), 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 production data by the data on area harvested. The actual yield captured on farm depends on several factors such as crop's genetic potential, the

amount of sunlight, water and nutrients absorbed by the crop. Crop production is measured in tonnes per hectare, in thousand hectares and thousand tonnes.

Insufficient or excessive rainfall can hinder plant development. The impact of drought and floods on crop yield differs across plants. Some crops resist droughts better than others due to their physiology. For example, cassava has long roots which allows it to reach soil moisture deeper in the soil and also limits transpiration via partial stomata closure and small leaf canopy(El-Sharkawy, 2007). Other crops, such as millet and sorghum, resists drought by having a short life cycle(Winch, 2006). Alternatively, some crops such as cassava, are vulnerable to excessive water (Blanc, 2011).Adequate precipitation timing is essential to fulfil water requirement at different growth stages. Since most Sub-sahara African (SSA) crops are rain-fed, farmers choose crops that are better suited to local climates. Maize is suited for regions with sufficient and consistent rainfalls. Millet and sorghum are drought tolerant than maize and usually grow well in regions with low and variable rainfall. Although cassava has higher optimal water requirements, it can accommodate low rainfall and resist long drought periods(Winch, 2006).

Barring and Hulme (1991) defined climatic variability to include the extremes and differences of monthly, seasonal, and annual values from the climatically expected value (temporal mean). The differences are usually termed anomalies. Rainfall anomaly is the deviation from the long-term mean rainfall of a given location, which could either be a positive or negative anomaly. A positive anomaly value indicates that the observed rainfall is greater than the mean value, while

negative anomaly value indicates observed rainfall less than the average rainfall. Rainfall anomaly is percieved as a phenomenon in which atmospheric circulation, rainfall, sea surface temperature changes (through changes in upwelling) and remote meteorological events are linked in a complex manner (Olaniran, 2002). The July-August period is considered to be an anomaly in the rainfall climatology of Nigeria because rainfall is reduced over southern Nigeria despite the great depth and humidity of the tropical maritime air near the coast. The climatological structure of the rainfall anomaly varies significantly for southern and northern Nigeria according to the weather zone that prevails over each area (Olaniran, 1988).

Studies conducted byHansen, Mason, Sun and Tall (2011), Maxwell and Fitzpatrick (2012) Lizumi, Yokozawa, Sakurai, Travasso, Romanenkov, Oettli, Newby, Ishigooka and Furuya (2014) have suggested that climate variabilityhave adverse impacts on global food production and food security. Climate variability driven by major inter-annual scale climate modes such as the El-nino Southern Oscillation (ENSO), has been playing a key role often leading to droughts and decrease in crop yields that could further result in famine in some food insecure regions. For example, the droughts in United States in 2012, heatwaves and associated Russian wheat embargo in 2010/2011, droughts in Australia in 2006/2007 and 2007/2008 that led to low levels of cereal stock and steep increases in food prices, likely worsened the access to affordable food for many consumers, including the poor in import-dependent countries (Food and Agriculture Organization [FAO],2007,2010, 2012). Climate variability results from the use of energy but its impact is manifested through changes in agroecological conditions and climatic

factors particularly precipitation and temperature. Precipitation especially rainfall and air temperature, the most important weather variables, play crucial role in agricultural production in Sub-Saharan Africa (SSA) (Amikuzuno and Donkoh 2012).

In Nigeria, distribution of crops is largely dependent on the rainfall pattern. For instance, tree crops are confined to the high rainfall region of the south while grain crops are cultivated predominantly in the low rainfall region of the north, hence, the type of crops cultivated in any area within the country is related to the rainfall pattern. Agricultural production is not isolated from the vagaries of weather despite the many years of advances of crop and animal husbandry in the country. For much of the country in 1973, the rains failed causing widespread crop failure. This situation was well captured by Oguntoyinbo (1982) as cited in Olaniran (2002) where he said that "early planting encouraged by the false start of the rains was subsequently followed by rainfall cessation. In consequence, crops already planted and beginning to germinate after the early rains were soon dried off by the lack of moisture (Olaniran, 2002). When crops do not fail, the vagaries of weather can still cause variation in yield. Apart from the socio-economic problems facing Nigerian farmers, rainfall variability constitute a major limiting factor in crop production. This is because bulk of the food produced in Nigeria is grown under rain-fed system. Olaniran(2001) presented data which shows more than fifty percent variation in millet yield at Kano between wet and dry years and the same range in sugar-cane yield at Bacita between dry and wet years.

In Kwara State Nigeria, rainfall variability is pronounced in time and space. The onset of effective rainy season seems to have been delayed in an unpredictable manner in recent years without delay in cessation (Olanrewaju, 2010a). The duration of rainy season as well as amount and distribution of rain days also vary significantly. This variable rainfall pattern has serious repercussion on the economy as it 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. Although, catastrophic weather phenomena such as drought and flood receive wide media coverage, it should be noted that far more agricultural production is lost in pockets of chronically poor rainfall or other adverse weather during otherwise average years. This brings about the need to study the anomaly of rainfall in respect to crop yields in Moro Local Government Area of Kwara state.

1.2 STATEMENT OF THE RESEARCH PROBLEM

The issue of climate change is no longer debatable.As rainfall fluctuates, it brings about rainfall anomaly. What is not clear is the nature of this variation in the study area, as theclimate of Kwara State has been confirmed towards aridity (Olanrewaju, 2003) with rainfall onset being delayed and the length of rainy season (LRS) getting shorter, which are indications that the state is becoming a drought prone area (Olanrewaju, 2010a).Agriculture has remained the chief source of livelihood in the study area and is the major means by which the teeming population of the community is fed. The researcher observed that there is declining crop yield in the study area probably due to late onset and short duration of rainfall which leads to rainfall anomaly. These anomalies could pose socio-economic and developmental challenges as they threaten food security and induce poverty.

The chief source of livelihood of the inhabitants of the study area is farming, which is mainly rain-fed agriculture. Hence fluctuation, or variation in rainfall may affect the occupation of the inhabitants, and leads to economic uncertainty of the community. According to Murali and Afifi (2014), the impact of rainfall variability are threatening food production systems, leading to losses of livelihood and food security. The author above studied the impacts of rainfall variability on agriculture, food security, livelihoods and human mobility in Chhattisgarh State, India and their findings confirmed that a co-ordination mechanism exist between rainfall changes (erratic rainfall patterns in terms of delayed monsoons, seasonal shifts, drought and floods) with livelihoods and food security of a number of farmers and farm labourers. Okonkwo, Arua and Festus(2015), opined that climate (rainfall) variability has detrimental effects on the livelihood of rural people who depend on agriculture, as the situation becomes critical because of the significant contributions of agriculture to the economy, as well as, social well being of the rural people. Their study examined the determinants of farmers'choices of livelihood and perceptions to the effect of climate variability in Anambra state and found that farm households percieved increase in rainfall, and decrease in agricultural yield as an effect of climate variability.

Several studies such asNdamaniandTsunemi (2015),Ayanlade (2009), Yamusa, Abubakarand Falaki (2015), have looked at rainfall variability both on decadal scales and climatic zonesas well itseffect on agricultural productions.Ndamani and Tsunemi (2015) analyzed the annual and seasonal rainfall variability and their relationship with crop production for a period of thirty-three (33) years in Ghana. The study analyzed seasonal, annual and concentration of rainfall using co-efficient of variation (CV) and precipitation concentration index (PCI)

respectively. Result revealed moderate seasonal and irregular annual rainfall concentration. Correlation analysis was used to assess the influence of rainfall on crop production and result revealed correlation between annual rainfall and crop production were negative for all the crops studied.

Yamusa,Abubakar and Falaki (2015), examined the implications of rainfall variability on some major food crops in the semi-arid region of Northern Nigeria for fifty (50) years from 1963 to 2012 using VISUAL-BASIC.NET programme. Onset of effective monsoon and dry spells was adopted in the study and correlation analysis was employed to assess the relationship between crop yield and dry spells. The result of the study showed a negative relationship which is significant at 1% confidence level for sorghum and maize. The study advised small holder farmers and policy makers on the implications of the reduced and erratic rainfall pattern to agricultural productivity and adaptation strategies was suggested.

Ayanlade (2009), examined the spatio-temporal variation in rainfall in Guinea savanna region of Nigeria, from 1970 to 2000. The study used ordinary kringing method for the interpolation of rainfall data and the result of the analysis showed rainfall varies both in time and space, as rainfall variability was high in Northern Guinea savanna (Yola, Minna, and Ilorin) with CV between 26% and 49%, while that of the Southern Guinea savanna was very low especially in Enugu and Shaki with CV of 9% and 8% respectively. The study further revealed anomalies such as decline in annual rainfall, change in peak rainfall, and false onset and cessation of rainfall are detrimental to crop germination and yield resulting in little or no harvest at the end of the season.

Literature had looked at the relationships between rainfall variability and crops yield in different places at different times, however, none of these studies have looked at the relationship between rainfall anomalies and crops yield especially in the study area to the best of the researcher's knowledge. Hence, this is the gap in knowledge the research intends to bridge.Therefore, from the above premise, a knowledge of the behavior of rainfall anomaly and its effect on the yield of crops for over two decades from 1991-2015 will contribute to the well being of the people. The study attempts to answer the following research questions:

i. What are the rainfall anomalous months and years within the period of 1991-2015 in the study area?
ii. What is the trend of crops yield from 1991 to 2015 in the study area?
iii. What is the relationship between anomalous rainfall and crops yield from 1991 to 2015 in the study area?
iv. What is the strength of the effect of rainfall anomalies oncrops yield from 1991 to 2015 in the study area?
v. What will be the pattern of anomalous rainfall andcrops yield in ten 10 years from 2016-2025?

1.3 AIM AND OBJECTIVES OF THE STUDY

This study aimed at analyzing the effect of anomalous rainfall on crops yield for over two decades (1991-2015) in Moro Local Government Area of Kwara State, Nigeria. This was achieved through the following specific objectives which include to:

i. determine the monthly and yearly anomalous rainfall periods in the study area.

ii. examine the trend of crops yield in the study area.

iii. examine the relationship between anomalous rainfall and crops yield in the study area.

iv. examine the strength of the effect of rainfall anomalies on crops yield in the study area.

v. forecast the trend of anomalous rainfall in relation to the yield of crops in ten (10) years' from 2016-2025.

1.4 HYPOTHESIS

In line with the foregoing aim and objectives of the research, a hypothesis was postulated thus: There is no significant relationship between anomalous rainfall and crop yield within the stated period of study in the study area. The hypothesis was tested at 0.05 level of significance.

1.5 SCOPE OF THE STUDY

The study focused on anomalous rainfall and its effect on crop yield in Moro Local Government Area of Kwara State. The selected crops weremaize, sorghum, yam, and cassava which are dominantly cultivated in the study area. The study considered the time period of twenty five (25) years (1991-2015). This is because of the available records of rainfall data in (mm) and crop yield in Ton/ha.

1.6 JUSTIFICATION OF THE STUDY

Change in long-term mean rainfall have significance for food production and poses greater risks to food security caused by changes in year-to-year variability and extreme weather events. Reduction in crop productivity have been attributed to

anomalously low rainfall events. However, even small changes in mean annual rainfall can impact on crop productivity. In this study, the researcher examined how anomalous rainfall influences the yield of maize, sorghum, cassava and yam in Moro Local Government Area, since farming in the area is majorly rainfed. This is necessary to clarify the nature of variation and its effect on the yield of crops in the area.

This study will help to provide detail information on the trend of rainfall anomalies, and crops yield in Moro Local Government Area. Thus, result of this study will be useful as an input data for adequate and effective planning for agricultural development by local farmers, Agricultural Extension Officers, Agro-Allied Companies, Government Agricultural Agencies, and Policy makers on crop cultivation towards improving yield of crops and economy of the area. This research will as well contribute to poverty alleviation, and food security problem in the area and add to the knowledge of assessing rainfall-crop yield relationship for the benefit of man.

CHAPTER TWO

CONCEPTUAL FRAMEWORK AND LITERATURE REVIEW

2.1 INTRODUCTION

Rainfall is an important factor influencing the production of crops. It is viewed by Agronomist and Meteorologist as a dominant climatic element influencing the yield and behavior of crops. This chapter focuses on the conceptual framework and literature review on rainfall anomaly in relation to the yield of crops.

2.2 CONCEPTUAL FRAMEWORK

2.2.1 The Concept of Climate Change and Variability

According to the United Nations Framework Convention on Climate Change (UNFCCC) (2007), climate change is one of the environmental problems threatening the economic development and sustainability of mankind worldwide. Natural climate cycle and human activities have contributed to an increase in the accumulation of heat trapping greenhouse gases (GHG) in the atmosphere, thereby contributing to increase in temperature in the global climate. Climate variability refers to variations in the prevailing state of the climate on all temporal and spatial scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system or to variations in natural or anthropogenic (Human-driven) forcings (Adedeji, Reuben and Olatoye, 2014).

Global climate change indicates a change in either the mean state of the climate or in its variability, persisting for several decades or longer. This includes changes in average weather conditions on earth, such as change in average global temperature, as well as changes in how frequently regions experience heat waves,

droughts, floods, storms, and other extreme weather. Changes in individual weather event will potentially contribute to changes in climate variability. Climate change could occur naturally as a result of a change in the sun's energy or earth's orbital cycle (Natural climate forcing) or it could occur as a result of persistent anthropogenic forcing such as the addition of GHG, sulfate aerosols, or black carbon to the atmosphere or through land-use change.

Many of the impact of climate change will materialize through changes in extreme events such as droughts and floods. Such extremes result in severe human suffering and hamper economic development and efforts at poverty alleviation. Unfortunately, assessments of climate change are often limited to mean temperature and precipitation, as knowledge of changes in extreme is sparse, particularly for Africa (Bello, Ganiyu, Wahab, Afolabi, Oluleye, Ig, Mahmud, Azeez and Abdulmaliq, 2012). The impact of climate change increasingly affects crop growth, availability of soil water, prevalent infection of disease, and pest infestation (Adejuwon, 2004; Zoellick and Roberts, 2009). These problems result in low and unpredictable crop yield, which invariably makes farmers vulnerable, especially in Africa (Ziervogel, Nyong, Osman, Conde, Cortes and Dowing, 2006). All these pose a threat to the environment and socio-economic related sector, as they adversely affect agriculture and food security, natural ecosystem, biodiversity and human health. Changes in rainfall pattern are likely to lead to water shortages (drought) or flood, threatening human development and their social, political, and economical survival (Zoellick and Roberts, 2009). The impact of climate change is global and developing countries, especially Africa is mostly affected. This is because, African

economy is predominantly agrarian, rainfed, and hence, fundamentally dependent on the vagaries of weather (Bello, et. al, 2012).

2.2.2 Rainfall Variability

Rainfall variability connotes the degree to which rainfall amount varies across an area through time. It is subjected to a large scale variation in time and space, which has taken a more pronounced dimension as a result of climate change. Rainfall variability is of two components which are areal (space) variation and temporal (time) variation. Both areal and temporal variability of rainfall are used to characterize the climate of a region in various ways and deduce evidence of climate change. According to Oguntunde, Abiodun and Gunnar (2012), the knowledge of climate (rainfall) variability over the period of instrumental records and beyond on different temporal and spatial scale is important to understand the nature of different climate systems and their impact on the environment and society. Most of the observational and numerical studies on climate are based on the instrumental records of about a century which are aimed at the understanding of the natural variability of climate system and to identify processes and forcings that contribute to this variability. This is essential to predict global and regional climate variations, and make sound projections of human induced climate change.

2.2.2.1 Inter annual Rainfall Variability

Inter annual variability of rainfall in the Sahel is of great concern as a result of the drought conditions that began in the late 1960s. According to Nicholson (2013), one of the results of early research on the region was identification of several important and perharps unique features of rainfall variability in the region. These

include an extremely large spatial scale of annual and decadal anomalies (Nicholson, 1980, 1986), decadal and interdecadal persistence of anomalies that is pronounced in the central Sahel (Lamb, 1983; Nicholson and Palao, 1993), extreme magnitude of variability and a dominant contribution of only two of the rainy season months (August and September) to the interannual and interdecadal variability (Nicholson and Palao, 1993).

2.2.2.2 Temporal Trend of Rainfall Variability

In West Africa, a decline in annual rainfall has been observed since the end of 1960s, with a decrease of 20% to 40% between 1931-1960 and 1968-1990 (Mitchell and Jones, 2005; Nicholson, 2013). Research works on the temporal trends of rainfall variability in the sahel are those of Nicholson (2005); Ali and Lebel (2009); Lebel and Ali (2009); Mahe and Paturel (2009). These analyses generally indicated conditions of improved rainfall in the 1990s and a few following years. A greening up in the regime as shown by vegetation index data, confirms this (Olsson, Eklundh and Ardo, 2005; Herrmann and Hutchinson, 2005; Herrmann, Anyamba and Tucker, 2005; Seaquist, Olsson, Ardo and Eklundh, 2006). However, the degree of improvement varies geographically.

Nicholson (2005), examined the season as a whole and the month of August for eight sectors of the sahel. These includes four latitudinal strips, each spanning two degrees of latitude and were divided into east and west sectors with a division at 15^0E. Updating century long-guage time series with Tropical Rainfall Measuring Mission (TRMM) satellite data for the years 1999-2003, the research concludes that recovery was greater in the western sahel (West of 15^0E) than in the eastern sahel and

that the recovery was relatively weak in the month of August. In all the northern-most regions, the rainfall during the period 1998 to 2003 was roughly comparable to that of the 1950s wet period. In the East, the patterns in rainfall were more strongly dependent upon latitude. The years 2000 to 2003 were relatively dry in the north and near the long-term mean in the central sahel,while the years 1994 to 1999 were relatively wet. In the southern-most latitudes of the eastern sahel, 1998 to 2003 appeared to have experienced rainfall. A weakness of the study was that rainfall conditions of the years 1998 to 2003, were established from satelite data from the TRMM, while earlier rainfall conditions were established from guages. However, a validation of TRMM that compared guages and satellite estimates for the year 1998, (Nicholson, Some and McCollum, 2003), showed zero bias in the TRMM estimates and the root mean square error of the TRMM estimates is 0.7/0.9mm/day for seasonal/ August rainfall.

Lebel and Ali (2009), provided further detail, examining conditions through 2007 and considering three longitudinal sectors within the region termed Western Sahel by Nicholson, (2005). Their time series were more homogeneous, as they were produced solely from guage data. Some recovery was shown in recent years, but it was confined to the eastern-most regions. The drought continued unabated in the West, where mean rainfall for the period 1990-2007 was roughly equal to the mean for the acknowledged drought period of 1970-1989. In the central Sahel, there was limited recovery. Rainfall for 1990-2007 was only some 10% above the mean for 1970-1989 and well below the average for the period 1950-1969. The study also noted the dissappearance of the pronounced August peak, consistent with the findings of Nicholson(2005), that the recovery in August was very weak.

Inter annual variability was reported to have been greater in recent years than in the previous 40 years (Ali and Lebel, 2009; Hastenrath and Polzin, 2011). Studies have examined post 2007 years, (Fontaine, Roucou, Gaetani and Marteau, 2011), suggests that in 2008, rainfall in the central sahel was near or just above long-term mean. The study also showed that the circulation characteristics associated with previous wet conditions in the sahel have again been occuring since the 1990s. These include a reinforcement of the low-level westerly winds south of the sahel, northward shift in the latitude of the African Easterly Jet (AEJ) and an intensification of the Tropical Easterly Jet (TEJ) (Grist and Nicholson, 2001; Nicholson, 2008).

Another point concerning inter annual variability is whether, In fact, the long dry interval ended (Elagib and Elhag, 2011). Nicholson(2005), confirmed wetter conditions in much of the sahel during the period 1998 to 2003. Ozer, Erpicum, Demaree and Vandiepenbeeck (2003), also indicated that the sahel drought ended in the 1990s. On the other hand, L'Hote, Mahe, Some and Triboulet(2002), examined a sahel rainfall index that extends from 1986 to 2000, and concluded that the drought continued through the 1990s.

In the tropical rainforest zone, decline in the mean annual precipitation of around 4% in West Africa, 3% in North Congo and 2% in Southern Congo for the period of 1960 to 1998 was observed by Malhi and Wright(2004). A 10% increase in annual rainfall along the Guinean coast during the last 30 years was however observed (Nicholson, Some and Kone, 2000). In other regions such as the southern Africa, no long term trend was noted. However, increased inter annual variability was

observed in the post 1970 period with higher rainfall anomalies and more intense and wide spread droughts reported (Fauchereau, Trzaska and Richard, 2003).

In Nigeria, trends of rainfall was reported with a mixed impact depending on the location, some studies reported a decline in rainfall, while some observed an increase in intensity of rainfall in the 20^{th} century. Among the sahelian studies, there were a number of analysis involving some stations over different periods of time, these include Adefolalu (1986); Bello (1998); Hess, Stephens and Maryah (1995); Alli (2010); Odjugo (2010); Oguntunde, Abiodun, Olukunle and Olufayo (2012).A downward shift of 8.8% rainfall from the long term mean of 1968 to 2008 was recorded in the Northwestern Nigeria (Ekpoh and Nsa, 2011), also a consistent decrease in annual rainfall of 8mm per year in the Northeastern part has been reported by Hess, Stephens and Maryah(1995).The general conclusion of these studies was that; a decline of rainfall in the dry season was observed over the years. A significant positive increase of 2.16mm in rainfall was recorded in the entire northern Nigeria within the period of 1970-2012 (Abdullah, Bose and Kasim, 2015), and a positive increase of annual rainfall of 17.1mm was also observed in North eastern Nigeria for the period of 1983 to 2013(Yahaya, 2015).

2.2.3 Rainfall Distribution Over West Africa

In West Africa, precipitation is characterized by seasonal movement of the Inter-Tropical Convergence Zone (ITCZ). During boreal summer, ITCZ moves northward and reaching near 20^{o}N, where as in winter time, it is located along the Gulf of Guinea coast. The ITCZ marks the convergence zone of moist monsoon air masses in West Africa originating from anti-cyclone system and the dry north-eastern

trade wind originating from the North African sub-tropical high. It is also called Inter-Tropical Discontinuity (ITD) (Nicholson, 2008, 2009a). The northward movement of the monsoon trough is often very variable, causing monsoon breaks with dry condition. During the northern summer time, the surface air flow is peaked by two easterly jets, the Tropical Easterly Jet (TEJ) and the African Easterly Jet (AEJ). The rainfall pattern over West Africa are experienced in the location of the monsoon trough (Nicholson, 2008, 2009a).

The main factors that influence rainfall distribution over West Africa are associated with Sea Surface Temperature (SST) in the Atlantic and the El-nino Southern Oscillation (ENSO). El-nino events significantly correlate with dry events in the sahel region (Camberlin, Janicot and Poccard, 2001). Warmer SST in the south Atlantic corresponds to strong rainfall in the Gulf of Guinea and the coast, resulting in lower rainfall in the sahel region from July until September, but no relation between sahel rainfall and ENSO events, especially at a low frequency scale. It is a clear response to SST variations in the Atlantic (Janicot, Trazaska and Poccard, 2001). The authors concluded that a complex influence of SST is responsible for rainfall patterns and trends in the sahel at different timescales, including SST-ENSO in the Indian ocean (Bader and Latif, 2003) and the Medittarranean sea(Rowell, 2003).

2.2.4 Causative Mechanism of Rainfall Anomaly

A combination of different factors is believed to be responsible for recent climatic anomalies and the seasonal and inter-annual variability of rainfall. They include, regional and global SST changes, the ENSO phenomenon, the ITD model,

the depth and strength of the West African Monsoon (WAM) winds, the propagation of the African Easterly Jet (AEJ) and Tropical Easterly Jet (TEJ), the Saharan/Sahel aerosol dust concentrations (Nicholson, 2013), and the bio-geophysical feedback mechanisms (Taylor, Lambin, Stephenne, Harding and Essery, 2002; Los, Weedon, North, Kaduk, Taylor and Cox, 2006; Oguntunde, Abiodun and Lischeid, 2011). Lucas, Timbal and Nguyen(2014), associated these changes to global warming caused by anthropogenic emmission of green house gases and the gradual expansion of the tropics. These factors are now treated in turn.

2.2.4.1The Inter-Tropical Discontinuity (ITD)

The ITD, is the most popularly accepted medium that influences rainfall distribution in Nigeria (Olaniran, 2002; Omogbai, 2010). It is established that to the southern part of the ITD, varying degrees of convective activity and precipitation takes place, whereas, little or no cloud development or precipitation occur to the northern part. In other words, rain falls mostly when an area is over-lain by the tropical maritime (mT) airmass and ceases when the area is over-lain by the continental tropical (cT) airmass. The ITD advances inland as far as 22-25^{0}N in August at the margin of the Sahara while it does not retreat equatorward beyond 4^{0}N during the Harmattan dry season (Olaniran,2002).

According to Olaniran (2002), five weather zones are associated with the ITD. Zone A to the north of the ITD is rainless as well as Zone B to the immediate south because they do not contain rain-producing clouds. Rainfall in the ITD occurs in zones C and D where conditions favour the development of clouds of great vertical extent.Thunderstorms and squall lines are associated with zone C weather and

monsoon rains with zone D weather. Consequently, rainfall is spatially discontinous when zone C weather prevails. On the other hand, the monsoon system gives continous rains which may last 12 hours or more (Olaniran, 1995).

The ITD model is a factor influencing rainfall distribution in Nigeria and a rainfall producing system which depicts rainfall activity over the country. Figure 2.1 shows the migration pattern of the ITD in an idealized atmospheric cross-section over the country.

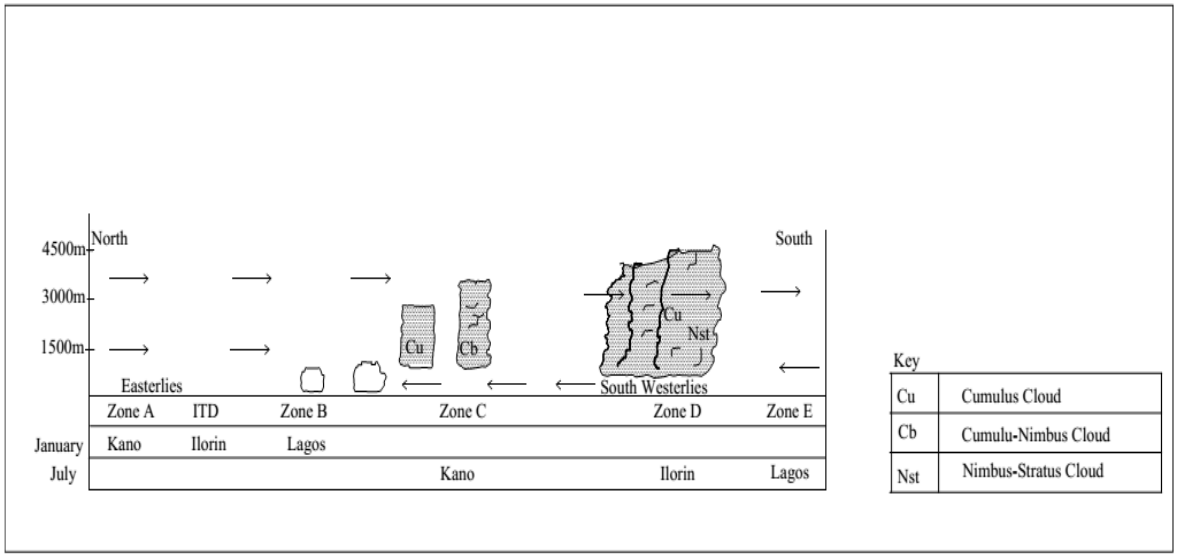


Fig 2.1: The ITD and the Weather Zones in an Idealized Atmospheric Cross-section from Southto North over Nigeria
Source: Olaniran, (2002).

When the fifth weather type associated with the ITD, zone E, prevails over an area, light rainfall usually results because zone E weather is dominated by layered stratiform clouds. The position of the ITD fluctuates seasonally and the different ITD zones affect different areas at various times. Between January/February and August, the ITD migrates northward and there is a corresponding shift northward of the area

of rainfall activity, and from the end of August when the ITD is at its most northerly position, zone E weather migrates a short distance inland causing a period of reduced rainfall in the coastal area, a phenomenon known as August break. During this period the southwesterlies become deflected into westerlies which bring little or no rain. This causes rainfall to increase eastward over southern Nigeria during the July-August period (Olaniran, 2002).

2.2.4.2 West African Monsoon (WAM)

West African rainfall depends on the West African monsoon (WAM), a large-scale circulation that forms from the seasonal reversal of winds due to the land-sea temperature contrast between the sahara desert and the equatorial Atlantic ocean. The largest portion of the rainfall is from deep convective systems e.g squall lines and Mesoscale Convective Systems (MCSs) and the ITCZ embedded within WAM system during the months of July, August, and September (Lavaysse, Diedhiou, Laurent and Lebel, 2006).

A difficulty has been in the approach of defining monsoon onset and its predictability as several varied parameters have been utilized to do so. Marteau, Moron and Philippon (2009) used threshold values of daily rainfall at individual stations to quantify the magnitude and length of initial wet spell and any subsequent breaks. According to Sultan and Janicot(2000); Drobinski, Bastin and Janicot(2009), the mean onset date over the sahel is June 24. Onset proceeds slowly and is characterized by a succession of active and inactive phases (Dieng, Rouchou and Lovet, 2008). There is little spatial coherence in the onset dates and consequently, little predictability (Marteau et al2009). The lack of coherence is a result of the

fragmented nature of the active and break phases (Dalu, Gaetani and Baldi, 2009). The withdrawal phase is relatively abrupt and rather uniformly distributed throughout the entire monsoon region. Model simulations by Flaounas, Janicot, Baston and Roca(2012), suggest that large-scale dynamics, extending beyond West Africa, control the monsoon onset and its timing. The associated convection north of 15^{o}N forces a westward propagating Rossby wave that reaches West Africa some 7 to 15 days later, with wave passage triggering convection in the sahel. Drobinski, Bastin and Janicot (2009), examined a case of late monsoon onset in Niger and Mali and discovered additional factors. During 2006, the onset was delayed until July 3. The delay was associated with an anomalous direction of the AEJ, which flowed northeasterly in a band over the Hoggar and Air mountains. There was also an unusually strong northeast harmattan in the lee of the mountains. The delay appeared to be related to the interaction of the AEJ and orography (Nicholson, 2013).

Four phases of the WAM has been defined by Thorncroft, Nguyen, Zhang and Peyrille (2011), depending on the location of the rainfall peak which are the oceanic, coastal, transitional and sahelian. The oceanic phase between November and mid-April is a broad rain belt which lies just north of the equator. The coastal phase generally prevails to mid-June, peak rainfall lies over the ocean but in the near coastal region around 4 to 5^{o}N (Le Barbe, Lebel and Tapsoba, 2002; Sultan, Janicot and Diedhiou, 2003; Gu and Adler, 2004; Schumacher and House, 2006; Thorncroft et al, 2011). The transition phase, where a decrease in rainfall is observed, occurs in early July. The first three phases is collectively refered to as the oceanic regime by Lebel, Diedhiou and Laurent (2003). The sahelian phase lasts from mid-July to September. Throughout this phase, the rainfall peak is more intense and remain just to the south

of the sahel, around 10^oN. Rainfall in the sahel is associated with this maximum termed as continental regime by Lebel et al(2003). The shift between the maximum at 5^oN in the coastal phase and 10^oN in the continental phase is very abrupt evoking the term "Monsoon Jump" (Sultan and Janicot, 2000; Le Barbe, Lebel and Tapsoba, 2002). Sultan and Janicot (2000); Ramel, Galle and Messanger (2006); Sijikumar, Roucou and Fontaine (2006), have proposed explanation for the abrupt shift, suggesting it is triggered by westward propagating disturbances, the saharan heat low, which intensifies and shifts northward at the time of the "jump". Gu and Adler (2004), pointed out that the shift is associated with a northward shift of the AEJ, associated horizontal and vertical shear zones, as well as the development of westward propagating waves. The shift is related to the interaction of the Atlantic equatorial cold tongue and the African monsoons (Okumura and Xie, 2004). Complex interactions among convection, AEJ dynamics and local topography, plays a role (Sultan et al 2003). According to Nicholson (2013), what underlies all of this mechanisms is a northward shift and intensification of the latitudinal temperature and pressure gradients over West Africa.

There are notable differences between the characteristics associated with the two spatial rainfall maxima, one is in the origin of precipitation (Gu and Adler, 2004). Early in the rainy season i.e, May - June, when the maximum is near the Gulf of Guinea, rain bearing synoptic systems tend to be eastward propagating wave signals. In the late rainy season, when the maximum lies well in to the continental interior, westward propagating wave signals are the dominant rain-bearing synoptic systems. The convective rain rate and the percent of area covered by cumulunimbus anvils are lower and the stratiform fraction is higher in the second spatial maximum (Sealy,

Jenkins and Walford, 2003; Schumacher and House 2006). Consistent within this, the size and organization of convective systems is greater during the peak monsoon season, but rainfall intensity is lower, than ealier in the season (Bell and Lamb 2006). The two spatial maximum also differs in the patterns of variability in recent years, with the second maximum exhibiting much more change. The rainfall peak associated with this regime has also appeared increasingly early in the season (Le Lay and Galle 2005), with the August peak disappearing in recent years (Lebel and Ali, 2009). The onset and cessation of the rainy season, the duration (length) of rainfall period, and the annual rainfall amount are controlled by the northward progression of WAM (Ward, 1992; Cifelli, Lang, Rutledge, Guy, Zipser, Zarislak and Holzworth, 2010).

2.2.4.3 The Tropical Easterly Jet (TEJ)

Tropical Easterly Jet develops as a response to the intense north-south temperature gradient between the Himalayan plateau and the Indian ocean, generally at a height of around 12-15 km. It is energetically maintained via tropical divergent circulations associated with the East-west walker circulation and North-south Hardley circulation. The TEJ's mean speed over the Sahel during boreal summer is roughly $18ms^{-1}$. It has frequently been described as a boreal summer feature, but this jet is also very strong in January through March, when it is located in the southern hemisphere with a core around 5 to 10^0S (Nicholson and Grist, 2003). The TEJ over West Africa exhibits little latitudinal change from year to year but its speed and east-west extent vary greatly (Grist and Nicholson, 2001; Nicholson and Grist, 2001; Sathiyamoorthy, 2005; Nicholson, 2008). The role played by the TEJ in interannual variability has been well documented, a stronger/weaker TEJ has been linked to wetter/drier conditions in the Sahel (Grist and Nicholson, 2001; Webster and Fasullo,

2003; Nicholson, 2008) and western equatorial Africa (Dezfuli and Nicholson, 2011; Nicholson, Dezfuli and Klotter, 2012). Its link to rainfall in equatorial Africa is apparent in both the boreal spring and boreal autumn. It has also been implicated as a factor in the mean climate of West Africa (Webster and Fasullo, 2003).

The link between the TEJ and rainfall appears to be of upper-level divergence associated with the jet core. The divergence results from strong meridional components associated with the TEJ over Africa (Nicholson and Grist, 2003). This pattern is particularly pronounced in wet years in the Sahel, and this appears to play a role in its impact on rainfall (Nicholson, 2009b). This is further consistent with the observation that a stronger TEJ is linked not only to more rainfall in the Sahel, but also to a more intensed rainbelt (Nicholson, 2008, 2009b). On the southern side of the TEJ axis, conditions are conducive to the acsent of air and consequently rainfall occurrence while the northern side is marked by subsidence. The TEJ, therefore, reinforces aridity over the extreme northern part of the country but causes a belt of above average rainfall in the central part (Olaniran, 2002).

2.2.4.4 The African Easterly Jet (AEJ)

The African Easterly Jet (AEJ) is among the most important features affecting the tropical African climate (Fontaine, Janicot and Moron, 1995). The AEJ found between 600-700 hPa exist due to meridional temperature gradient between the warm sahara desert to the north and the cool gulf of guinea to the south. The axis of the jet appears above the strongest surface temperature gradient and its intensity varies from $10ms^{-1}$ in wet years to $12ms^{-1}$ in dry years (Grist, Nicholson and Barcilon, 2002).

However, its location varies remarkably and is of critical importance in rainfall variability over northern Sahel (Nicholson and Grist, 2001).

It has been suggested that the strength and location of AEJ is dictated not only by the temperature gradient, which produces a vertical shear, but also by the low level westerlies, upon which the shear is imposed (Nicholson and Grist, 2001). Moreover, the surface wetness gradient can also enhance the temperature gradient (Cook, 1999). It has been noted by Fontaine, Janicot and Moron (1995); Grist, Nicholson and Barcilon (2002); Nicholson and Grist (2001), that in wet years the AEJ tends to be weaker and more poleward while it is stronger and more equatorward in dry years.

2.2.4.5 Sea-surface Temperature (SST)

Sea-surface Temperature (SST) is the temperature of the sea surface representing the condition in the surface mixed layer underlying the ocean. It is a geophysical variable of importance to meteorological services, the world climate research programs, and other large and small-scale research programs. Its distribution in local, regional, and global scales are of interest to scientist for the study of variety of processes in the sea, coastal areas, and in the atmosphere. These ranges from local air-sea interaction and their relationship to local weather which includes rainfall (Akinbobola, Balogun and Oluleye, 2015).

The role of SST in rainfall variability is increasingly being understood (Adejuwon, Balogun and Adejuwon, 1990; Folland, Owen, Ward and Colman, 1991; Colman, Davey, Graham and Clark, 2000; Odekunle, Balogun and Ogunkoya, 2005). The basic that is central to all sorts of explanation of this phenomenon is that a lot of atmospheric disturbances are due to anomalously high or low temperature of the

ocean surface. An anomalously low SST in the atlantic ocean has long been recognised as a significant cause of inter-annual climatic variability in West Africa (Odekunle et al, 2005). The unusually low SST is observed particularly around the Gulf of Guinea. The low SST is believed to be affected by the combined action of a cold current - The Benguela current, and a two-sided divergence of the Ekman transport found within guinea coast (Flohn, 1971). It is however, probable that the upwelling in the region is initiated by persistent equatorial easterlies in the cold tongue region to the south. The ocean-atmosphere interactions promotes a number of consequences on the moist south westerly winds. These includes:

a.) Chilling effect at the coast when the sea surface is cold, resulting in the winds acquiring negative buoyancy. Warming on the land may reverse the situation.

b.) The chilling effect may promote an increase in pressure and therefore strengthening of the winds. This chilling and strengthening may inhibit precipitation around the coastal area but enhances rainfall and wind further inland after appropriate warming has taken place (Odekunle et al,2005).

c.) It has been argued by Carlson(1969), that low SST can effect a change in the temperature contrast between the potentially hot saharan area and the relatively colder southern region. Increase in the temperature contrast enhances easterly shear through the process known as thermal wind adjustment. The increase in easterly shear should in turn result in increased precipitation in the sahel region only (Odekunle et al,2005).

It is also believed that enhanced thermal contrast would result in the ITD moving further north, which could promote more rainfall in the north. The SST-

rainfall relationship described above depicts the gulf of guinea as the main area of the atlantic ocean having a significant influence on the nature of precipitation in West Africa (Odekunle et al, 2005).

Modulation of the African monsoon by regional and global-scale SST provides explanation for variations in the sahelian rainfall on multi-year to decadal time-scales. Relationships between SST patterns and sahelian rainfall are well established from statistically based climatoligical analyses and have been used with some success in seasonal rainfall forecasts in the region (Ward, Folland, Maskell, Colman, Rowell and Lane, 1993). Since the late 1960's, the sahelian drought has been shown to have tele-connections with ENSO, a phenomenon associated with periodic flunctuations in the intensity of the inter-tropical atmospheric and oceanic circulations that is usually co-incident with an anomalous warming of the eastern tropical pacific ocean (Ekpoh, 1991;Nicholson, 1993; Akonga, 2001; Ekpoh and Nsa, 2011). Giannini, Saravanan and Change (2003), identified SST as the principal driver of Sahelian rainfall variability which they modeled succesfully and used the model to also represent the land-atmosphere interaction, via moisture feedbacks.

2.2.4.6 The El Nino Southern Oscillation (ENSO)

The El Nino Southern Oscillation is a planetary scale dominant mode of inter annual climate variability that has a periodicity of 2 to 7 years characterized by a warming/cooling in the pacific ocean near the peruvian coast. During the period when the central-eastern pacific ocean warms up above average, heavy rainfall is experienced over Northern Peru and Ecuador(Enos, 2013). The evolution of this warm waters is referred to as El Nino. La Nina is the term that corresponds to a

cooling below average across the central eastern pacific waters. The warming/cooling of the pacific ocean to the east coupled with warming/cooling to the west is associated with an air pressure differences between two centres, one located at Darwin (Australia) and the other at Tahiti (central pacific). The see-saw pressure differences is known as the Southern Oscillation (SO). The El Nino/La Nina phenomenon together with the southern oscillation is termed the El Nino Southern Oscillation, hence the term ENSO (Nicholson and Kim, 1997).

The ENSO in the tropical pacific ocean has been confirmed as one of the important factors influencing rainfall variability for some regions in Africa (Nicholson, Some and Kone, 2000; Nicholson and Selato, 2000; Hulme, Doherty, Ngara, New and Lister, 2001). Hulme et al (2001), observed a strong ENSO relationship with high rainfall during a warm ENSO event for equatorial East Africa and low rainfall during a warm ENSO event for southern Africa which is consistent with ealier studies. In west Africa, there has been a controversy on the influence of ENSO on rainfall, while there is a general consensus among researchers on ENSOs influence in some regions, for instance the Guinea coast, where it tends to increase rainfall, (Nicholson, 2001), there is controversy over its influence in the sahel. Authors cited at the beginning of this paragraph found a weak correlation between ENSO and sahelian dry conditions. For example, although dry conditions prevailed throughout the sahel and most part of West Africa in 1997, El Nino appears to have had minimal impact on the dry conditions experienced in the region (Nicholson et al 2000). This suggests other factors may be important as Hastenrath (1990), and Ward (1992) to mention but a few, suggest that the impact is larger. Ward (1992), further notes that ENSOs influence appear to be greater during dry years than wet years. The

different opinion among several authors is due to the complex nature of ENSOs influence in the region.

2.2.4.7 The Saharan/Sahel Aerosol Dust Concentration

The main impact of dust is on the atmospheric radiation budget. The particulates serve as ice nuclei and cloud condensation nuclei (deMott, Sassen and Poellot, 2003; Hui, Cook, Ravi, Fuentes and D'Odorico, 2008; Wiacek, Peter and Logmann, 2010). The radiative effect depends on the composition of the dust, that is, on its relative role in absorbing and reflecting radiation (Nicholson, 2000). Hence, the radiative effects are different for mineral-based Saharan-dust and smoke introduced by biomass burning (Huang, Zheng and Prospero, 2009). The dust appears to intensify the African Easterly Jet, consistent with the mid-level heating, and weaken the Tropical Easterly Jet (Konare, Zakey and Solmon, 2008). Dust outbreaks also affect saharan heat low. The radiative effect increases its thickness, but the impact of the dust on AEJ affects the heat low. Studies conclude that the net effect is to reduce precipitation over the sahel, particularly that associated with deep convection (Huang et al 2009; Kluser and Holzer-Popp, 2010; Solomon, Elgundi and Mallet, 2012). However, Lau, Kim, Sud and Walker (2009), suggests that the dust can strength the monsoon and shift it northward, which implies an increase in rainfall over the sahel.

2.2.4.8 Biogeophysical Feedback Mechanism (BFM)

Reduced rainfall , combined with human and animal activities could reduce the vegetation cover and increase the reflectivity, or albedo of the land surface (Olaniran, 2002). Higher albedo changes the heat balance of the surface-atmosphere system and ultimately this leads to increased divergence in the lower atmosphere and

reduced uplift over the higher albedo region. These changes, in turn, lead to less rainfall and maintenance of drought condition (Farmer and Wigley, 1985).

Crop production is affected biophysically by meteorological variables, including rising temperatures, changing precipitation regimes, and increased atmospheric carbon dioxide levels. Biophysical effects of climate change on agricultural production will be positive in some agricultural systems and regions and negative in others, and these effect will vary through time (Parry, Rosenzweig, Iglesias, Livermore and Fischer, 2004).

2.2.5 The Concept of Drought

Droughts are recognized as an environmental disaster and have attracted the attention of environmentalist, ecologists, hydrologists, meteorologist, and agricultural scientists. Drought occur virtually in all climatic zones, such as high, as well as low rainfall areas and are mostly related to the reduction in the amount of precipitation received over an extended period of time, such as a season or a year (Mishra and Singh, 2010). Temperatures, high wind, low relative humidity, timing and characteristics of rain, including distribution of rainy days during crop growing seasons, intensity, duration of rain, onset and cessation, play a significant role in the occurrence of droughts. In contrast to aridity, which is a permanent feature of climate, and restricted to low rainfall areas, a drought is a temporary aberration (Wilhite, 1992).

Many drought definitions are adopted in different fields (meteorology, hydrology, agriculture, water resources) with reference to various hydrometeorology variables (Panagoulia and Dimou, 1998). World Meteorological Organisation (1986),

defines drought as a sustained, extended deficiency in precipitation. The United Nations Convention to Combat Drought and Desertification (1994), defines it as a naturally occurring phenomenon that exists when precipitation has been significantly below normal recorded levels causing serious hydrological imbalances that adversely affect land resources production systems. The FAO (1983), defines drought hazard as the percentage of years when crop fails from the lack of moisture. However, drought definitions vary, depending on the variable used to describe the drought. Hence, drought definitions can be classified into different categories which are; Meteorological drought (precipitation below average), hydrological drought (low river flows and water level in rivers, lakes and ground water), agricultural drought (low soil moisture) and socio-economic drought (a combination of the above).

According to Mishra and Singh(2010), Drought indices have been derived in recent decades. Commonly, drought index is a prime variable for assessing the effect of drought and defining different drought parameters, which include, intensity, duration, severity, and spatial extent. Drought variable should be able to quantify the drought of different timescales for which a long-time series is essential. The most commonly used time scale for drought analysis is a year, followed by a month. Although, the yearly timescale is long, it can be used to obtain information on the regional behavior of droughts (Mishra and Singh, 2010). The monthly timescale seems to be more appropriate for monitoring the effect of a drought situation related to agriculture (Panu and Sharma, 2002). A number of different indices have been developed to quantify a drought, each with its own strengths and weaknesses. They include the Palmers Drought Severity Index (PDSI) by Palmer (1965), Rainfall Anomaly Index (RAI) by Van Rooy (1965), Deciles by Gibbs and Maher(1967), Crop

Moisture Index (CMI) by Palmer (1968), Bhalme and Mooley Drought Index (BMDI) by Bhalme and Mooley (1980), Standardized Precipitation Index (SPI) by McKee, Doesken and Kleist (1993; 1995) and Reclamation Drought Index (RDI) by Weghorst (1996). Based on studies of drought indices, practically all drought indices use precipitation either singly or in a combination with other meteorological elements depending on the type of requirement (Mishra and Singh, 2010).

Drought produce a complex of impacts that span many sectors of the society, including economy and may reach beyond the areas experiencing a drought. In Africa, since the late 1960s, the Sahel, has experienced a drought of unprecedented severity in recorded history (Mishra and Singh, 2010). The drought had a devastating impact on this region and was a major impetus for the establishment of the United Nations Convention on Combating Drought and Desertification (Zeng, 2003). While the frequency of drought in this region is thought to have increased from the end of the 19^{th} century, three long droughts had dramatic environmental and societal effects upon the Sahel nations (Mishra and Singh, 2010). According to the above author, famine followed severe droughts in the 1910s, the 1940s, 1960s, 1970s and the 1980s, although, a partial recovery occurred from 1975 to 1980. While atleast one particularly severe drought has been confirmed in each century since 1600s, the frequency and severity of the recent Sahelian drought stands out. Famine and dislocation on a massive scale from 1968 to 1974, and in the early and mid-1980s was blamed on two spikes in the severity of the 1960 to 1980s drought period (Butterbury and Warren, 2001).

2.3 LITERATURE REVIEW

2.3.1 Rainfall Anomaly Trend

Rainfall anomaly denotes the difference between the long-term average rainfall and the rainfall that is actually occuring. In other words, the long-term average rainfall is one that would be expected, the anomaly is the difference between what would be expected and what is happening. Rainfall anomaly, the departure from a reference value or long-term average of rainfall is percieved as a phenomenon which atmospheric circulation, changes in sea surface temperature, rainfall and remote meteorological occurences are linked in a complex and incomprehensible manner(Olaniran,2002). The occurrence of an extreme dry and wet years, known as anomalous years could either be a positive or negative anomaly. Positive anomaly value indicates observed rainfall value is greater than the average threshold value, which implies rainfall is wetter than normal while negative anomaly indicates observed rainfall is less than average value,which means rainfall is drier than normal.

Several studies such as Ali and Lebel (2009); Bader and Latif(2003); and Olaniran (2002), have looked at rainfall anomalies both on decadal scales and climatic zones. The spatial rainfall variability of the Sahel was significantly dry. The variability showed that only 28% of the area was significantly dry, while 15% of the Sahel was significantly wet. The spatio-temporal pattern of precipitation from 1950 to 2006 was characterized by greater inter annual variability in recent years than the previous 40 years and by contrast the Western Sahel remained dry and the Eastern Sahel returned to wetter conditions (Ali and Lebel, 2009). The warming trend in the Indian ocean played a crucial role on the drying trend over the Western Sahel from 1950s to 1990s(Bader and Latif, 2003).

There is no discontinuity in the rainfall series of central Africa, however, discontinuity in rainfall trend first occurred at the end of the 1950s in West Africa. The main discontinuity period occurred between 1968 and 1970, followed by a second one at the beginning of the 1980s. Rainfall deficit is greater north of 10^{o}N. Regions leeward of mountainous areas experienced moderate rainfall decrease(Mahe, L'Hote, Olivry and Wotling, 2001),. This is consistent with studies of Moron (1994), Nicholson, and Kim (1997), and Paturel, Servat, Kouame, Lubes, Ouedraogo and Masson (1997) for the same regions and concluded that the long term trend of rainfall series of West and Central Africa showed major climatic discontinuity.

In semi-arid highlands of Northern Ethiopia, episodes of droughts of varying severity occurred. The occurrence of this droughts is associated mainly with the seasonal rainfall variability (Gebrehiwot and van der Veen, 2013). Gebrehiwot and van der Veen (2013), attempted to investigate the temporal and spatial variability of climate parameters for the period of 1954-2008, and concluded that there is an overall slight decrease in rainfall over the study period in Northern Ethiopia. In south western Ethiopia, inter-annual rainfall variability was reported to have been low in recent years. This is as a result of the poor monthly rainfall distribution and rainfall concentration ranging from moderate to high in half of the period. Negative rainfall anomalies was experienced for much of 1983, 1984 and 1994, showing local level rainfall trend and variability(Girma,Johanssonand Garedew, 2016).

Rainfall anomalies in Nigeria have been examined through three periods from the palaeo period (20,000 years BP to 1500 AD), through the historical period (1500-1900 AD), to the instrumental period which coincides with the 20^{th} century from

1921-2000(Olaniran, 2002).Nigeria can be divided into three regions based on the spatio-temporal occurrence of rainfall anomalies in the country. The first, is the Sahelian zone (area of the country North of 11^{o}N latitude), where rainfall changed. As rain belt shifted southward by about 60km, annual rainfall reduced by 100-150mm during the last three decades, while most rains occurred in 1-3 months. The second region is the Southern Nigeria where the rainfall is characterized by alternating wet and dry conditions on the decadal timescale. The region also experienced reduced rainfall during the last three decades, but of the order of 100mm. Seasonal rainfall distribution became less equable. The rainfall belt contracted eastward at the coast by about 160km. The third region is the savanna belt, this belt is a transitional zone between the Sahel and southern Nigeria, but took more of the character of the Sahel than that of Southern Nigeria during the 20^{th} century as rainfall belt was displaced southward by about 230km. The impact assessment of rainfall anomalies in Nigeriashows the vulnerability of Nigeria to environmental degradation, and drought. This cause decline in agricultural productivity, thereby raising problem of food security for the nation.

Rainfall characteristics in Nigeria have been examined for dominant trend notably by Olaniran (1990 and 1992). They showed that there has been a progressive early retreat of rainfall over the whole country, and consistent with this pattern, they reported a significant decline of rainfall frequency in September and October which respectively coincide with the end of the rainy season in the northern and central parts of the country. The pattern of rainfall in northern Nigeria is highly variable in spatial and temporal dimensions with inter-annual variability of between 15 and 20 percent(Oladipo, 1993a). As a result of the large inter-annual variability of rainfall, it

often results in climate hazards, especially floods and severe drought with their devastating effects on food production and associted calamities, and sufferings (Okorie, 2003; Adejuwon, 2004).

Akinsanola and Ogunjobi (2014), analyzed rainfall and temperature variability in Nigeria over thirty (30) years from 25 synoptic stations. The result showed anomalies between -0.2 and -1.6 being predominant in the first decade of the study. Five stations showed positive anomaly while the greater part of the country were normal conditions in the third decade. This suggests a sequence of alternating decreasing and increasing trend in mean annual precipitation which implies that rainfall had been on the increase within the year of consideration. The rainfall anomaly overthe country has a composite nature in which some dry years were mixed with wet years and vice versa. The decrease in rainfall may be due to failure of rain-producing mechanisms such as Inter-Tropical Discontinuity (ITD), Africa Easterly Jets (AEJ), Tropical Easterly Jets (TEJ) to organise thunderstorm, squall-line that are responsible for over 70 percent of the total annual rainfall(Akinsanola and Ogunjobi, 2014).

Ifabiyi, and Ojoye (2013), observed that the downward trend in rainfall amounts in the 1970s and 1980s was responsible for the drought periods of 1972/1973 and 1980, and the upward trend in the amount of rainfall between 1990 and 2009 accounts for the flooding episodes in Northern Nigeria. The general increase of 5% annual rainfall in the Sudano-Sahelian zone, was due to an observable 5.4% increase in mean raindays and 4% increase in the rains that fall as heavy rains, and found to be responsible for the increase in run-off in the zone. It is concluded that

the Sudano-Sahelian zone of Nigeria has been experiencing an increase in annual rainfall with little recession.Ayansina, and Ogunbo (2009), investigated the seasonal rainfall variability in Guinea savanna Ecological zone of Nigeria and concluded that rainfall variability continues to be on the increase as an element of climate change.

Ekwe, Joshua, Igwe and Oshinowo (2014), examined monthly and annual rainfall trends in Nassarawawhich shows that 1996 is the wettest year, while 2010 has the lowest negative rainfall deviation. In analyzing the month for the period, it was noticed that August recorded the highest rainfall value of 2498 mm which is the month where clouds pervades the sky. The anomalous departures from the mean is very small with the highest positive departure from the mean approximately 12% in 1996. This shows a flunctuating rainfall pattern over Nasarawa state. Rainfall regime is markedly seasonal with a long dry season in Kafanchan, Kaduna state between 1974-2008. This is because the months of June and October were significantly drier. Rainfall yield is declining, which started from 1990. The decline in the annual rainfall yield is predominantly as a result of the substantial decline in July, September and October rainfall, which are the critical months for agricultural production in the area(Abaje, Ishaya and Usman 2010).

2.3.2 Crop Yield Trend

2.3.2.1 Maize Yield

There is continous increase in maize production all over the world and this is attributed to both increase in area of production and increase in yield per hectares. Maize grain production in the world in 1970 was about 266 million metric tonnes (mmt), while in year 2000, it was over 592mmt and exceeded 844mmt in 2010. Of the

total global production, United States of America (USA) is far the biggest producer, contributing between 37-43% of total world production(FAOSTAT, 2012). In 2010 world ranking, United States was followed by China with 177mmt, Brazil with 56mmt, Mexico with 23mmt and Argentina with 21mmt(FAOSTAT, 2012). Maize production in the United States and other developed countries of the world is highly mechanized on large scale production, where hybrids, maize varieties are commonly grown with high inputs in terms of agro-chemicals.

According to the Forum of Agricultural Research in Africa, [FARA] 2009,Africa is a minor producer of maize by world standard, accounting for only 7% of global production, while the average annual production were estimated at 32mmt during 1985-1987, it increased to 49mmt in 2005-2007. According to the International Institute of Tropical Agriculture [IITA](2009), area planted with maize in West and Central Africa increased from 3.2 million in 1961 to 8.9 million in 2005, leading to increased production from 2.4 mmt in 1961 to 10.6 mmt in 2005. Basic facts about maize production in Africa as highlighted by FARA (2009) stated that:

1. Africa accounts for 7% (49mmt) of global maize production.
2. Maize yield in Africa (1.7 tons/ha) account for 36% of global maize yield (4.9 tons/ha).
3. Maize production in Africa is increasing faster (2.8% per annum) than global production (2.5% per annum), however, global yields are increasing faster (1.6% per annum) than yields in Africa (1.3% per annum).

The average yield of maize in Nigeria as it is found in other Sub-Sahara Africa countries is generally low at 1.68tons/ha, which is very low compared to average yield in United States 9.3 ton/ha from 1986 to 2011(FAOSTAT, 2013).

2.3.2.2 Sorghum Yield

Sorghum (*Sorghum bicolor L. Moench*) is one of the most important cereal crops and in the supply of food energy ranks fourth with only three other starchy crops namely maize, rice and wheat(FAOSTAT, 2013). Sorghum is the most popular staple food in Africa and Asia, where it is mostly grown at subsistent level. Sorghum is adapted to grow in hot, arid, and semi-arid climatic conditions. Due to its tolerance of wide variety of climatic conditions, sorghum production is one of the principal contributors to food security of the rural populations (Sekoli and Morojele, 2016). Total world production of sorghum exceesds 50 million tonnes, one-third of which is from a small area in developed countries. Average yields are very high on the American continent which is greater than 3.0 ton/ha, while they are low in India and Africa with less than 1.0 ton/ha. Africa accounts for a quarter of the world's production, Nigeria and Sudan contributes nearly half of the production(Idrissa, 2005). Sekoli and Morojele (2016), determined the production trend of sorghum over a time period of 53 years from 1960 to 2013 for Lesotho, which showed the yield of sorghum flunctuated erratically throughout the period. The average yield of sorghum was 1.0 ton/ha with yield exceeding this amount recorded in only 18%, i.e nine out of the over fifty years in the study period. The highest production at 85,800 metric tonnes in 1978 gave the yield of 1.45 tons/ha, which was exceeded by yield of 1.48tons/ha at production of 22,800 metric tonnes in 1998. The author above stated a decline in yield rather than an increase which might be related to the subsistence

nature of sorghum production in Lesotho, however, the result shows an increase in yield of sorghum over the time in the study period rather than a decline.

In the year 1978, the total sorghum production in Nigeria was estimated to be 4.8million tonnes. This figure has risen to about 7million tonnes annually. Consequently, Nigeria becomes the highest sorghum producer in West-Africa sub-region, accounting for 71% of the regional production for human consumption and has risen from fourth position in 1995 to the third largest producer of sorghum in the world after USA and India, where more than 90% of their sorghum harvest is used for animal feed(Okpeke, 2006). Tahir (2014), studied trend productivity of some cereal crops in Nigeria, which shows sorghum productivity was marginal with highest productivity level of about 16,202 kg/ha recorded in 1983. Subsequently, productivity declined to 9,691kg/ha in 1991 exhibiting a fluctauting trend with minimal positive and negative changes over the study period. Maikasuwa and Ala(2013), examined trends in area and productivity of sorghum from 1993-2012 in Sokoto, revealed a negative growth trend for area and positive trend for productivity. The quadratic time term indicated a stagnated growth in area and accelerated growth in productivity. However, the result failed to show the yield of sorghum over time in the area of concern.

2.3.2.3 Cassava Yield

Africa claims 62% of the total world production of cassava (*Manihot Esculenta*). Nearly two-third of cassava production in Africa about 38.3million tonnes is grown in Nigeria, making it the largest producer in the world with about 19% of global market share (Adebayo, Haggblade, Sanni and Westby, 2009; Sanni, Onadipe,

Ilona, Mussagy, Abass and Dixon, 2009). Between 1961 and 1999, total cassava production in Africa trippled from 33million tonnes per year in the early 1960s to 87million tonnes per year in the late 1990s (FAOSTAT, 2012). Factors such as erratic rainfall pattern, food shortages, economic stagnation and population growth have had a much greater influence on cassava production in Africa than anywhere in the world (Scott, Rosegrant, Mark and Ringler, 2000).

According to the, Food and Agriculture Organization (FAO) and International Fund for Agricultural Development (IFAD), (2005), the average cassava yield in Africa was between 5 and 10 tons/ha in 1954. The Collaborative Study on Cassava in Africa (COSCA), found the average yield was between 10 and 15tons/ha in the six COSCA study countries in the early 1990s. This implies that cassava yield was increasing in Africa in the early 1990s because of the planting of high yielding varieties and the adoption of better agronomic practices. In 1991, their study showed the average cassava yield for the six COSCA study countries was 11.9 tons/ha. The average yield was highest in Nigeria where the mean was 14.7 tons/ha, followed by Ghana with mean of 13.1 tons/ha and Tanzania, Cote d'Ivoire, The Congo, Uganda was around 10 tons/ha respectively.

Nigeria grows cassava in large quantities, its cultivation is on small farms often in fields to be set aside as fallow and even cropped on marginal lands replacing crops that require greater soil fertility (Adebayo et al,2009). Nigeria's cassava production is by far the largest in the world, a third more than production in Brazil and almost double the production of Indonesia and Thailand. Cassava production in other African countries, appears small in comparison to Nigeria's substantial might.

Food and Agriculture Organization, (2004), estimated cassava production in Nigeria to be approximately 34 million tonnes in 2002. The trend of cassava production as reported by Central Bank of Nigeria mirrored the FAO data until 1996(Federal Ministry of Agriculture and Natural Resources (FMANR), 1997), and thereafter rose to the highest estimate of production at 37 million tonnes in 2000. The third series provided by the Project Coordinating Unit (P C U), of the Federal Ministry of Agriculture and Rural Development had the most conservative estimate of production at 28 million tonnes in 2002 (P C U, 2003).

Expansion of cassava production has been relatively steady since 1980 with an additional push between the years 1988 to 1992 owing to the release of improved IITA varieties. By zone, the North central zone produced over 7 million tonnes of cassava per annum from 1999 to 2002, South-south produced over 6 million tonnes, while South-west and South-east produces less than 6 million tonnes per year. The North-west and North-east production are small by comparison at 2.0 and 0.14 million tonnes respectively (Phillips, Taylor, Sanni, and Akoroda, 2004).

2.3.2.4 Yam Yield

Yam (*DioscoreaSpp*) are one of the most important food crops in West Africa, except for cereals(Bassey, 2017). They are the second most important tuber crops in the whole world after cassava, in terms of production (IITA, 2013). They also form an important food source in other tropical countries including East Africa, the Caribbean, South America, India and South-East Asia(Bassey, 2017). Yam world production is estimated at 52mmt planted in more than 5million hectares in 57 countries worldwide, 95 percent of which is produced particularly in West Africa.

(FAO, 2004). In South-East Asia, particularly Phillipines, annual production is estimated at 15 metric tonnes. A declining trend in production was observed with output dropping to 15,799 metric tonnes in 2012 from 30,074 metric tonnes in 2006(Bureau of Agricultural Statistics, 2002). Phillipines has varieties of yam which have the potential yields from 10-56 metric tons/ha (Anyanwu and Ildefonso, 2015).

According to Degras (2000), yam production increased by about 70 percent from 1960 to 1970 due to an increased in surface area (44 percent) and yield (18 percent). It was observed that the annual output of yam had fluctuated since then reflecting changes in area cultivated and yield. However, output was much higher between 1986 and 1995 while the lowest performance occurred between 1970 and 1983 when agricultural indices were generally low.According to FAO (1997), the estimated world production was about 30 million tonnes, in which approximately 90 percent was produced in the yam belt of West and Central Africa. The production trends indicated that world yam production grew at 2.5 percent per year between 1965 and 1974 and 1.9 percent per year from 1975 to 1985(Bassey, 2017). The growth rate of FAO statistics jumped to 10 percent per annum between 1985 and 1990. This was as a result of the combined effort of increase in yield at the rate of 4 percent per year and increase in area by 6 percent per year.

In West Africa, the corresponding annual growth rate were 5 percent for the yield and 7 percent for area harvested (Manyong, Asiedu and Olaniyan, 2001). The leading yam producing country Nigeria, with 75 percent of world production in 1997 experienced an annual growth rate as high as 6 percent for the yield of yam(Bassey, 2017). Yield is relatively low compared with other West African countries. The high

production of yam in Nigeria is related to area under cultivation, with an average yield of 9.55 ton/ha obtained in Nigeria, 10.83 ton/ha in Cote d'ivoire, 10.94 ton/ha in Benin Republic and 12.74 ton/ha in Ghana. Yam growth rate for 2011 was 5.4 percent, but reduced to 4.9 percent in 2012 (Central Bank of Nigeria, 2012), higher yields however, continued, Nigeria produced over 45.004 mmt in 2014 (FAO, 2014), which is attributed to the combined effort of National Root Crops Research Institute (NRCRI) and IITA, Ibadan.

According to Idumah, Owomboand Ighodaro (2014), yam production in Nigeria has more than trippled over the past 45 years from 6.7 million tonnes in 1961 to 39.3 million in 2006. This increase is attributed more to the large area planted with Yam than increase in productivity (Nwosu and Okoli, 2010). There has, however been a general decline in yam production in Nigeria over the years. Madukwe, Ayichi and Okoli(2000); Agwu and Alu(2005); and IITA(2009), reported that both area under yam cultivation and total yam output were declining. The decline in average yield per hectare has been more drastic, as it dropped from 14.9 percent in 1986-1990 to 2.5 percent in 1996 to 1999 (C B N, 2002; Abgaje, Ogunsunmi, Oluokun and Akimloju, 2005). According to Nwosu and Okoli (2010), the declining trend of yield may not be unconnected with inefficiency of resource use and allocation. Yahaya, Tsado and Odinukaeze(2014), in their study of the effect of rainfall variation on yam production from 2001 to 2010 in Kuta community, revealed a continous rise in the yield of yam from 2001 (11.26 tons per ha) to 2009 (16.19 tons per ha). By 2010 however, a drop in yield compared with ealier year (14.19 tons per ha) was noticed. This therefore shows that there was a minimal variation in the yield of yam in the study area throughout the study period.

2.3.3 Effect of Rainfall Anomaly on Crop Yield

Assessment of the effect of climate change on agriculture focus on either crop yield or crop production. Different methods are used to evaluate the effect of climate on yields. According to Olaniran (1981), there are generally three ways of establishing whether climate-agricultural relationships are significant. The first is the study of fundamentals of plant-climate relationships, namely: the radiation and moisture balance for various crops in various climatic environments. The climate control of maize growth at Samaru, Nigeria was investigated using this approach, by Kowal and Kassam(1973) and Sorghum by Kowal and Andrew (1973).

The second method of determining climate-agricultural relationship is by studying agricultural data and climate data for a number of places within a given area, for as long as consistent records of both agriculture and climate allow, and deducing agroclimatological relationship from analysis of the data. Thus, Olanrewaju (2010b), examined the impact of climate on rice production in the lower Niger River Basin of Edu/Lafiagi Local Government Areas of Kwara State, while Jimoh and Nwaokenye (2011) examined the patterns of the variations in some climatic parameters on the efficient yield rates of cassava in some parts of Kwara State. The third method is the study of plant-climate relationship using the simulation model. It can be expressed in form of diagrams or flow charts, which are then formalized as mathematical formulae to yield a model of the real system of interest. Simulation models used in agroclimatology are process models combining weather parameters with the physiology of growing crops. They are thus, referred to as crop-growth models or crop simulation models (Jayeoba, Ezeaku and Ajayi, 2006).

In recent years, rainfall anomalies have led to numerous incidences of droughts which have the potential to cause undesirable effects on crop production and food security.High climatic variability represents a delicate balance between agricultural production and food security. Studies show that the changes in agriculturally-relevant variables of climate are likely to reduce yields of maize, rice, wheat, and other food crops in the semi-arid regions of the world (Lobell, Cassman and Field, 2009). Due to heavy dependence on rainfall for agricultural production, any significant variability in annual amount of rainfall could have an equally significant effect on agricultural production (Ati, Stigter, Iguisi and Afolayan, 2009). As earlier studies of Oladipo (1993b); Ati, Stigter and Oladipo (2002), in Northern Nigeria indicated declining annual rainfall totals creating scarcity of water for agricultural production and needs for more effective water resouces development.

2.3.3.1 Rainfall Anomaly on Maize Yield

The study of Rowhani, Lobell, Linderman and Ramankutty (2011) on climate variability and crop production such as maize, sorghum and rice in Tanzania, opined that both intra and inter-seasonal changes in temperature and precipitation influences cereal yield in Tanzania. Bewket (2009), analyzed rainfall variability on crop production in Ethiopia from 1975-2003 and found that the relationship between rainfall variability and maize yield is low and negative because of the significant inverse relationship ($r = -0.661$) between them. This implies that as rainfall variability increase, the yield of maize decreases.Rainfall anomalies contributes to 24% of variation of total maize yield in Tanzania, maize requires more rainfall as the pattern in anomalies of rainfall and maize yield forms aweak relationship between maize production and total rainfall.This suggest the importance of other climatic and non

climatic factors such as onset and cessation of rainfall, rainfall duration, rainfall intensity, soil temperature, soil fertility, pest and disease,labour, fertilizer and insecticides applicationhave influenceon annual crop production(Ndamani and Tsunemi, 2015).

In Akim Achiase, Ghana, no relationship exist between the average annual rainfall and the quantities of maize produced annually (Aninagyei and Appiah, 2014). However, in South-Western Nigeria, maize yield and rainfall variability has a significant relationship with a co-efficient of correlation ($r \leq 0.4$)(Awotoye and Mathew, 2010). This implies that the production of maize is dependent on the amount of rainfall in the region. The study of Oruonye, Ahmed, Gambo and Tukura (2016), on the impact of rainfall variability on maize yield in Gassol Local Government Area of Taraba state from 1985-2014 found that the effect of rainfall variability ($r = 0.476$) on maize yield is low. This means that other factors apart from rainfall variability influences crop yield in Gassol LGA as the co-efficient of determination explains that rainfall variability amounts to only 23% of the total variance influencing maize yield in the study area.

In Kwara state,the impact of rainfall characteristics on maize yield is low and insignificant, as rainfall fluctuates the yield of maize reduces.Rain days has great influence on maize yield (Ifabiyi and Omoyosoye, 2011).Maize requires a considerable amount of rainfall for effective growth and yield, it is highly sensitive to excessive rainfall and continous daily rainfall pattern typical of the tropics during rainy season (Ajadi, Adeniji and Afolabi, 2011). Ajadi et al (2011) found that co-efficient of variation for maize is 26%, while the relationship ($r = 0.057$) between

rainfall variation and maize yield is weak. This implied that as rainfall increased, the yield of maize reduced in Ilorin. The study further revealed that 21.7% of the variation in maize yield is accounted for by climate variables. This implies that the impact of climate on maize yield variation over the years is low and it is attributed to other factors influencing crop production.

2.3.3.2Rainfall Anomaly on Sorghum Yield

Rainfall variability hasconsiderably high impact on sorghum yield in Ethiopia. Sorghum requires less rainfall for germination because it is a drought resistant crop.Bewket (2009) found a strong relationship between rainfall variability and sorghum yield in Tanzania, the yield of sorghum was high in 1996 likewise the amount of rainfall was high during the period. However, rainfall anomalies contributes to only 16% of variation in sorghum yield. This shows that sorghum require less rainfall, as the pattern of variation in anomalies of rainfall and sorghum yield has low relationship. InEthiopia sorghum yield reduced, as rainfall variability increased. Rainfall variability has less influence on crops yield (Tengen and Deressa, 2017).

In the Nigerian Arid Zone, Adejuwon(2005), analyzed the relationship between climate variability and crop production from 1983 to 1999 in Maiduguri (Borno) and Potiskum (Yobe) states. The relationship between sorghum yield and total seasonal rainfall at Maiduguri and Potiskum is not significant, so also the relationship between sorghum yield and monthly total rainfall at Maiduguri. However, at Potiskum, there is a significant relationship between sorghum yield and September rainfall with a co-efficient of correlation value (r = 0.55) at 95%

confidence level. Two-third of variability in the yield of sorghum is determined by rainfall variability. Sorghum yield is determined by 66% of variation in rainfall at Maiduguri and Potiskum.Awotoyeand Mathew (2010), also studied the impact of climate variability on grain crops in South-Western Nigeria from 1990-2006 and found that sorghum yield and rainfall variability has a significant relationship with a low co-efficient of correlation ($r \leq 0.4$). This implies that the yield of sorghum is dependent on the amount of rainfall in the region.

The study of Ajadi et al (2011) on the impact of climate on urban agriculture in Ilorin city corroborates the study of Awotoye and Mathew,(2010) in South-Western Nigeria, as their findings revealed that the co-efficient of correlation ($r = 0.131$) between climatic (rainfall) variation and sorghum yield is weak. This implied that with increase in rainfall, the yield of sorghum reduces in Ilorin. Their findings further revealed that 18.6% of variation in sorghum yield is determined by climate variables. This means that the impact of climate on the yield of sorghum over the years of is low.

2.3.3.3 Rainfall Anomaly on Cassava Yield

Cassava is found to be positively and significantly impacted by rainfall as researches have studied their relationships. Ayanlade, Odekunle and Orimoogunje(2010), analyzed the impact of rainfall variability onCassava in Enugu, Yola, Makurdi, Kaduna, Jos, Shaki, Minna, Lokoja, and Ilorin,from 1970-2000,and found that there was no significant relationship between rainfall variability and

cassava yield, except in Makurdi, Yola, Minna, and Lokoja. But relationship (r = 0.32, 0.38, 0.38, and 0.30) is significant between rainfall and cassava yield in Ilorin, Shaki, Enugu, and Jos. This implies that amount of rainfall in the growing season determines yield of cassava in Ilorin, Shaki, Enugu, and Jos. In the whole of the study period, cassava yield in response to rainfall variability showed that rainfall has positive impact on cassava yield, while some years such as 1981/1982, 1982/1983, 1991/1992, and 1998/1999 established negative impact of rainfall variability on the yield of cassava.

Rainfall variability has low impact on cassava yield in the Niger-Delta region of Nigeria because rainfall is adequate for cassava yield as water requirement for cassava germination is always met. Alexander,Bakpoand Woke (2015) opined that cassava yield is determined by 1.44% of annual rainfall, as the relationship between temporal rainfall on cassava yiels is weak. Rather than water scarcity, water availability possess danger for cassava yield because it was observed that cassava yield increased with decrease in rainfall. Rainfall and cassava yield varies from year to year in South Western Nigeria. The study of Awotoye and Mathew(2010) on the impact of climate variability on cassava yield revealed that cassava yield is dependent on the amount of rainfall, however, their relationship is significantly low.

The study of Akpenpuun and Busari(2013), on the impact of climate on cassava in Kwara state from 2002-2011 revealed that the relationship (r = 0.485) between rainfall variation and cassava yield is low at 95% confidence level. This implies that there is low relationship between rainfall and cassava, because as rainfall increased, the yield of cassava decreased. The study further revealed that 99.9% of variation in cassava yield can be explained by climatic parameters. This implies that

the effect of climate on cassava yield variation over the years under consideration in Kwara state is significant. Jimoh and Nwaokenye (2011), also assessed the patterns and trends of the variations in some climatic parameters on the efficient yield rates of cassava in some parts of Kwara State and observed that climatic parameters varied widely within the study time frame and with pronounced effects on cassava yields.The rates of cassava yields vary with year due to either edaphic or disease infestation factors and no one climatic variable that does not have some far reaching effect on the production of cassava.

2.3.3.4 Rainfall Anomaly on Yam Yield

Ayanlade et al, (2010), in their study of climate variability on yam in Guinea savanna part of Nigeria, found that the effect of rainfall variability in the month of growing season has no significant relationship on the yield of yam in almost all the stations in the region except Enugu with a co-efficient of correlation of 38% at 0.05 confidence level. This implies that variation of rainfall in Enugu contributed greatly to the variation in the yield of yam. In other stations, theimpact of rainfall variability on yam yield is low. Yam yield in response to rainfall variability for the region showed positive impacts on the yield of yam in 1970/1971, 1971/1972, 1989/1990, and 1990/1991respectively. However, negative impacts were prominent in 1981/1982, 1982/1983, 1983/1984, 1992/1993, and 1993/1994 respectively. With positive impacts, rainfall during these periods has supportive impact on the yield of yam there by facilitating increase in yield, while negative impacts implies that the variations of rainfall led to a decrease in yam yield.

Yahaya, Tsado and Odinukaeze(2014), analyzed the effect of rainfall variation on yam production in Niger state and reveal rainfall variation was minimal but there

is a strong relationship between rainfall variation and yam yield, and a positive response between yam yield and moderate rainfall that was well distributed. Zakari, Mohammed, Medugu and Sandra,(2014), examined the effect of rainfall variability on yam yield in Abuja and reveals that a weak positive relationship exist between rainfall variability and yam yield. The result further revealed that 0.2% of rainfall variability influences the yield of yam in Abuja. This is attributed to other factors that have influence on crop production.

The temporal variation of rainfall occurrence and its effect on tuber crops in Niger Delta, revealed that CV for rainfall and yam was 6.68% and 10.86% respectively. This shows that the deviation from their means are not much, like that of rainfall and yield of cassava, because rainfall is always available for yam production. The effect of rainfall variation on yam yield explains thatonly 10% ofvariation in yam yield is determined by rainfall in the Niger Delta region(Alexander et al, 2015). Awotoye, and Mathew(2010), studied the impact of climate variability on yam yield for a period of 17 years from 1990-2006 in South-Western Nigeria, using correlation analysis. The mean annual rainfall and rain days was computed and result revealed that the yield of yam is dependent on the amount of rainfall as there was a significant relationship between rainfall variability and yam yield with a low co-efficient of correlation ($r \leq 0.4$). This implied that rainfall and yam yield varied from year to year as both variables fluctuates.

Akpenpuun and Busari (2013), observed clearly that variation in crop yield in Kwara State could be attributed to climatic influence on agriculture,as their study evaluated the impact of climate on the yield of yam and other tuber crops in Kwara

state from 2002-2011. The result obtained from the study showed that the relatioship (r =0.547) between rainfall variation and yam yield is strong at 95% significant level. The result further revealed that 99.8% of the variation in the yield of yam can be explained as the effect of climate (rainfall). This implied that the impact of climate on yam yield variation over the years under study in Kwara state is significant but Ajadi et al, (2011) examined the impact of climate on urban agriculture in Ilorin cityand observed that CV for yam yield is very high with a value of about 77% and a deviation value of 1.43. The CV which showed the relative deviation between crop yield indicated that yam is heterogenous with value greater than 50%. The result further showed that rainfall variation in Ilorin has a weak relationship with yam yield and about 55.4% of variation in the yield of yam is explained by climatic parameters, which means that the impact of climate variability on the yield of yam over the years under study is high, eventhough, the relationship between rainfall variability and yam yield is negatively weak. As indicated by Bewket (2009) although correlation coefficient may not be statistically significant, it should be noted that any form of correlation between rainfall and crop is indicative of the fact that farmers are vulnerable.

2.3.4 Rainfall-Crop Prediction

Relatively little research is conducted to support the application of climate forecast in decision making in the small-scale/subsistence agriculture sector, where farmers are particularly vulnerable to the vagaries of climate. The usefulness of climate forecast for application in agriculture can be enhanced when translated into agricultural outlooks which can be facilitated through generation of crop yield forecast (Lumsden and Schulze, 2007). The key weather variables for crop prediction

are rainfall, temperature, radiation and relative humidity (Sivakumar and Hansen, 2007). According to Deblas-Reyes, Hagedorn and Palmer (2006), seasonal climate forecast are able to provide insight into the future climate evolution on timescales of seasons and longer because slowly evolving variability in the oceans significantly influences variations in weather statistics. Seasonal forecast can be produced using mathematical models of the climate system. A wide range of forecast methods, both empirical-statistical techniques and dynamical methods, are employed in climate forecasting at regional and national levels(World Meteorological Organization, 2003).

Using models of global climate, and crop production, Alcamo, Dronin, Endejan, Golubev and Kirilenkoc(2007), suggested that decreased crop production in some Russian regions could be compensated by increased production in others, resulting in relatively small average changes. However, their result indicates that the frequency of food production shortfalls could double in many of crop growing areas in the 2020s, and triple in the 2070s. Although, water availability is increasing in average, the water resource model predicted more frequent low run-off events in the already dry crop growing regions in the south and a significantly increased frequency of high run-off events in much of central Russia (Alcamo et al 2007).

Rowhani et al (2011), showed that in Tanzania, by 2050, projected seasonal temperature increases by $2^{o}C$ reduce average maize, sorghum, and rice yields by 13%, 8.8%, and 7.6% respectively. Potential changes in seasonal total precipitation as well as intra-seasonal temperature and precipitation may also impact crop yields by 2050, although to a lesser extent. A 20% increase in intra-seasonal precipitation variability reduces agricultural yields by 4.2%, 7.2%, and 7.6% respectively for

maize, sorghum and rice. The study showed climatic impact on crop yields by 3.6%, 8.9%, and 28.6% for maize, sorghum, and rice respectively focusing only on the climatic average, ignoring climatic variability. It highlights that, in addition to shifts in growing season means, changes in intra-seasonal variability of weather may be important for future yields in Tanzania. According to Laux, Jackel, Tingem and Kunstmann(2010), maize yield is likely to increase for the 2020s and decrease for 2080s by approximately 15% in Cameroon.

Andy, Ramirez-Villegas, Herrera Compo and Navarro-Racines(2012) analyzed the impact of climate change on cassava production in Africa based on projections to 2030. Result indicated that cassava is positively impacted in many areas of Africa, with -3.7% to 17.5% changes in climate suitability across the continent. Other staple crops that were projected alongside cassava were found to experience negative impact, with the greatest impact for beans with a value of -16%, potato, -14%, banana, -2.5% and sorghum, -2.66%. The study concludes that cassava is potentially highly resilient to future climatic changes and could provide Africa with options for adaptation while other major staple food crops face challenges.

CHAPTER THREE

STUDY AREA AND METHODOLOGY

3.1 INTRODUCTION

This chapter focuses on the study area and research methodology. Location of the study area, climate, soil and vegetation, and relief and drainage of the study area were discussed in details. The methodology of the research comprising of the types of

data, sources of data used, agro-climatological derivations, and data analysis techniques were also discussed.

3.2 THE STUDY AREA

3.2.1 Location and Size

Moro Local Government Area lies within latitudes 8^{o} 31'N to 9^{o}31'N and between Longitudes 4^{o} 15'E to 4^{o} 45'E (Figure 3.1). Moro Local Government Area (LGA) is one of the sixteen LGAs of Kwara State with its headquaters at Bode-Saadu. Moro LGA is bounded to the north by Niger State and Kaiama LGA, to the south by Asa, Ilorin West and Ilorin South Local Government Areas, to the west by Oyo State, and to the east by Edu, Ifelodun, and Ilorin East LGAs. It is made of five districts : Lanwa, Ejidongari, Olooru, Malete and Paiye. It has a land area of about 3,272km^2.

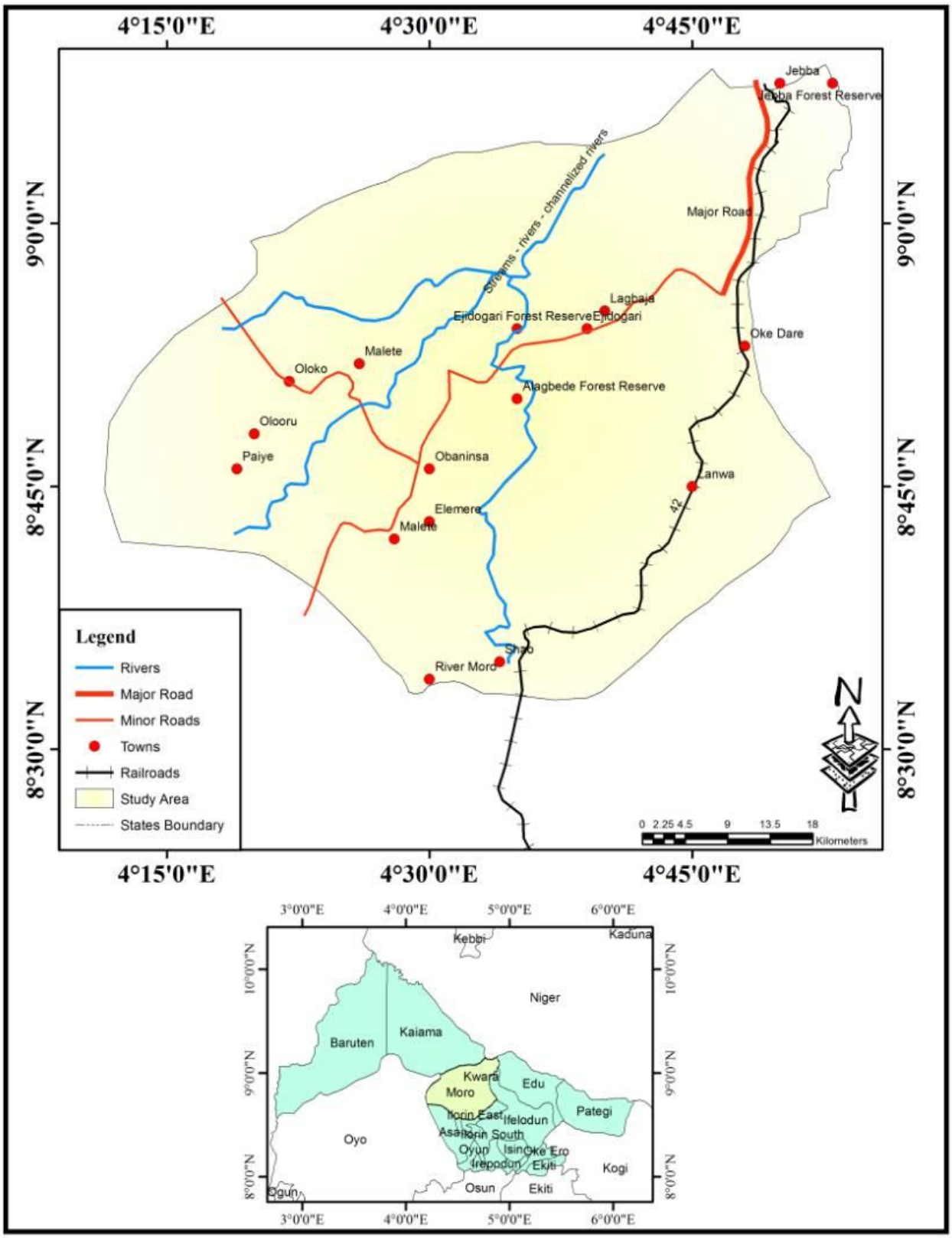


Fig 3.1: The Study Area
Source: Adapted from the Administrative Map of Kwara State, 2016

3.2.2 Climate

Based on Koppen's world climatic classification, Moro LGA lies within a region described as tropical climate (Aw).The climate of the area is characterized by both wet and dry seasons,and by double rainfall maxima. The rainy season begins at about the end of March and lasts till October, while the dry season begins in November and ends in early April. The total annual rainfall in Moro Local Government Area ranges between 800mm and 1500mm (Muhammad-Lawal and Omotesho, 2006). Temperature is uniformly high throughout the year except in July-August when the cloud in the sky prevents direct insolation (Olanrewaju, 2010b). The study area has a mean temperature of $30^{o}C$ – $35^{o}C$(Taiwo, 2005). This range places the study area within the transitional zone between the climate and vegetation types of northern and those of southern Nigeria. This zone may occur along the edge of forests where vegetation shifts from trees to grasses. This zone also called an ecotone, between forest and grassland may be relatively narrow between 50 to more than 100 kilometers wide, they are important for monitoring climate change and climate change adaptation. However, they are highly threatened by climate change interacting with other anthropogenic stresses (Shadangi and Nath, 2008).

Crop yield is attributed to the influence of climatic factors such as precipitation (rainfall) and temperature. The total amount of rainfall and its distribution determines the choice of crops to be cultivated in an area. In heavy and evenly distributed rainfall areas, tree crops such as cocoa, rubber etc are grown, while in low and uneven distributed rainfall areas, grain crops like sorghum, millet etc are grown. Though rainfall has major influence on the yield of crops, yields are not

always directly proportional to the amount of rainfall as excess or little (anomalies), above optimum reduces yields.

3.2.3 Soiland Vegetation

The soil type in Moro LGA is lateritic in nature. It is reddish brown due to high content of iron. They contain gravel of various sizes and are sticky when wet and hard when dry. The soils are derived mainly from the basement complex formation and other sedimentary rocks and are rich in nutrient, good for the cultivation of yam, cassava, maize, millet, sorghum, wheat e.t.c, . Soil fertility is an important component of crop yield, and seen as an increasingly significant component of yield as annual rainfall increases. However, the fertility of these soils is being lost to erosion and unhealthy human activities, such as overgrazing and overcultivation(Oyebanji, 2000). Rainfall variability affects soil water availability to crops and thus, pose crop production risk. Crops grown on land completely depends on the soil type on which they are grown. Soil factors such as soil moisture (water), which is a principal constituent of plant growth influences the environment, as it moderates soil temperature from extremes.

The natural vegetation is the guinea and derived savanna. Notable trees in these areas are locust bean, Akee-apple and shea-butter. There are fringe forests along the river Moro. Common grass species found in this area include elephant grass (*Pennisectum purpurenum*), goat weed (*Argeratum conyzoids*), tridax grasses (*Tridax procumbens*), wild hemp (*Sidaacuta*) among others(Oluwatoyin, 2015). The savanna zone in general has an enormous potential for food production.

3.2.4 Relief and Drainage

The landscape of Moro LGA consists of relatively flat and undulating land with inter-spersed hills and valleys. The relief ranges from less than 300m to about 680m above mean sea level(Ajibade, 2002). The relief affects crop growth indirectly as increase in altitude causes a decrease in temperature and an increase in rainfall. The steepness of the slope of the area could result in run-off of rain water and loss of nutrient of the rich top soil, which eventually affects the yield of crops in the area. The major river in the study area is the River Niger at Jebba South which forms the natural boundary of Kwara State in the North and the River Moro in Shao town. The drainage system of the area serves as source of water for agriculture. Crop production will increase if irrigation is intensified, but these may increase the rate of environmental degradation such as erosion, which in turn affects crop yield as the production area is reduced (Kang, Khan and Ma, 2009).

3.3 METHODOLOGY

3.3.1 Reconnaissance Survey

Reconnaissance survey was carried out in the study area. This was aimed at getting the researcher acquainted with the geographical landscape and agricultural conditions of the environment. The Kwara State Agricultural Development Project (KWADP) office in Ilorin was visited in order to obtain information on availability of data on crop yield and monthly rainfall records that will be used in the study. The researcher further enquired from the KWADP official if a synoptic station was located in the study area and was answered in affirmative, thatthe KWADP is divided in to zones, where the study area falls under zone C.

3.3.2 Types of Data Used

Two sets of data were used for this study. The first set of data includemonthly and yearly rainfall data in (mm), from where Rainfall Anomaly Index was derived. The second set is agricultural data on Maize, Sorghum, Yam, and Cassava yields in thousand Tons per hectare over a period of twenty-five (25) years (1991-2015).

3.3.3 Sources of Data

Secondary source of data was used for the study. Monthly and Annual rainfall records in (mm) and crop yield in thousand tons per hectare was obtained from Kwara State Agricultural Development Project (KWADP) office, Ilorin.

3.3.4 Agro-Climatological Derivations

Rainfall data collected for the study area was used to derive the Rainfall Anomaly Index (RAI). Rainfall Anomaly Index (RAI) expresses the degree of rainfall deviation in relation to the long-term mean rainfall for the specific period. In this technique, the precipitation values for the period of study were ranked in descending order of magnitude with the highest precipitation being ranked first and the lowest ranked last. The average of the ten highest precipitation values as well as that of the ten lowest precipitation values for the period of the study were calculated as developed by Van Rooy (1965) and given as:

Positve Anomaly:

$$RAI = 3\ \frac{(P-\bar{P})}{(\bar{m}-\bar{P})}$$

Negative Anomaly:

$$RAI = -3\frac{(P-\bar{P})}{(\bar{x}-\bar{P})}$$

Where $\bar{P}$ =Actual long-term average rainfall.

P = Rainfall for the specific year.

m = Mean of the ten highest values of P on record.

x =Mean of the ten lowest values of P on record.

The threshold values of +3 and -3 have been assigned to the mean of the ten most extreme positive and negative anomalies respectively as developed by Van Rooy (1965).

The classification of the Index as used by Van Rooy (1965) is as follows;

Table 3.1: Rainfall Anomaly Index classes

RAI	Class Description
≥3.00	Extremely Wet
2.0 to 2.99	Very Wet
1.0 to 1.99	Moderately Wet
0.50 to 0.99	Slightly Wet
0.49 to -0.49	Near Normal
-0.50 to -0.99	Slightly Dry
-1.0 to -1.99	Moderately Dry
-2.0 to -2.99	Very Dry
≤-3.00	Extremely Dry

Source: Shen, Howard, Yin, Khurshed, and Akbar (2003)

3.3.5 Harmonization of Data

Data harmonization is the improvement of data quality and utilization through combining multiple data sources into an unambiguous entity, it converts data from one format to another. It involves both machine and human control and the usual reason is to adopt a new system that is different from the previous one. It enhances the quality and utilization of data and makes it possible to transform data for data analysis. The methods of data harmonization are LOGARITHM, SQUARE ROOT harmonization, BOX-COX technique, LOGIC harmonization, VARIANCE, STABILIZING harmonization and SMEMAX harmonization.

The yield of crops in tons per hectare (tons/ha) and rainfall in millimetre (mm) are measured in different units, and therefore, must be transformed to a common base beforecorrelation (Sawa and Adebayo2011). For the purpose of this research, the crops and rainfall data were transformed to a common base using $\log_{10}$ by means of MINITAB software.

3.3.6 Data Analysis

Both descriptive and inferential statistics were used in analyzing the results, descriptive tools such as the mean, standard deviation and co-efficient of variation were analyzed. The inferential statistics were used to test the hypothesis.

Objective (i): To determine the monthly and yearly anomalous rainfall records within the stated period of 1991-2015, the Rainfall Anomaly Index developed by Van Rooy (1965) was used and the results presented in histogram.

Objective (ii): To examine the trend of crop yield between 1991-2015 in the area, time series analysis was used where graphs of crop yield against years were drawn. Linear trend lines and linear trend equations were fitted to show direction of change.

Objective (iii): To examine the relationship between anomalous rainfall and crop yield within the stated period, bivariate correlation analysis was employed. This was done using harmonized data and hypothesis was tested at 0.05 significance level.

Objective (iv): Toexamine the strength of the effect of rainfall anomalies on the yield of crops within the stated period of 1991-2015 in the study area, simple linear regression analysis was utilized. Where the strength was given by the value of coefficient of determination (R^2).

Objective (v): To forcast the trend of anomalous rainfall and yield of crops in ten 10 years' time from 2016-2025, linear regression analysis was used.

The equation used is: $Y= a + bx$

Where Y= Crop yield in Ton/ha

a = Constant

b = Slope

x = Rainfall Anomaly

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 INTRODUCTION

This chapter present results and discusses rainfall anomalies and its relationship with maize, sorghum, cassava and yam yield in Moro Local Government Area. The order of presentation of results is guided by the earlier stated objectives.

4.2 RAINFALL CHARACTERISTICS OF THE STUDY AREA

4.2.1 Variation in Monthly Rainfall of the Study Area

Monthly rainfall variation of an areadescribes the quantity of water available to the area for agricultural purposes and gives upper limit to the area's potential in regard to crop production.Table 4.1 presents the statistical characteristics of monthly rainfall of the study area.

Table 4.1: Monthly Rainfall Variation of Moro LGA (1991-2015)

Month	Mean	SD	CV%
January	7.72	18.38	238.1
February	12.87	15.33	119.1
March	38.34	25.29	65.96
April	90.22	51.56	57.2
May	148.2	55.52	37.5
June	180.9	69.82	38.6
July	165.8	70.92	42.8
August	150.9	76.76	50.9
September	218.0	81.33	37.3

October	137.5	43.39	31.6
November	11.9	13.47	113.2
December	3.94	9.76	247.7

Source: Author's Computation (2018)

It was observed that the month of September has the highest mean rainfall (218mm) with a co-efficient of variation of 37.3%. The months of May, June, and July recorded a co-efficient of variation of about 37.5%, 38.6%, and 42.8% with a mean rainfall of 148.2mm, 180.9mm, and 165.8 mmrespectively. The month of August has a mean rainfall of 150.9 mm with a co-efficient of variation of 50.9% which is a bit higher than that of May, June, July and September. It was observed that the month of December recorded the lowest mean rainfall (3.94 mm) with the highest co-efficient of variation of 247.7%, because it is a dry month. This implies low variation in rainfall pattern within the rainy months of the study period.

4.2.2 Variation in Annual Rainfall of the Study Area

Table 4.2 depicts the annual rainfall variation in the study area from 1991 to 2015.It was observed that 1997had the highest mean rainfall (141.2mm) with a CV of 84.5%, while the year 1991 revealed the lowest mean rainfall (72.5mm) with a CV of 145.5%in the first decade. In the second decade, 2004 had the lowest mean rainfall (70.87mm) with a CV of 95.6%, while 2009 had the highest mean rainfall (130.2mm) with a CV of 83.7%. The highest co-efficient of variation of 145.5% was recorded in 1991. The year 1999 recorded the lowest CV of 74.1% within the entire study period. The study period records a baseline mean rainfall of about 1152.1mm with a low co-efficient of variation of about 21.5%.

The annual rainfall variation of an area is also an important indicator for describing rainfall.Knowledge of the rainfall behaviour allows for the safer planning of agricultural practices aimed at improving crops yield. Table 4.2 depicts the annual rainfall variation in the study area from 1991 to 2015.

Table 4.2: Annual Rainfall Variation of Moro LGA (1991-2015)

Year	Mean	SD	CV%
1991	72.5	105.5	145.5
1992	89.9	101.1	112.5
1993	71.1	93.3	131.2
1994	94.5	82.65	87.5
1995	103.9	83.38	80.3
1996	100.1	91.09	90.9
1997	141.2	119.3	84.5
1998	91.0	85.09	93.5
1999	104.9	77.72	74.1
2000	78.9	89.67	113.7
2001	75.6	65.13	86.2
2002	85.7	74.75	87.2
2003	82.6	98.56	119.3
2004	70.87	67.76	95.6
2005	95.37	82.34	86.3
2006	103.3	87.04	84.3
2007	123.1	123.97	100.7
2008	115.1	102.80	89.3
2009	130.2	109.01	83.7
2010	97.1	83.47	85.9
2011	104.4	91.68	93.5
2012	134.8	134.46	99.7
2013	75.0	61.81	82.4
2014	94.28	75.34	79.9

2015	73.3	68.27	93.1
Mean	**1152.1**	**96.35**	
SD	**247.86**	**20.33**	
CV%	**21.5**	**21.1**	

Source: Author's Computation (2018)

4.2.3 Monthly Rainfall Pattern of the Study Area

The average annual or seasonal rainfall of an area does not give sufficient information regarding its capacity to support crop production, because crop production is largely dependent on rainfall distribution pattern. Figure 4.1 shows the monthly rainfall pattern in the study area from 1991 to 2015.

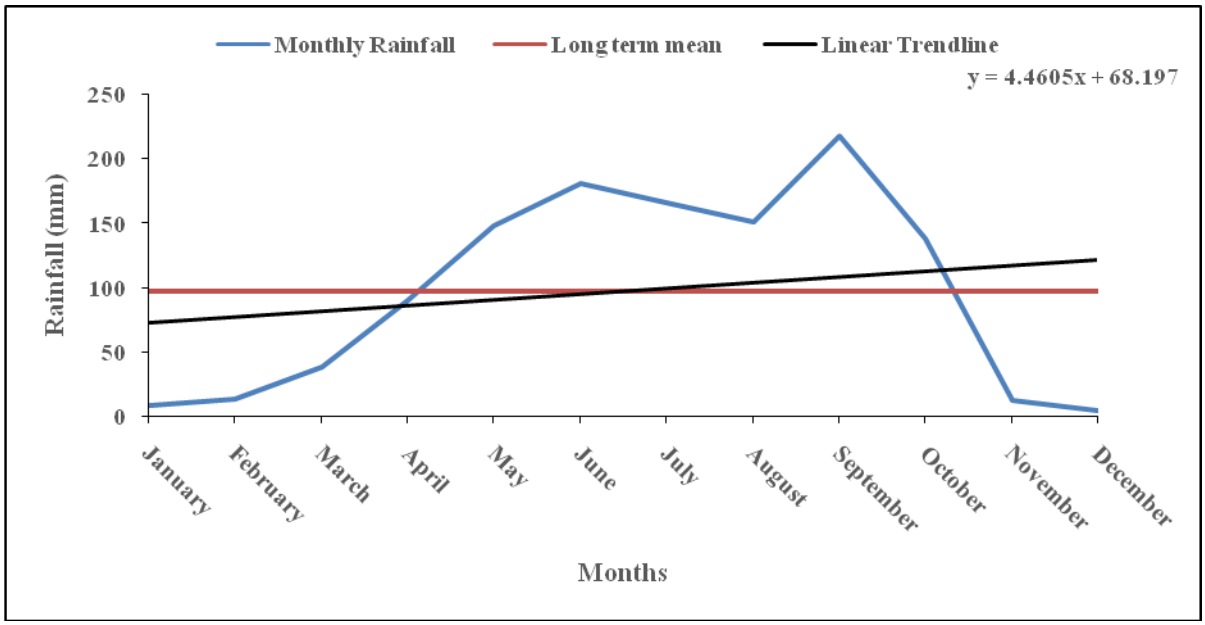


Figure 4.1: Monthly Rainfall of Moro LGA (1991-2015)
Source: Author's Computation (2018)

It can be observed from Figure 4.1 that rainfall increased from January to March and increased to reach a peak in June. However, there was a decrease in July and August, which indicates a little dry spell. In September, rainfall reached another peak, and decreased from October, to December. It was observed that rainfall pattern

of the study area has two peaks (double maxima). This is in line with the study of Akinsanola and Ogunjobi (2014), which observed that rainfall pattern below latitude 10^0N is bimodal having a primary peak in June-July, and secondary peak in September with little dry season in August known as the 'August break'. The monthly rainfall in Moro LGA increased within the study period, which is indicated by the positive trend line equation (Y= 4.7135x + 69.799).

4.2.4 Pattern of Annual Rainfall of the Study Area

Rainfall is unevenly distributed in places. Annual rainfall distribution pattern shows the erratic nature of the rainfall of an area over the years.The pattern of annual rainfall in the study area from 1991 to 2015 is given in Figure 4.2.

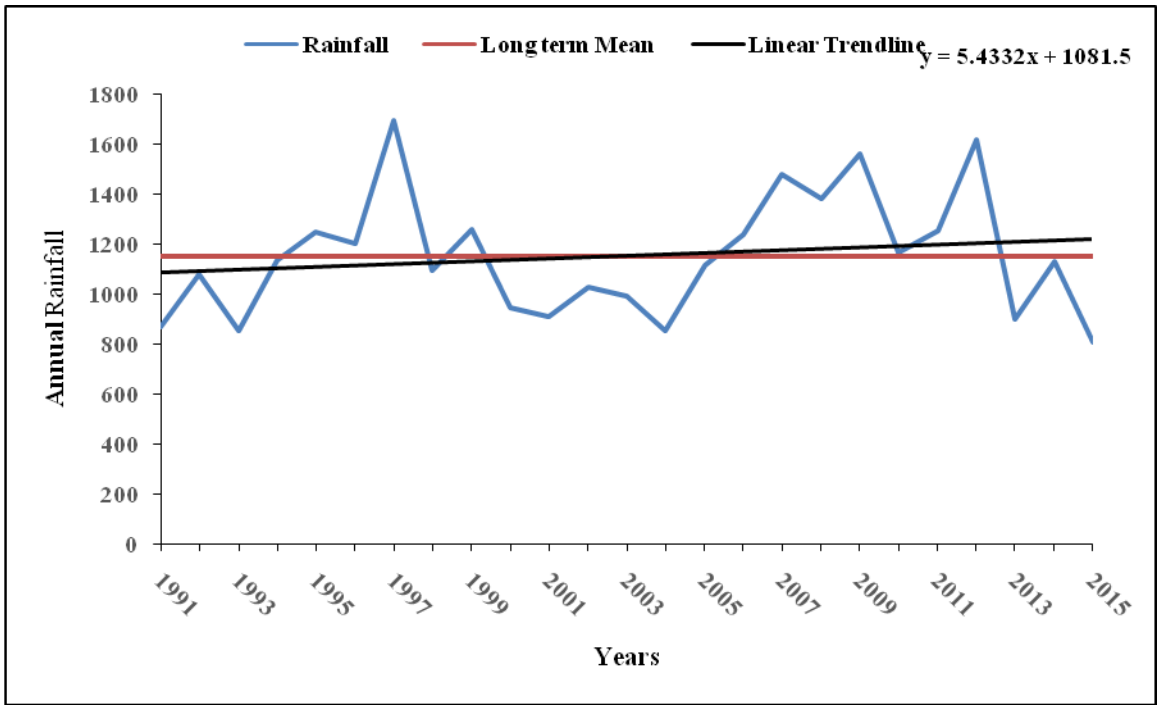


Figure: 4.2: Annual Rainfall of Moro LGA (1991-2015)

Source: Author's Computation (2018)

From Figure 4.2 fluctuation was observed in the annual rainfall pattern, in the first decade of the study period, with rainfall increasing and decreasing between 1992,

1993, 1994 and 1995, and attained a peak in 1997. However, there was a decrease from 1998 to 2000. Looking into the second decade, the first four years (2001 to 2004) revealed low rainfall which decreased steadily. Result revealed an abrupt increase in rainfall from the year 2005 to 2007, and a fluctuation between the years 2008 to 2015. Rainfall reached its maximum in 2012, in the second decade of study. In the whole study period, rainfall attained a peak in 1997, while minimum was observed in 2004. An increasing trend in annual rainfall was observed. The increasing rainfall disagrees with the study of Ekwe et al (2014), which found a general decline in annual rainfall for Nasarawa state. Although, both area lies within the guinea savanah region, the disparity in their annual rainfall trend is because of thedifference in climatic conditions, as Nasarawa state lies within a regiondescribed as local steppe climate (Bsh) in Koppen's classification of climate. The observed increase in annual rainfall trend of Moro LGA is supported by the positive trend line equation (Y= 5.4332x + 1081.5).

4.3 MONTHLY RAINFALL ANOMALIES OF THE STUDY AREA

4.3.1 January Rainfall Anomaly

The deviation in the long term mean rainfall shows the nature of rainfall pattern in Moro LGA. The anomalous rainfall for the month of January, from 1991 to 2015 is presented in Figure 4.3.

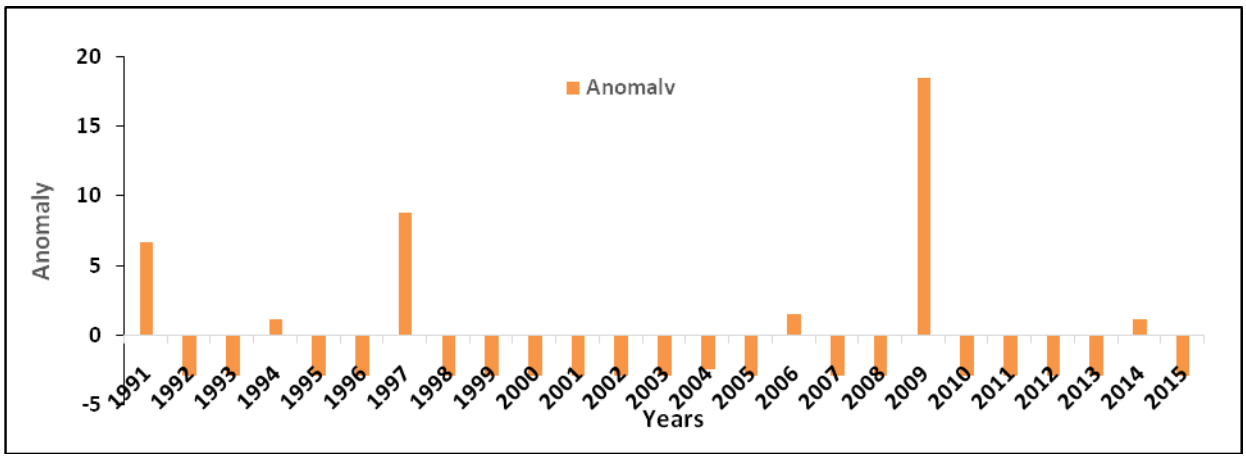


Figure 4.3: January Anomaly of Moro LGA (1991-2015)
Source: Author's Computation (2018)

From Figure 4.3, there were few positive anomalies revealed in the years 1991, 1994, 1997, 2006, 2009, and 2014, with values ranging from 1.08 in 2014 to 18.51 in 2009, which had the highest anomaly value. This shows a moderately wet to an extremely wet condition. Even though, the month of January is a dry season month in the study area, rain still falls in a reasonably fair amount.

4.3.2 February Rainfall Anomaly

The extremes and differences of the monthly rainfall value from the climatically expected temporal mean shows the nature of rainfall variation in Moro LGA. Figure 4.4 shows rainfall anomaly for the month of February from 1991 to 2015.

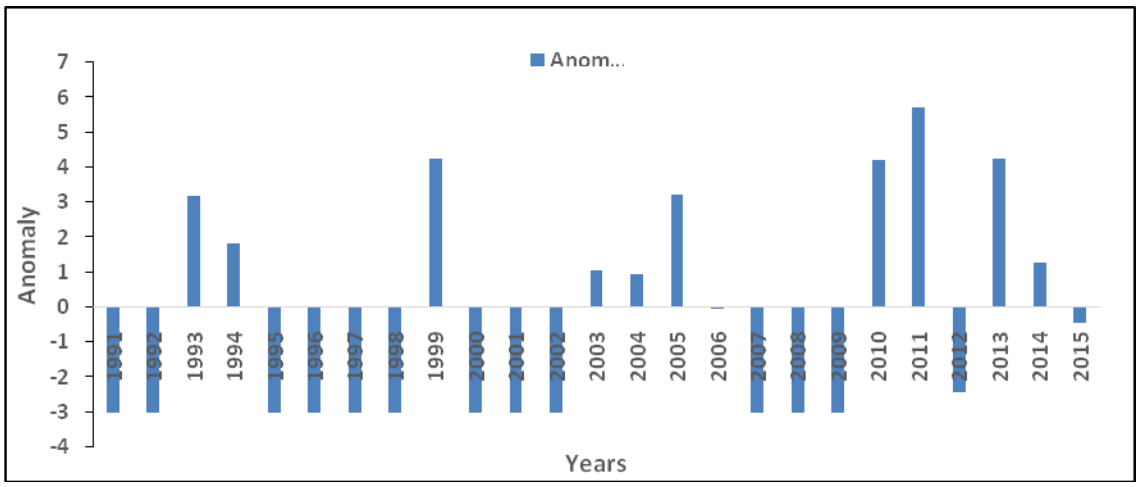


Figure 4.4: February Anomaly of Moro LGA (1991-2015)
Source: Author's Computation (2018)

In Figure 4.4, positive anomalies were also recorded, which were more than those of January. These anomalies occurred in 1993, 1994, 1999, 2003, 2004, 2005, 2010, 2011, 2013, and 2014, with values ranging from 1.07 in 2003 to 5.70 in 2011, revealing a moderately wet to some extremely wet years, with 2011 having the highest value of anomaly. This could be disastrous as it caused flooding in some places in the area.

4.3.3 March Rainfall Anomaly

An assessment of the pattern of anomalous rainfall condition of Moro LGA has been carried out showing theextreme wet or dry conditions for the month of March,from 1991 to 2015 is indicated inFigure 4.5

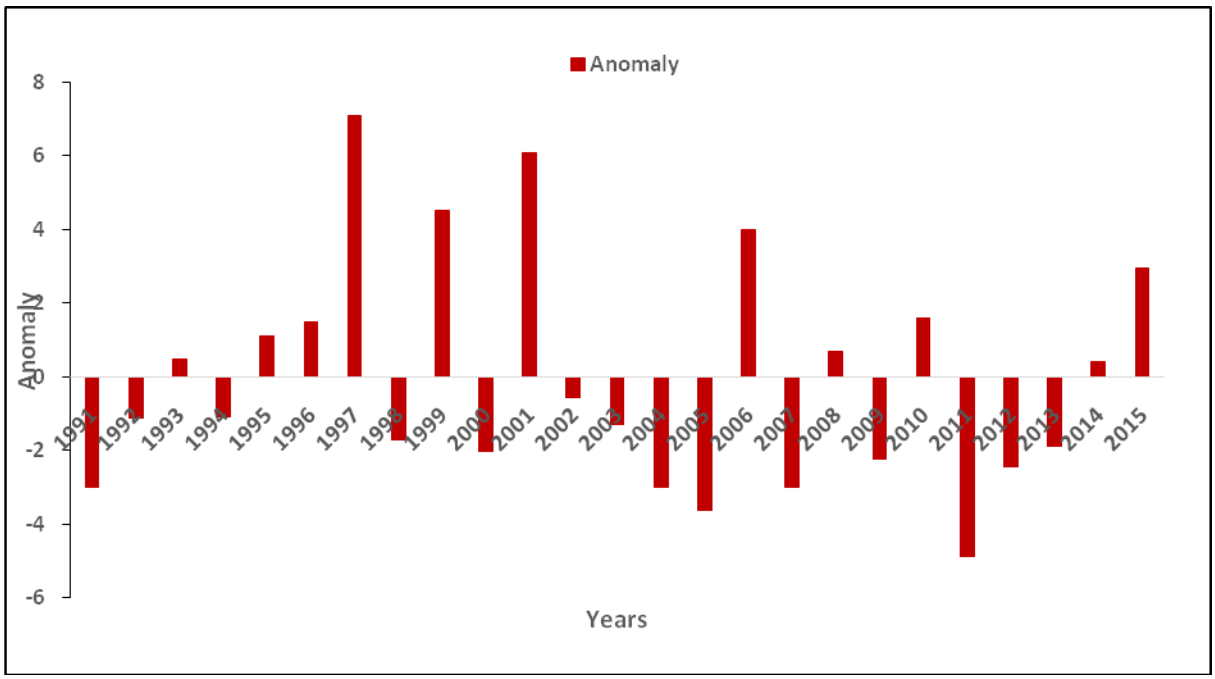


Figure 4.5: March Anomalyof Moro LGA (1991-2015)
Source: Author's Computation (2018)

In Figure 4.5, March which marks the beginning of the wet season in Moro LGA, shows a fluctuation of both dry and wet years. The month recorded 1993, 1995 to 1997, 1999, 2001, 2006, 2008, 2010, 2014 and 2015 as being wet years and other years recorded negative anomalies (dry) with values ranging from -4.88 in 2011 to -1.08 in 1994. However, 1997 was the wettest year with anomaly value of 7.08, while 2011 was the driest year, when a mild drought was experienced.

4.3.4 April Rainfall Anomaly

To better understand the pattern of rainfall in Moro LGA, the extreme wet and dry conditions was analysed.Rainfall anomalies for the month of Aprilfrom 1991 to 2015 are shown in Figure 4.6

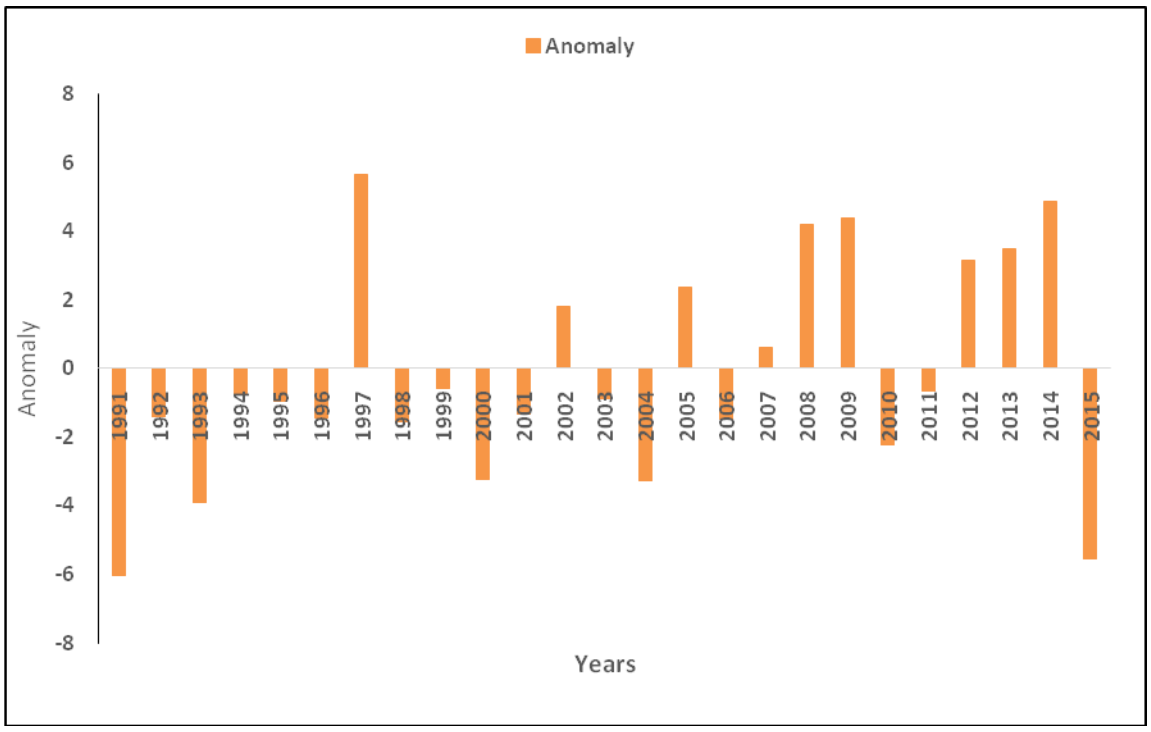


Figure 4.6: April Anomalyof Moro LGA (1991-2015)
Source: Author's Computation (2018)

In Figure 4.6, the years 1991 to 1996 revealed negative anomalies of extremely dry to slightly dry years, 1997, the wettest year revealed a positive anomaly of an extremely wet condition with a value of 5.66. From the year 1998 to 2001, negative anomalies of values from -3.22 in 2000, to -0.58 in 1999 were recorded, revealing an extremely dry to slightly dry conditions in the first decade of the study period. Wet years were recorded in the year 2002 and 2005 with alternating dry years in 2003, 2004, and 2006. This is in agreement with the study of Abaje et al, (2010),which revealed dry years in the month of April of year 2003, 2004, and 2006 in Kafanchan. Extremely wet years were revealed from 2008 to 2014, with 2007 being a slightly wet year, likewise, negative anomalies were revealed in year 2010, 2011 and 2015 revealing both extremely dry and a slightly dry year.

4.3.5 May Rainfall Anomaly

Rainfall anomalies are expressed as departures from long term means. Figure 4.7 shows rainfall anomaly for the month of Mayfrom 1991 to 2015.

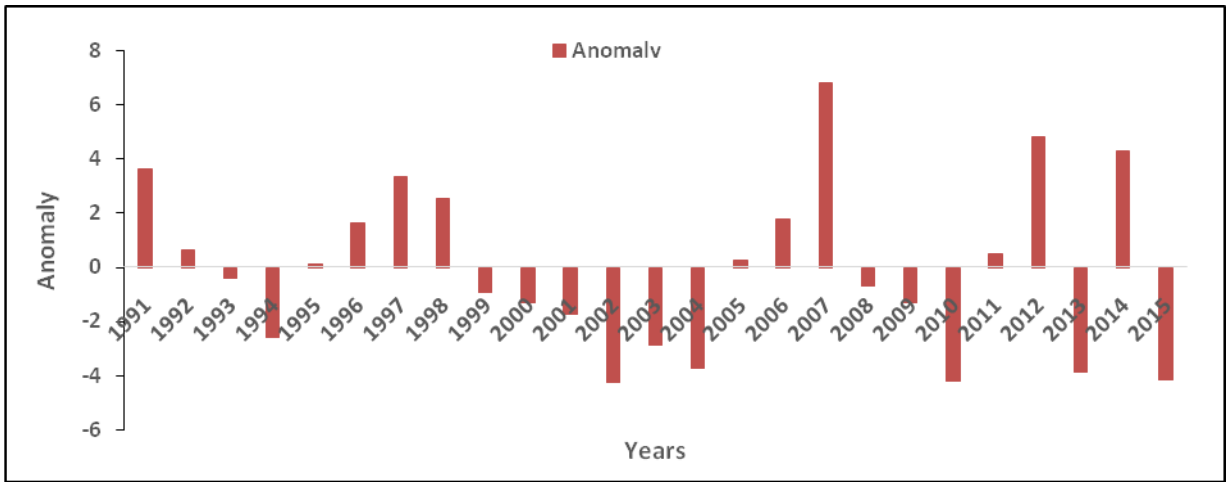


Figure 4.7: May Anomalyof Moro LGA (1991-2015)
Source: Author's Computation (2018)

From Figure 4.7, it can be seen that some dry years (1993, 1994, 1999, and 2000) were recorded in the first decade of the study period, recording negative anomalies with values of -2.58, -0.91, and -1.31 respectively revealing a slightly dry to a very dry year in 1994. However, the other years within the decade recorded positive anomalies of extreme wet years, with the exception of 1995 indicating a near normal rainfall condition. Moderately dry to extremely dry years were revealed from 2001 to 2004 and at the tail end of the second decade, slightly dry to an extremely dry year from 2008 to 2010 was revealed. In the year 2013 and 2015, an extremely dry condition was revealed. This is in agreement with the study of Abaje et al, (2010),which revealed dry years in the month of May of the years 2001, 2002, 2003, 2005, and 2008 respectively at Kafanchan. However, positive anomalies value (0.28, 1.76, and 6.82) were revealed in 2005, 2006, and 2007 respectively with 2007 having

the highest positive anomaly indicating a flood year, while 2011 revealed a slightly wet year, 2012, and 2014 revealed exremely wet years which indicated flood years during this period in the study area.

4.3.6 June Rainfall Anomaly

Rainfall anomaly showing the composite nature in which some of dry years were mixed with wet years.The rainfall anomalous conditions for the month of June,from 1991 to 2015 are given in Figure 4.8

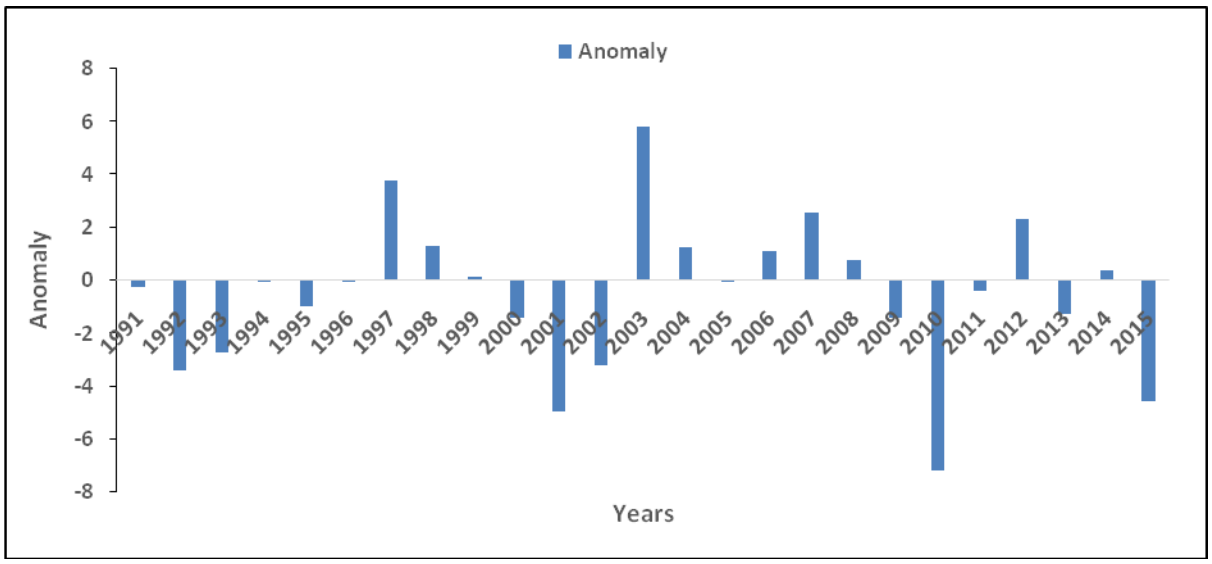


Figure 4.8: June Anomalyof Moro LGA (1991-2015)
Source: Author's Computation (2018)

Near normal rainfall were revealed in some years (1991, 1994, 1996, 2005, 2011 and 2014) within the study period in Figure 4.8. An extreme dry year (1992) to some slightly dry years (1993, 1995, and 2000) were revealed, with values ranging from -3.39 to -0.97 anomalies in the first decade of the study period. This is in line with the study of Abaje et al, (2010), the study revealed dry years in June from 1993 to 2000 atKafanchan. Figure 4.8 shows that 2001, 2002, 2010 and 2013 were

moderately dry years, while 2003 was an extremely wet year with 5.82 anomalous value.

4.3.7 July Rainfall Anomaly

An assessment of the pattern of anomalous rainfall condition of Moro LGA has been carried out showing the extreme wet or dry conditions. Figure 4.9 shows rainfall anomaly for the month of Julyfrom 1991 to 2015.

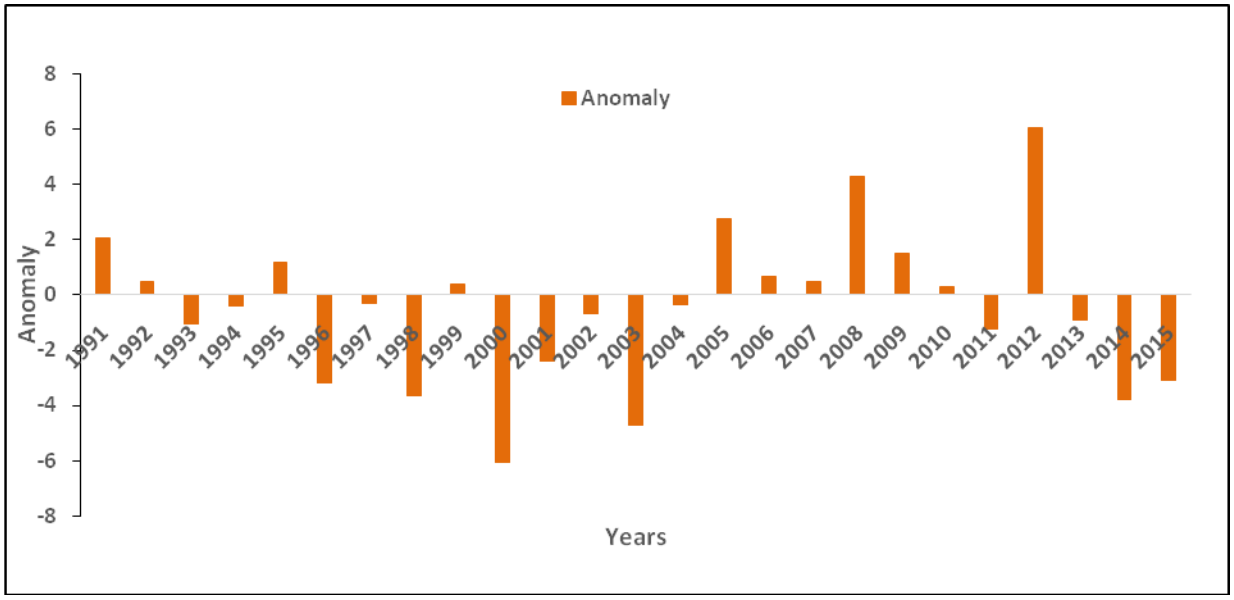


Figure 4.9: July Anomalyof Moro LGA (1991-2015)
Source: Author's Computation (2018)

In Figure 4.9, negative anomalies of extremely dry to moderately dry years were revealed in 1993, 1996, 1998, and 2000 ranging from a value of -6.06 to -1.03, with alternating wet years within the first decade of the study. July 2000 was the driest month. In the second decade, negative anomalies were also recorded from 2001 to 2003 revealing a slightly dry to extremely dry years. This is in agreement with the study of Abaje et al, (2010), which revealed dry years in July of the year 1993, 1996, 1997, 1999, from 2000 to 2003, 2005 and 2006 respectively at Kafanchan. The years 2005 to 2010 were wet years, however, 2011, 2013, 2014, and 2015 were dry years

with values ranging from -1.21, -0.92, -3.76, and -3.09 respectively. An extremely wet year was also revealed in 2012, this was the cause of the 2012 flooding Nigeria experienced and the study area in particular. The year 2008 was also an extremely wet year in the study area.

4.3.8 August Rainfall Anomaly

Rainfall anomalies are expressed as departures from long term mean rainfall of a given location. To ascertain the pattern of deviation, RAI was used in analysing rainfall anomalies. The deviation from long term mean of August rainfall from 1991 to 2015 are presented in Figure 4.10.

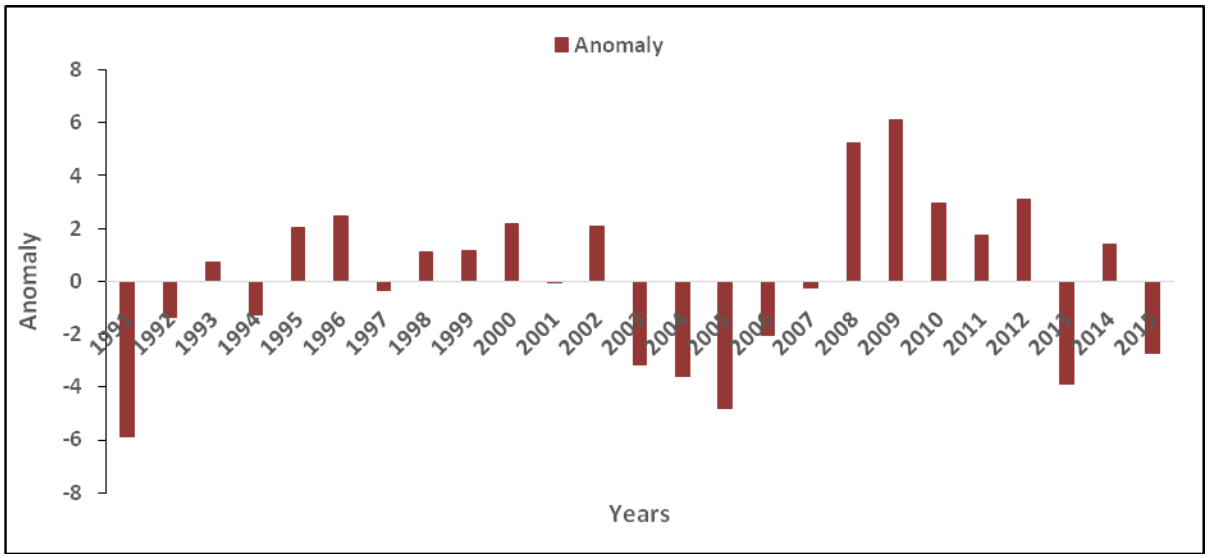


Figure 4.10: August Anomalyof Moro LGA (1991-2015)
Source: Author's Computation (2018)

In Figure 4.10, negative anomalies of extremely dry (1991) to moderately dry (1992 and 1994) years were revealed in the first decade of the study period. This agrees with the study ofAbaje et al, (2010), as the study revealed dry years from 1995 to 1998 at Kafanchan. In the second decade of the study period, moderately wet, very wet, and extremely wet years were revealed from 2008 to 2012 with values ranging from 1.73 in 2011 to 6.09 in 2009 while negative anomalies were recorded from 2003

to 2006 with values ranging from -2.05 in 2006 and -4.78 in 2005, which is also in line with the study of Abaje et al, (2010),which revealed dry years in 2005, 2006, and 2008. Likewise, in 2013 and 2015, a very dry and an extremely dry condition was revealed in Moro LGA. However, from 2008 to 2012, extremely wet years were revealed, with the exception of 2010 and 2011, which revealed a positive anomaly value of 2.95 and 1.73, indicating a very wet and moderately wet years respectively.

4.3.9 September Rainfall Anomaly

The rainfall pattern of Moro LGA shows a secondary peak in September, with low variation. The anomalous rainfall for the month of September, from 1991 to 2015 is presented in Figure 4.11.

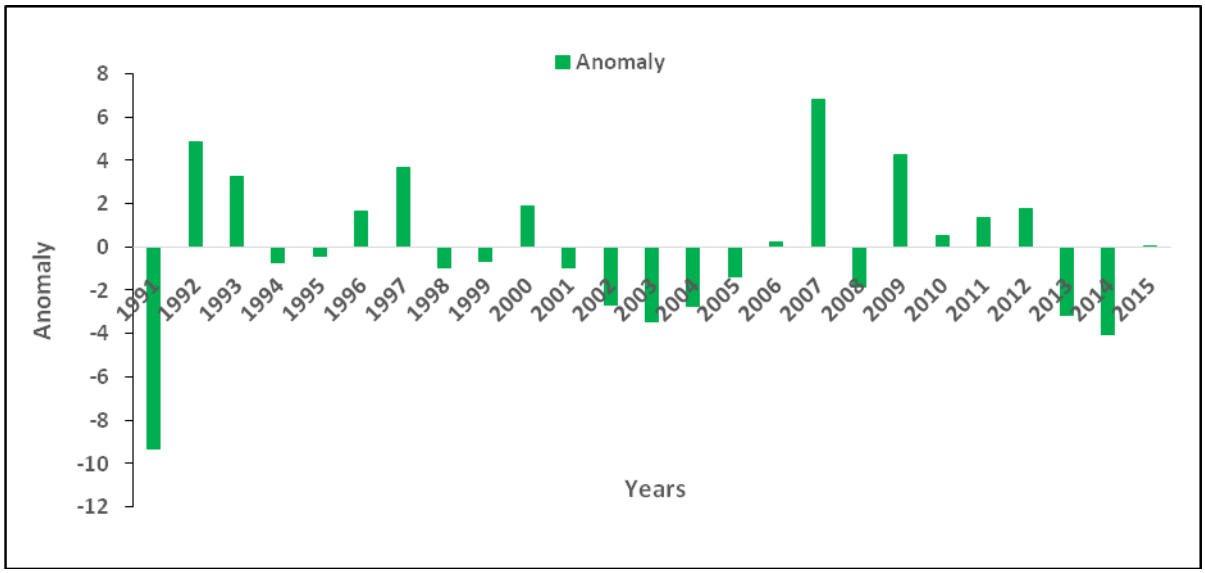


Figure 4.11: September Anomalyof Moro LGA (1991-2015)
Source: Author's Computation (2018)

Figure 4.11 revealed negative anomalies in 1991, 1994, 1998 and 1999 ranging from -0.67 to -9.33 revealing an extremely dry year (1991) in the first decade of the study period. This is in contrast with the study of Abaje et al, (2010),which revealed only 1993and 1996 to be dry years in September from 1993 to 2003, where

other years within these sub-period, revealed wet years. Likewise, in the early years of the second decade, negative anomalies of values ranging from -0.99 to -3.46 in 2001 to 2005 were recorded, revealing a slightly dry, to an extremely dry condition within Moro LGA. This agrees with the study of Abaje et al, (2010),which revealed dry years in 2002, from 2004 to 2006, and 2008 respectivey in Kafanchan.Whereas, 1992, 1993, 1997 2007 and 2009 were years of extreme wet rainfall in Moro Local Government Area. Thestudy area experienced flood in 1992, 1997, 2007, and 2009, which was as a result of the extreme wet years recorded in these periods.

4.3.10 October Rainfall Anomaly

Rainfall anomaly showing the composite nature in which some of dry years were mixed with wet years. Extremely wet or dry conditions for the month of October,from 1991 to 2015 are indicated inFigure 4.12.

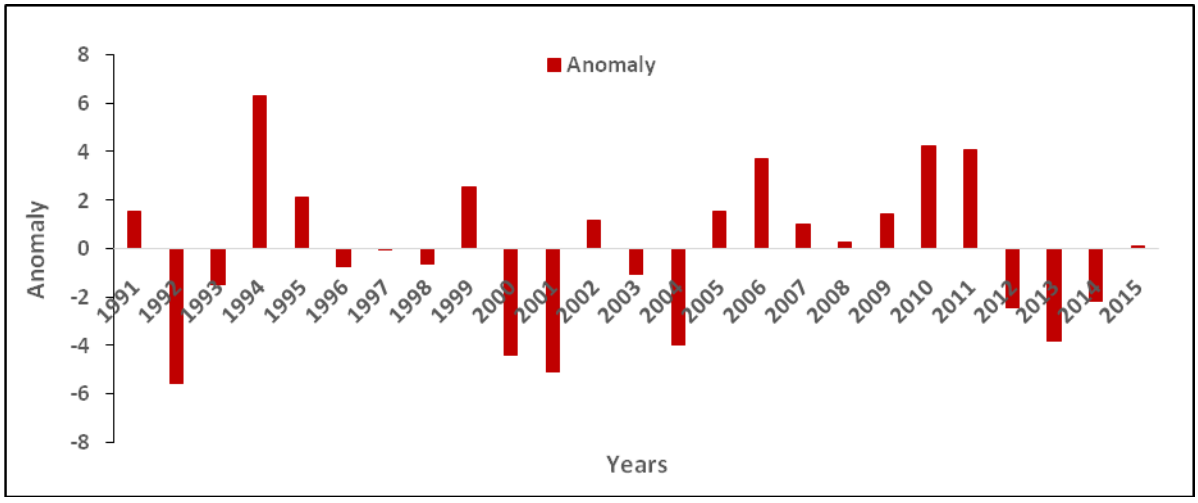


Figure 4.12: October Anomalyof Moro LGA (1991-2015)
Source: Author's Computation (2018)

In October, which marks the end of the wet season (Figure 4.12), negative anomalies were recorded in 1992, 1993, 1996, 1998, and 2000 in the first decade, revealing a slightly dry (1996 and 1998) to extremely dry years with values ranging

from -0.64 in 1998 to -4.42 in 2000. A negative anomaly of -0.2 was recorded in 1997, revealing a near normal rainfall condition. The year 1992 was the driest year of the study period.

In the second decade, a fluctuation between wet and dry years was revealed from 2001 to 2004, with the year 2002 being a positive anomaly of value 1.16 revealing a moderately wet year. The years 2001, 2003, 2004, were very dry. This seem to be in agreement with Abaje et al, (2010),in which the study revealed dry years from 1991 to 2008, with the exception of 1994, 1995, and 2003 which revealed wet years in the month of October at Kafanchan. This continued unabatedly until 2011, alternating between moderately wet and extremely wet years. From 2012 to 2014, negative anomalies of very dry and extremely dry years were revealed, with 2015 capping it with a near normal rainfall.

4.3.11 November Rainfall Anomaly

In Figure 4.13, November which marks the beginning of dry season in Moro LGA, positive anomalies were recorded in 1993, 1995, 1996, 1997, and 1999 revealing a slightly wet (1993, 1996, and 1999) and some few extremely wet (1995 and 1997) years in between with values ranging from 0.99 to over 3.0 in the first decade of the study period. In the second decade, few positive anomalies were recorded in 2004, 2005, 2009, 2010, and 2014. All these years revealed a slightly wet to some extremely wet years in the study period, with other years being extremely dry in Moro LGA.

The deviation in the long term mean rainfall shows the nature of rainfall pattern in Moro LGA. Rainfall anomalies for the month of Novemberfrom 1991 to 2015 as shown in Figure 4.13

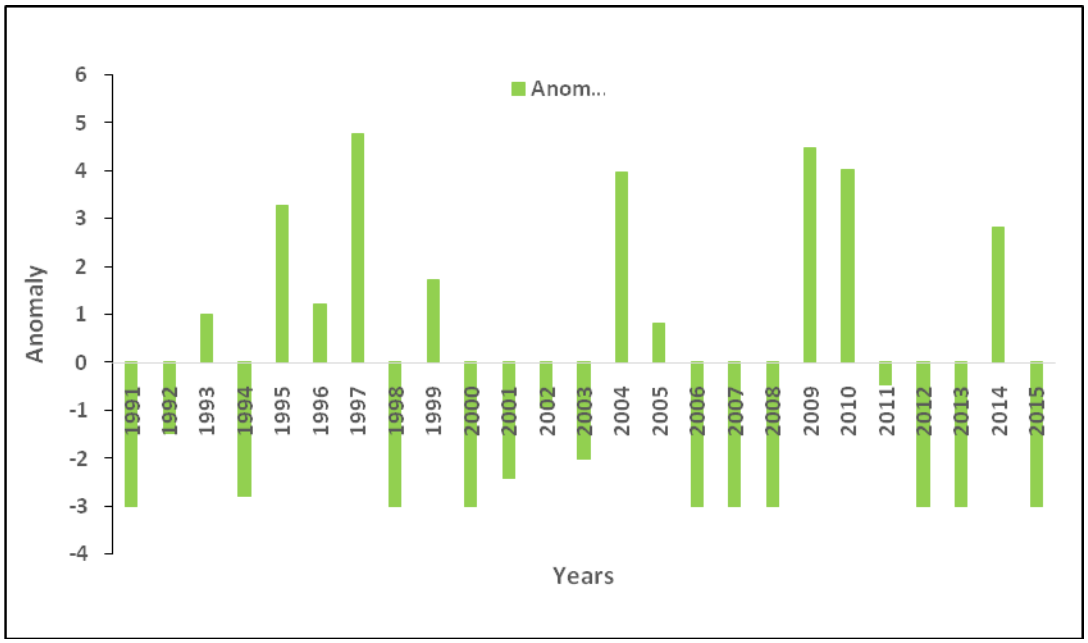


Figure 4.13: November Anomalyof Moro LGA (1991-2015)
Source: Authors Computation (2018)

4.3.12 December Rainfall Anomaly

In Figure 4.14, only a few years (1995, 2005, 2010, and 2013) recorded positive anomalies in December ranging from 1.72 to 15.4 revealing moderately wet to extremely wet conditions respectively, while the remaining of years revealed an extreme dry condition in Moro LGA. This is a dry season in the area.

The extremes and differences of the monthly rainfall value from the climatically expected temporal mean shows the nature of rainfall variation in Moro LGA.The anomalous rainfall for the month of December, from 1991 to 2015 is presented in Figure 4.14.

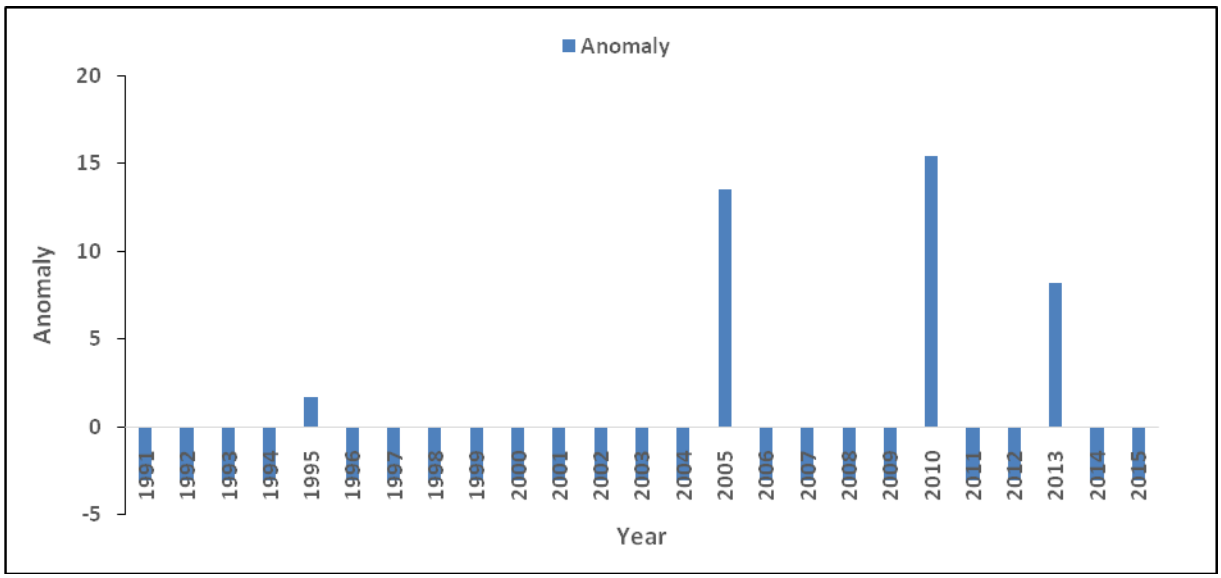


Figure 4.14: December Anomalyof Moro LGA (1991-2015)
Source: Authors Computation (2018)

4.4 ANNUAL RAINFALL ANOMALY OF THE STUDY AREA

The annual rainfall anomaly indices calculated, indicated rainfall anomaly ranging from a lowest negative anomaly of -0.29 (a near normal rainfall condition) in 1994 to a highest positive anomaly of 6.81, (an extremely wet year) in 1997 (see Appendix II and Figure 4.15). This agrees with the study of Abaje et al (2010),and Ekwe et al (2014), as both studies revealed wet conditions in these years. The first four years of the study period revealed a near normal rainfall to some extremely dry conditions (1991, and 1993). Closely followed by from 1995 to 1997, was a moderately wet, to extremely wet years (1997), followed by a fluctuation between a moderately wet year and a very dry year in 1999 and 2000. This agrees with Ekwe et

al (2014), as the study also found wet year and a dry year in 1999 and 2000, but in contrast withAbaje et al, (2010), as the study revealed wet conditions in both years.

An assessment of the pattern of anomalous rainfall condition of Moro LGA has been carried out showing the extreme wet or dry conditions. There were notablerainfall anomalies in between 1991 to 2015 shown inFigure 4.15.

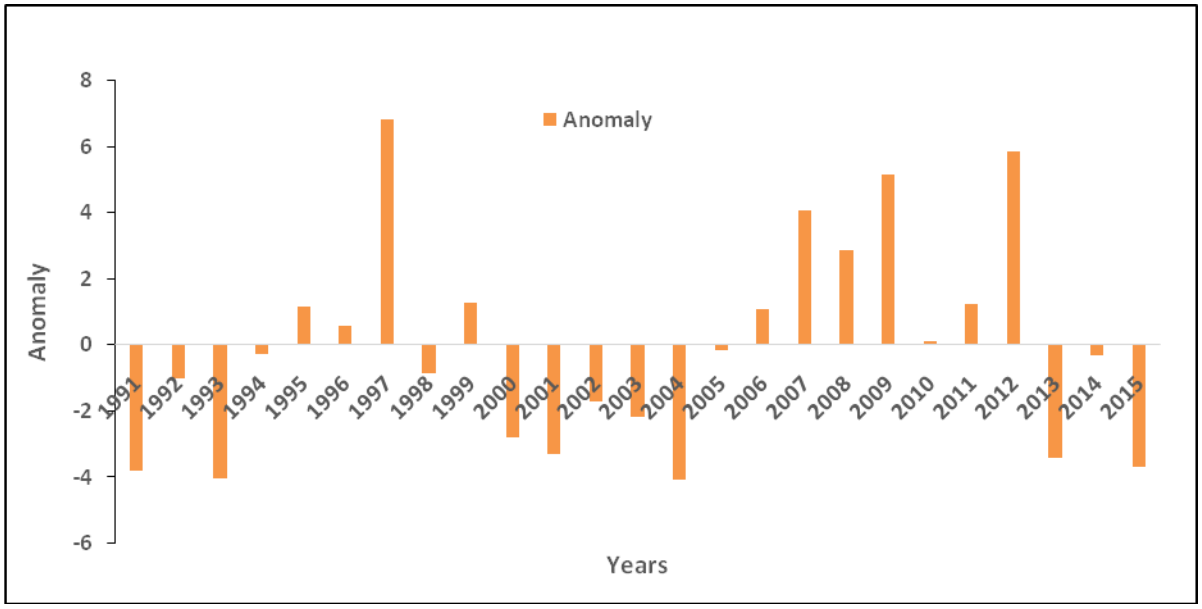


Figure 4.15: Annual Rainfall Anomalyof Moro LGA (1991-2015)
Source: Author's Computation (2018)

In the second decade of the study period, the first four years (2001 to 2004) were characterized by negative anomalies of values ranging from -1.69 in 2002 to -4.08 in 2004 revealing a moderately dry to extremely dry conditions. This agrees with the study of Abaje et al, (2010)and that of Ekwe et al (2014), as both studies revealed dry years in Kafanchan and Nasarawa state.

A near normal rainfall condition was revealed in the year 2005 with a value of -0.16 marking the beginning of wet years in the study period, which was closely followed until 2012. Within this period, 2007, 2009, and 2012 revealed an extremely

wet year (flood years), 2006 and 2011 revealed a moderately wet year. In 2008, result indicates a very wet year while 2010 shows a near normal rainfall condition. This disagrees with the study of Abaje et al, (2010) and Ekwe et al (2014), as both studies revealed dry years in 2008 at Kafanchan and in 2008 and 2010 at Nasarawa. At the tail end of the study period, from 2013 to 2015, result revealed a fluctuation between a near normal rainfall and extremely dry conditions in Moro LGA.

4.5 TREND IN CROPS YIELD IN THE STUDY AREA

4.5.1 Trend in Maize Yield

Figure 4.16, revealed that the yield of maize increased between 1991 and 2015. There was significantly low yield in 1997 while the yield was relatively high in 1994 within the first decade of the study period. Within the second decade, fluctuation was steady, with 2001 having a low yield, and high yield was revealed from 2010 to 2014, with a little drop in yield in 2015. The annual mean yield of maize in Moro is 1.34 tons/ha with a co-efficient of variation of 14% in the study period (see Appendix III).This agrees with the findings of (FAOSTAT, 2013), which revealed that the average yield of maize found in Nigeria is 1.68 tons/ha from 1986 to 2011. The yield of maize in the area was on the increase. This increasing trend in yield is supported by the positive trend line equation ($Y= 0.0202x + 1.0814$).

To ascertainrainfall anomaly effect on crop yield, there is need to analyse the trend of change. Figure 4.16 shows the trend of maize yield for the study areafrom 1991 to 2015.

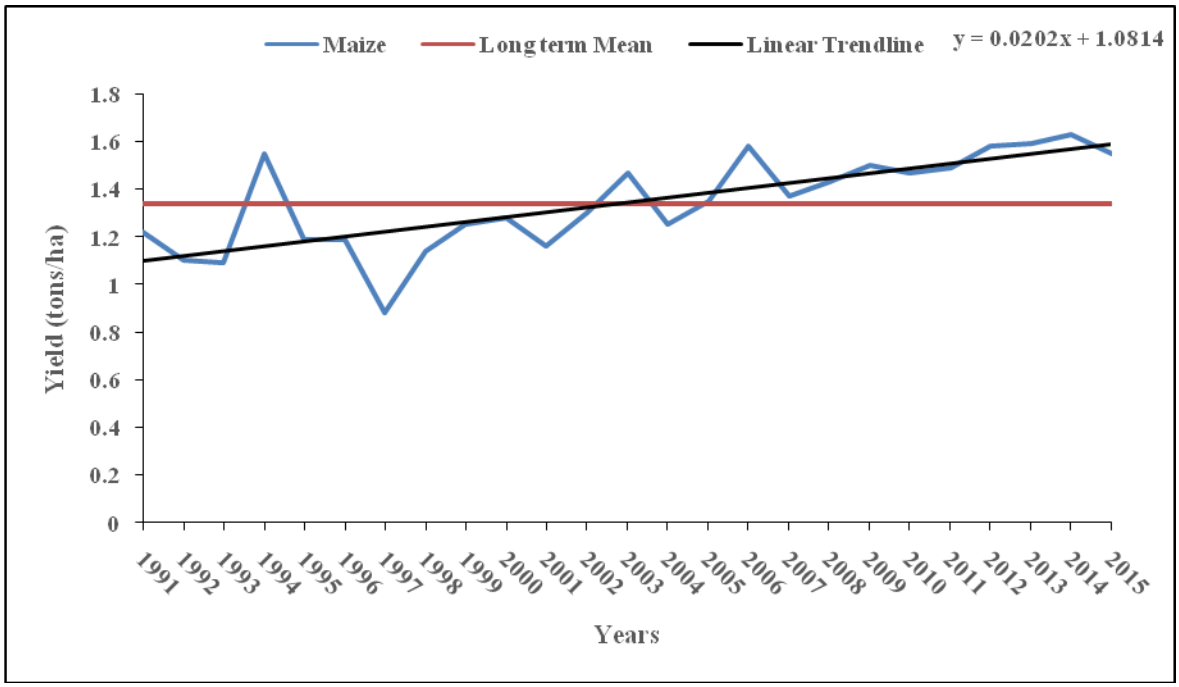


Figure 4.16: Yield of Maize for Moro LGA (1991-2015)
Source: Author's Computation (2018)

4.5.2 Trend in Sorghum Yield

Figure 4.17, shows that there was low yield of sorghum in 1992, while yield was relatively high in 1999 and 2000, within the first decade of the study period. The high yield continued within the first two years of the second decade with a significant drop in 2003. Fluctuation continued in the rest of the years within the second decade with 2003 and 2005 having the lowest yield, while yield was high in 2002. Likewise, from 2013 to 2015, sorghum yield was relatively high.

Sorghum is one of the dominantly cultivated crops affected by variation in rainfall, to ascertain its effect, it is necessary to analyse trend of sorghum yield over the years. The trend in sorghum yield for the study areafrom 1991 to 2015 is given in Figure 4.17.

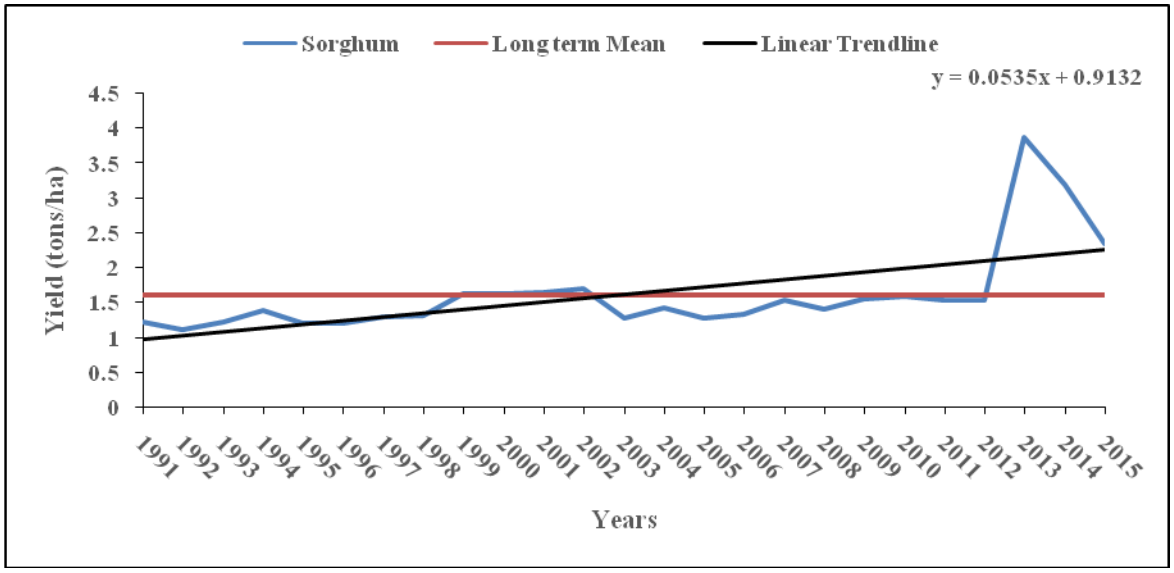


Figure 4.17: Yield of Sorghum for Moro LGA (1991-2015)
Source: Author's Computation (2018)

The annual mean yield of sorghum was 1.61 tons/ha with a co-efficient of variation of 39.5% (Appendix III). This is in contrast with the study of Idrissa (2005), and Sekoli and Morojele(2016), as both study revealed average yield of sorghum as 1.0 ton/ha for Lesotho and Africa. The positive trend line equation Y= 0.0535x + 0.9132 revealed that the yield of sorghum was on the increase in the study area.

4.5.3 Trend in Cassava Yield

Cassava is one of the crops vulnerable to excessive water, it is necessary to analyse its trend in other to ascertain the level at which its affected by rainfall

anomaly. Figure 4.18 shows the pattern of cassava yield variation for the study area from 1991 to 2015.

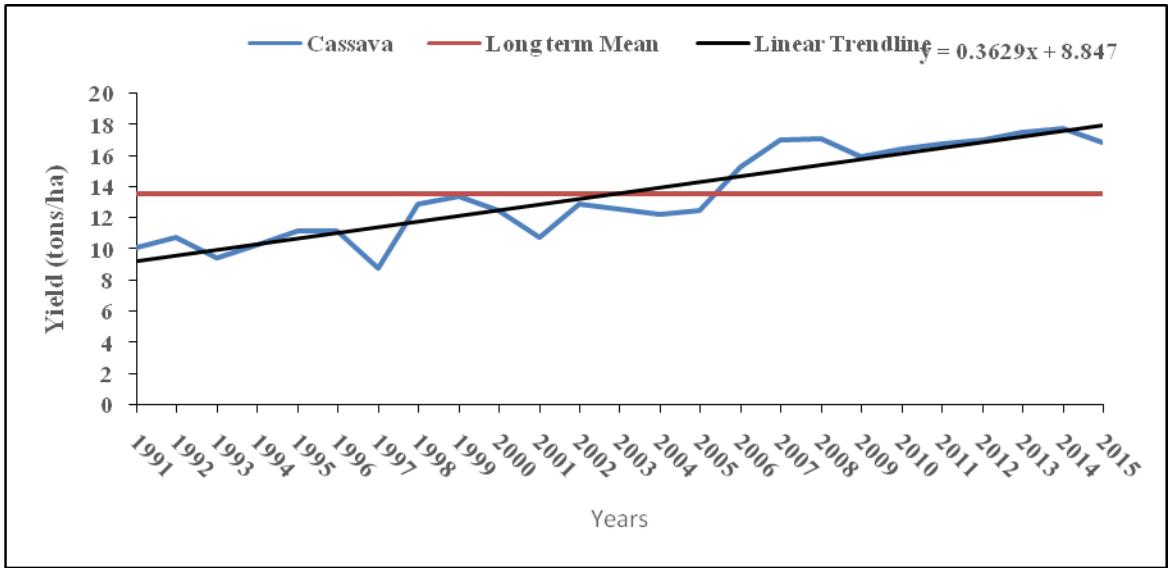


Figure 4.18: Yield of Cassava for Moro LGA (1991-2015)
Source: Author's Computation (2018)

The yield of cassava was relatively higher than the yield of maize and sorghum. Figure 4.18, showed low yield of cassava in 1993 and 1997, while cassava yield was relatively high in 1998 and 1999 within the first decade of the study period. Within the second decade, yield varied significantly around 12 tons/ha from 2002 to 2005, while the other years within the decade from 2006 to 2015, an annual increase in yield of about 15 tons/ha to a little above 17 tons/ha was revealed. In the whole of the study period, there was low yield of cassava in 1997, while the yield was relatively high in 2014. This is attributed to the wet and dry years experienced in this period, its vulnerability to excessive water(Blanc, 2011), and to its physiology which allows it reach soil moisture deeper in the soil(El-Sharkawy, 2007).

The annual mean yield of cassava in Moro LGA is 13.56 tons/ha with a co-efficient of variation of 21.5% in the study period (see Appendix III). This is lower

than the findings ofFAOandIFAD (2005), on COSCA for Nigeria (14.7 tons/ha), but slightly higher than that of Ghana (13.1 tons/ha) and Tanzania, Cote d'Ivoire, The Congo, and Uganda which is around 10 tons/ha respectively in 1991. There is an increasing trend in cassava yield in the area, which is supported by the positive trend line equation (Y = 0.3629x + 8.847).

4.5.4 Trend in Yam Yield

Yam is one of the staple crops produced in Moro LGAaffected by variation in rainfall, to ascertain its effect, it is necessary to analyse trend of yam yield over the years. Fluctuations in the output of yam for the study area from 1991 to 2015 are given in Figure 4.19

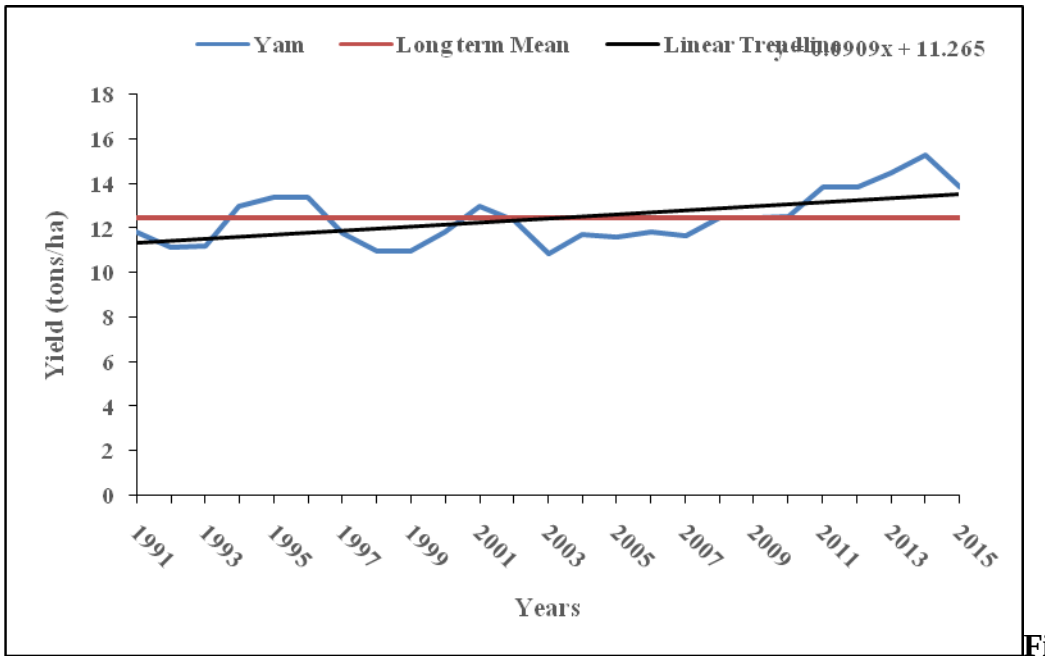


Figure 4.19: Yield of Yam for Moro LGA (1991-2015)
Source: Author's Computation (2018)

Figure 4.19,shows significant fluctuation in the yield of yam, with a low yield in 1998, while the yield was relatively high in 1995 and 1996 within the first decade of the study period. There was an increase in annual yield around 11 tons/ha from

2004 to 2007 in the second decade. Low yield of yam was observed in 2003, while yield was high in 2010. Little variation in the yield of yam was observed from 2011 to 2015, even though the yield recorded in this period was high. There was low yield of in 2003, while yield was relatively high in 2014.

The annual mean yield of yam is 12.45 tons/ha with a co-efficient of variation of about 9.49% in the study period (see Appendix III). This is higher than the findings of CBN (2012), which revealed average yam yield for Nigeria as 9.55 tons/ha, 10.83 tons/ha for Cote d'iviore, 10.94 tons/ha for Benin Republic, but, lower than the average yield for Ghana which is 12.74 tons/ha. It is also higher than the findings of Yahaya et al (2014), which also found the yield of yam as 11.26 tons/ha in 2001 at Kuta community. The trend line equationY = 0.0909x + 11.265showedan increasing trend in the yield of yam in the area.

4.6 RELATIONSHIP BETWEEN RAINFALL ANOMALIES AND CROPS YIELD IN THE STUDY AREA

Rainfall anomalies and maize yield have a very weak insignificant positive relationship (r = 0.001). This means that, as rainfall anomalies increase negatively or positively, the yield of maize decreases or increases in the study area if all other conditions remain the same. This is because maize does not need too much or too little rainfall, but between 600-1000mm to yield properly, as excess rainfall will lead to yellowing of leaves and too little rainfall will lead to stunted growth. The hypothesis that there is no significant relationship between rainfall anomalies and maize yield at 0.05 significant level is accepted.

The deviation from the long term average rainfall have influence on the yield of crops. The correlation co-efficient (r) between the harmonized annual rainfall anomalies and the selected crops yield were computed and presented in Table 4.3.

Table 4.3: Correlation Matrix of Crop Yield and Rainfall Anomaly

Crops	'r' Value
Maize	0.001
Sorghum	-0.194
Cassava	0.221
Yam	0.065

Source: Author's Computation (2018)

This agrees with the studies of Oruonye et al (2016),Ndamani and Tsunemi(2015), Awotoye and Mathew(2010), which all revealed that the relationship between rainfall and maize yield is weak. However, this finding disagrees with the study ofIfabiyi and Omoyosoye (2011), andBewket (2009) as the studies revealed a weak but negative relationship.

The relationship between rainfall anomalies and sorghum is a weak insignificant negative relationship (-0.194). This implies that as rainfall anomalies increased positively, the yield of sorghum decreased if all other conditions remain the same, as too much rain during grain formation causes wasting of pollen grains and development of black fungal disease which reduces sorghum yield. Therefore, the stated null hypothesis that there is no significant relationship between rainfall anomalies and sorghum yield at 0.05 significant level is accepted. This agrees with

the study of Tengen and Deressa (2017), although, the study revealed a strong negative relationship.

The correlation coefficient between rainfall anomalies and cassava yield is 0.221, indicating an insignificant but positive relationship. This implies that as rainfall anomalies increased, the yield of cassava increased if all other conditions remain the same. This is because it is a root crop that is vulnerable to excessive water. This agrees with the finding of Alexander et al (2015), Akpenpuun and Busari(2013), as well as Awotoye and Mathew (2010), which revealed weak relationship between rainfall variation and cassava yield. The stated null hypothesis postulated ealier in chapter one is therefore accepted.

The correlation coefficient (r= 0.065) between rainfall anomalies and yam is insignificantly positive but very weak. This implies that as rainfall increased, the yield of yam increased in the study area within the stated period of study if all other conditions remain the same and the hypothesis stated is accepted. This agrees with the study of Ayanlade et al (2010), Ajadi et al (2011), Zakari et al (2014), which revealed that rainfall variability has a weak relationship with yam yield. However, the study ofAjadi et al (2011) revealed a weak negative relationship between rainfall variability and yam yield.

4.7 VARIATION IN CROPS YIELD ACCOUNTED FOR BY RAINFALL ANOMALIES

Table 4.4 shows that rainfall anomalies account for only 0.1% in the variation of maize yield. This disagrees with the study of Bewket (2009), Ajadi et al(2011), and Oruonye et al (2016), as the studies revealed that rainfall anomalies accounted for

about 25%, 22%, and 23% respectively in the variation in yield of maize in their study areas.

Rainfall anomalies accounts for 3.8% in the variation in yield of sorghum. This is in contrast with Bewket (2009) and Ajadi et al (2011), who reavealed about 18.6% and 16% respectively of variation in sorghum yield was accounted for by variation in rainfall in their study areas. However, the study of Adejuwon (2005), revealed that about 66% of variation in sorghum yield was accounted for by the variation in rainfall at Maiduguri and Potiskum.

It is necessary to ascertain the strength at which deviation from the long term average rainfall have influence on the yield of crops, in order to make inference. Table 4.4 shows by how much rainfall anomalies account for variations in the selected crops yield in the study area.

Table 4.4: Model Summary of Anomalies and Crop Yield

Variable	R	R Square	Adjusted R Square	Std. Error of the Estimate
Maize	0.001	0.001	-0.043	0.06799
Sorghum	-0.194	0.038	-0.004	1.29353
Cassava	0.221	0.049	0.007	0.09503
Yam	0.065	0.004	-0.039	0.04116

Predictor (constant), Anomalies
Source: Author's Computation (2018)

Rainfall anomalies accounts for 4.9% in the yield of cassava. This disagrees with the study of Alexander et al (2015) which revealed that rainfall variation accounts for only 1.44% in the yield of cassava in the Niger-Delta region, while the study of Akpenpuun and Busari (2013) revealed that 99.9% of the variation in the yield of cassava is accounted for by rainfall variation in Kwara state. Rainfall anomalies accounts for 0.4% in the yield of yam in Moro LGA. This agrees with the study of Zakari et al (2014), which revealed that 0.2% of the variation in yam yield is acccounted for by the variation in rainfall in Abuja. However, it disagrees with the study of Alexander et al (2015), Akpenpuun and Busari (2013) and Ajadi et al (2011) which revealed that 10%, 99.8%, and 55.4% respectively of yam variation accounted for by the variation in rainfall in their respective study areas. All these low proportions accounted for by the anomalies suggest that the variation in crops yield could be attributed to other factors such as variations in onset and cessation of rainfall, length of rainy season, rainfall intensity, soil temperature, timely fertilizer and insecticides application, soil fertility, pest and disease outbreak, low access to loans, changes in government policies on farming input provisions etc.

4.8 ANOMALOUS RAINFALL AND CROP YIELD PREDICTION FOR THE STUDYAREA

4.8.1 Prediction of Rainfall Anomalies

From the predicted anomalous rainfall in Moro LGA, it was observed that from 2016 to 2019, rainfall will deviate below average indicating negative anomalies, which will decrease in magnitude approaching a near normal rainfall condition in

2020. These will gradually increase in 2021 and 2022, each indicating a moderately wet and a very wet year.

The predicted annual rainfall anomalies for the study area from 2016 to 2025 is shown in Figure 4.20.

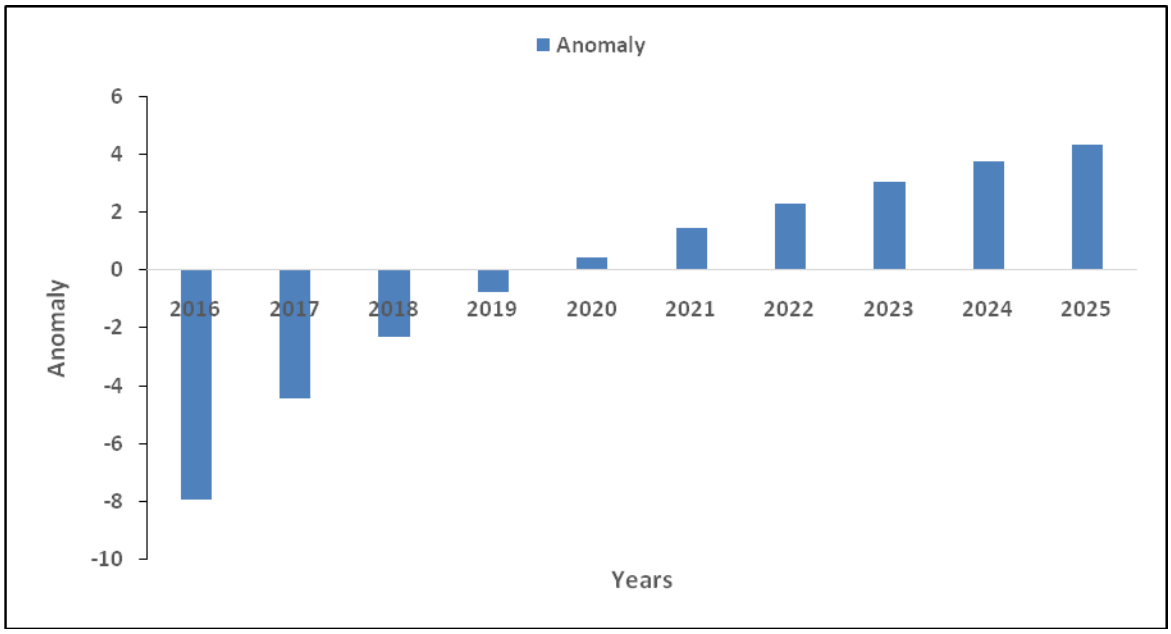


Figure 4.20: Predicted Anomalous Rainfall for Moro LGA (1991-2015)
Source: Author's Computation (2018)

From 2023 to 2025, it was estimated that rainfall anomaly will further increase from 3.08 in 2023, to 3.75 in 2024, and 4.36 in 2025 (see Appendix V). This indicates the coming years will experience an extremely wet condition, based on the average rainfall of Moro LGA.

4.8.2 Maize Yield Prediction

It is vital to analyse the future trend of maize yield in Moro LGA, in order to make effective planning. Figure 4.21 shows prediction of maize yield for the study area from 2016 to 2025.

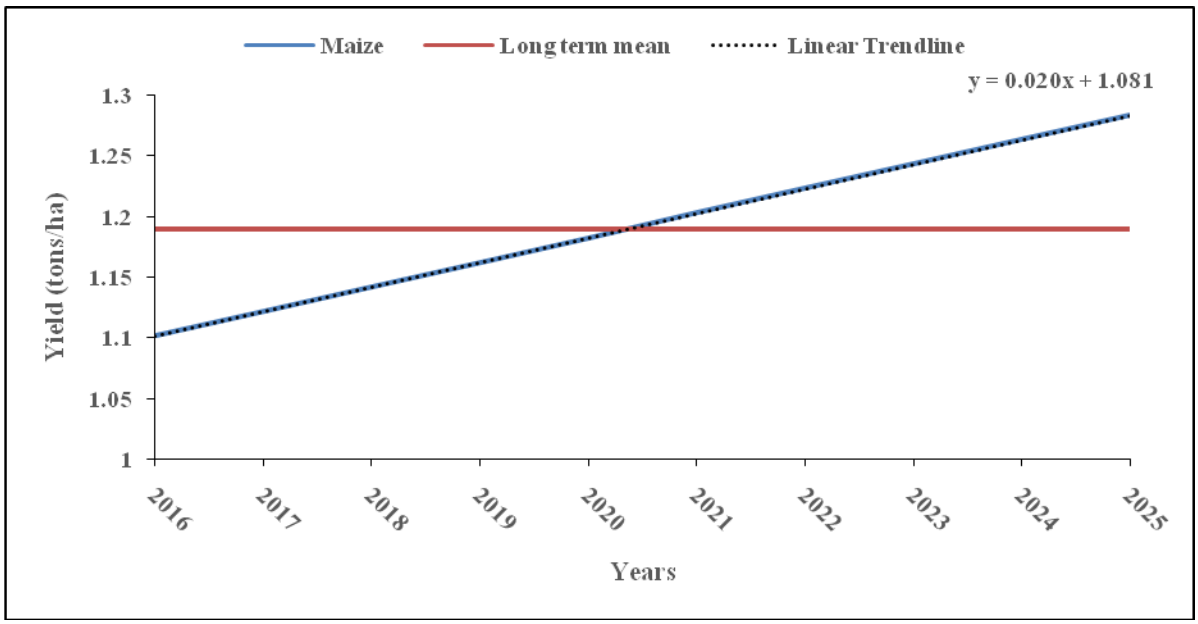


Figure 4.21: Predicted Yield of Maize for Moro LGA (1991-2015)
Source: Author's Computation (2018)

The predicted yield of maize in Moro LGA will be on the increase in the coming years because the rains will be increasing, as it is observed that maize yield will be 1.10 tons/ha in 2016. It will increase in 2017 to a value of 1.12 tons/ha, 1.14 tons/ha in 2018 and 1.16 tons/ha in 2019. By the year 2020, the yield of maize will further increase to 1.18 tons/ha, and 1.20 tons/ha in 2021. In 2022, maize yield will be 1.22 tons/ha in the study area. In 2023, the yield of maize in the study area will increase to 1.24 tons/ha, it will further increase to 1.26 tons/ha in 2024 and 1.28 tons/ha by the year 2025 (see Appendix V). The increasing trend of the predicted yield is supported by the positive trendline equation Y=0.0202x + 1.0814.

4.8.3 Sorghum Yield Prediction

Forecasting trend of sorghum yield, is necessary for effective plan towards improving yields. Figure 4.22 shows predicted sorghum yield for the study area from 2016 to 2025.

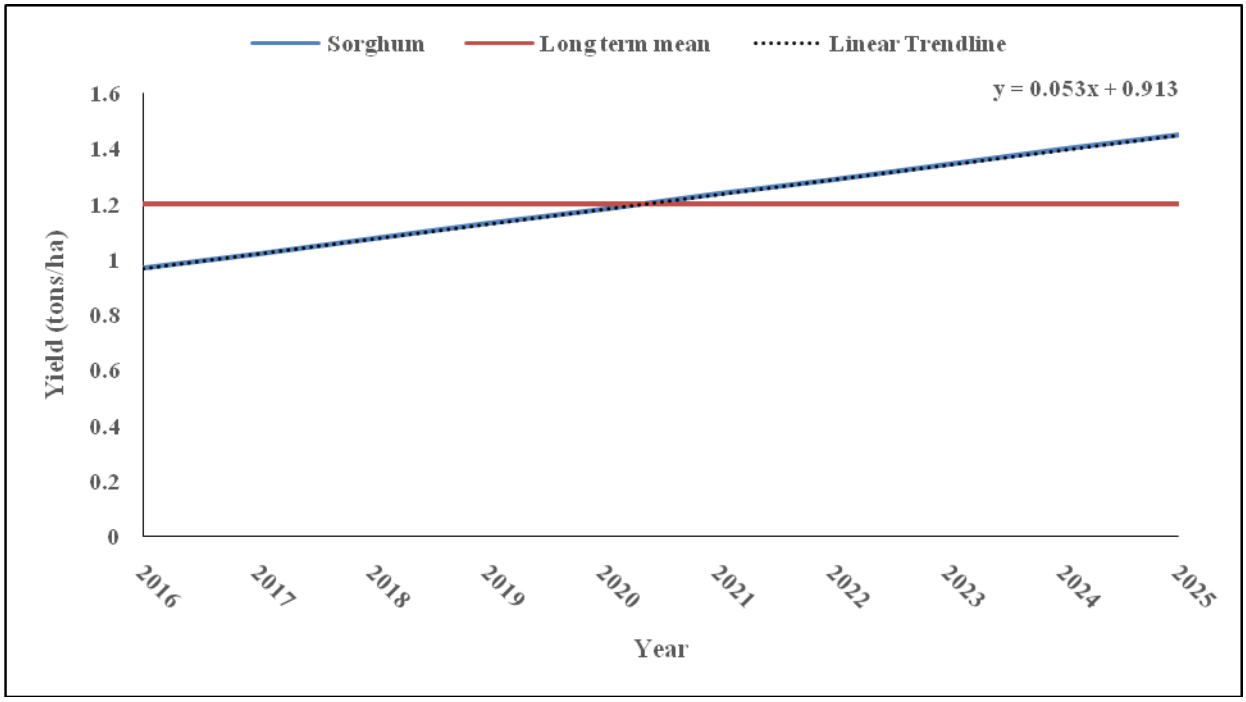


Figure 4.22: Predicted Yield of Sorghum for Moro LGA (1991-2015)
Source: Author's Computation (2018)

The predicted yield of sorghum in Moro LGA will increase in the coming years, as the yield will be 0.96ton/ha in 2016. This will increase to 1.02 tons/ha in 2017, 1.07 ton/ha in 2018, and 1.12tons/ha in 2019.It will further increase to 1.18 tons/ha in 2020, 1.23 tons/ha in 2021, and 1.28 tons/ha in 2022.By the year 2023, the yield of sorghum will increase to 1.34 tons/ha and 1.39 tons/ha in 2024. This will further increase to 1.44 tons/ha by the year 2025 (see Appendix V). This increasing trend is supported by the positive trendline equation Y= 0.0535x + 0.913.

4.8.4 Predicted Cassava Yield

The prediction of cassava yield trend is necessary foreffective planning towards improving yields in Moro LGA. The prediction of cassava yield for the study area from 2016 to 2025 is shown in Figure 4.23.

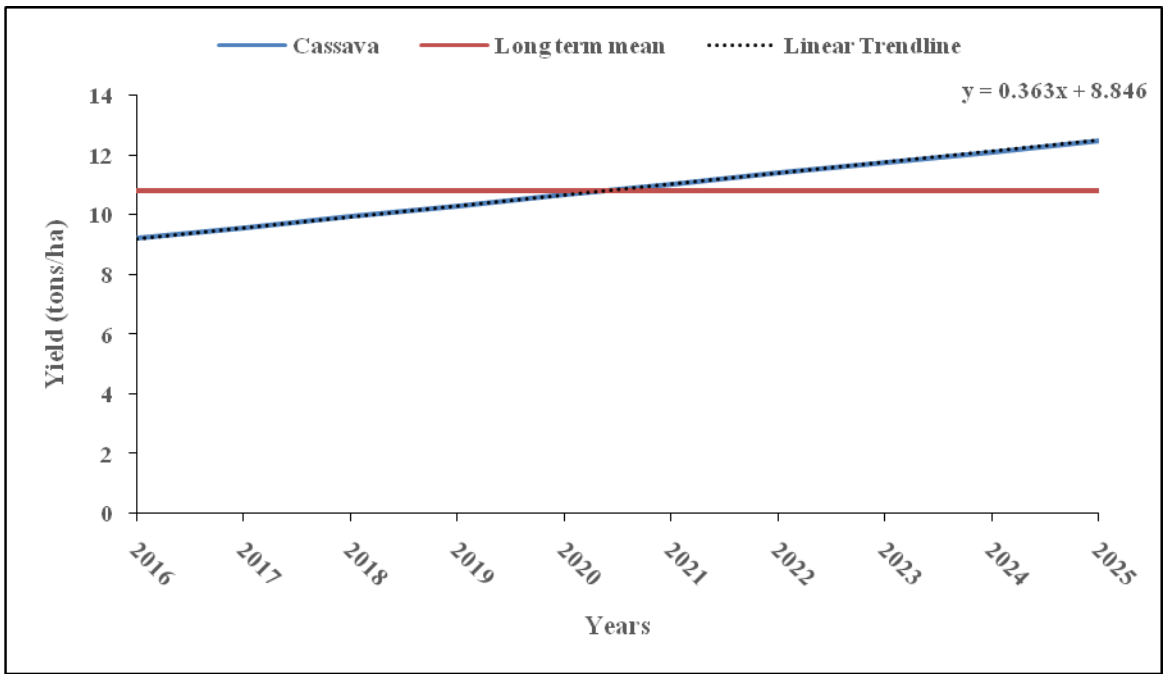


Figure 4.23: Predicted Yield of Cassava for Moro LGA (1991-2015)
Source: Author's Computation (2018)

The predicted yield of cassava from 2016 to 2025 in Moro LGA as shown in Figure 4.23 will also increase in the coming years. The yield of cassava will be 9.21 tons/ha in 2016 and 9.57 tons/ha tons/ha in 2017. By the year 2018, the yield of cassava will increase from 9.93 tons/ha to 10.30 tons/ha in 2019. By 2020, cassava yield will be 10.66 tons/ha and will further increase to 11.02 tons/ha by 2021.In 2022, the yield will increase to 11.39 tons/ha, and 11.75 tons/ha in 2023. By the year 2024, the yield of cassava will increase to 12.11 tons/ha and 12.48 tons/ha in 2025 (see Appendix V). The increasing trend in yield is supported by the positive trendline equation Y= 0.363x + 8.8466.

4.8.5 Yam Yield Prediction

Analyzing the future trend of yam yield is vital in planning policy towards improving the economy of Moro LGA. The prediction of yam yield for the study area from 2016 to 2025 is shown in Figure 4.24.

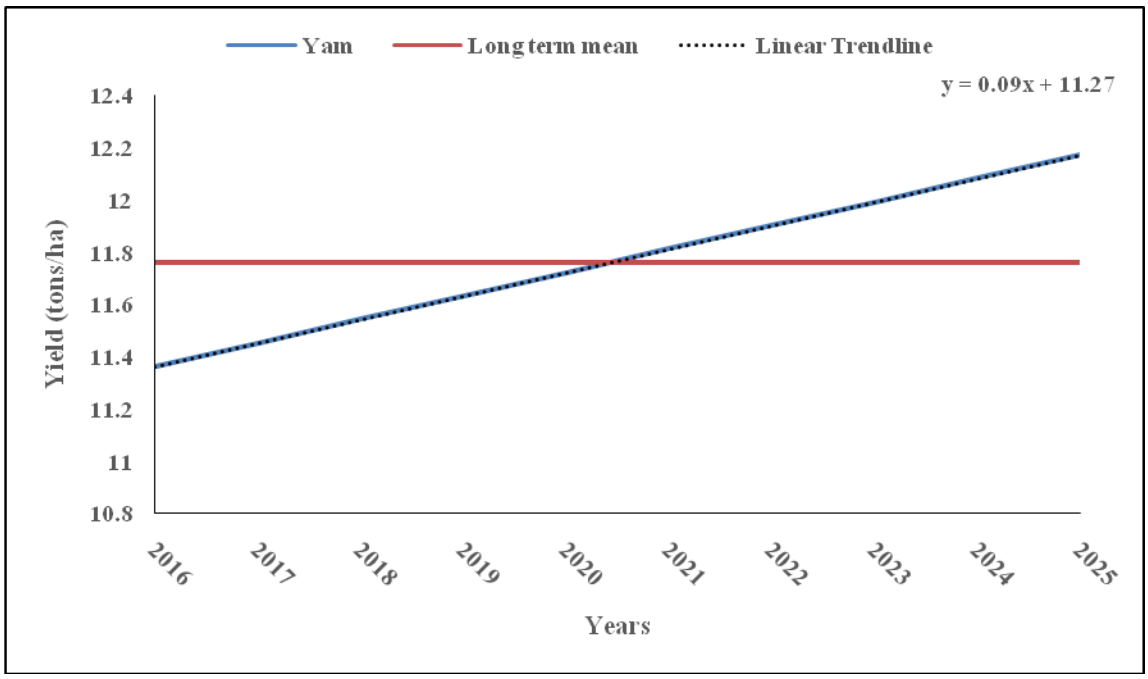


Figure 4.24: Predicted Yield of Yam for Moro LGA (1991-2015)
Source: Author's Computation (2018)

The yield of yam in Moro LGA will increase as predicted in Figure 4.24 in the coming years, as yam yield will be 11.36 tons/ha in 2016 and 11.45 tons/ha in 2017. By 2018, the yield will increase to 11.54 tons/ha and 11.63 tons/ha in 2019. By the year 2020, yam yield will be 11.72 tons/ha and will further increase to 11.81 tons/ha by the year 2021.In 2022, the yield of yam will increase to 11.90 tons/ha and by 2023, it will increase to 11.99 tons/ha. By the year 2024, yam yield will further increase to 12.08 tons/ha and 12.17 tons/ha by the year 2025 (Appendix V). The increasing trend of yam yield is supported by the positive trendline equation Y= 0.09x + 11.27.

4.9 DISCUSSION

Table 4.1 and 4.2 shows the characteristics of monthly and annual rainfall variation in Moro Local Government Area from 1991 to 2015. The relatively low coefficient of variability of the annual rainfall totals, compared with the variability of monthly totals was observed. While the coefficient of variation for annual totals vary from 74% to 145%, those of monthly totals vary from 31% to 247%. There is no significant pattern in the variability of annual total rainfall.

January, February. November and December, are dry months in the study area, therefore, the coefficient of rainfall variability of these months is high. In general, very high coefficient are recorded for the dry season months throughout the country. These dry months recorded a coefficient of variability as high as over 100%, which agrees with the study of Adejuwon and Ogunkoya (2006), that revealed a coefficient of rainfall variability from the coast through the forest zone, to the southern-guinea zone to be above 100% recorded in the months of November, December, January and February. This implied that the percentage periodic change is greatest in months with smallest average rainfall and decreases as amount of rainfall increases.

In the monthly rainfall pattern, it was observed that rainfall is bimodal having two peaks in June and September, with a little dry season in August known as the 'August break'. An increasing trend was observed in the annual rainfall pattern with steady fluctuations, as rainfall reached its maximum in 1997 and minimum in 2004.

The months of November to February experienced few wet years, even though they are dry season months. However, these wet years have little or no impact on crop

yield. Positive anomalies were revealed in the year 1991, 1994, 1997, 2006, 2009, and 2014. This implies that, these years experienced wet conditions in the month of January. Positive anomalies were also revealed, for the other months in the dry season. This implies that, the years 1993, 1994, 1999, from 2003 to 2005, 2010, 2011, 2013, and 2014, experienced wet conditions.

The months of March to October make up the rainy season in the study area. However, these months experienced negative anomalies that revealed dry years within the study period. In March, which marks the onset of rainfall in the study area, fluctuation of both dry and wet years was experienced, with about eleven occurrences of wet years within the study period, while the remaining fourteen years experienced dry conditions. In April, the number of wet years occurrence reduced to about nine out of the twenty-five years of study period. These years are 1997, 2002, 2005, from 2007 to 2009, and from 2012 to 2014, while the remaining years experienced dry conditions.

In May, it was observed that wet years occurred from 1991 to 1998, with the exception of 1993 and 1994, which experienced dry conditions in the first decade of the study period. These dry years continued unabatedly from 1999 to 2004, likewise, from 2008 to 2010, and 2013/2015 respectively. In June, negative anomalies were recorded in 1991, 1994, 1996, 2005 and 2011. These anomalies reveal a near normal rainfall condition in the study area. However, slightly dry to extremely dry years occurred from 1992 to 1995, from 2000 to 2002, and in the years 2009, 2010, 2013, and 2015 in the study area.

In July, it was observed that dry years were experienced in 1993, 1994, and from 1996 to 1998, likewise, from 2000 to 2004 respectively. However, this month also experienced extreme wet years from 2005 to 2010. From the year 2011 to 2015, the study area experienced dry years with the exception of 2012 which experienced an extreme wet year. This year coincides with the year Nigeria experienced flooding. In August, which is characterized by little dry season, known as the August break, dry years were experienced from 1991 to 1994, with the exception of 1993. The year 1997 and 2007 records a negative anomaly of near normal rainfall condition. From the year 2003 to 2006, dry years were experienced, likewise, in 2013 and 2015. However, wet years were experienced in the remaining years under study. The little dry season experienced in August is as a result of absence of the African Easterly Jet(Omotosho,2007).

In September which, marks the secondary peak of rainfall, the year 1991 experienced an extremely dry year, while 1994, 1995, 1998, and 1999 experienced slightly dry years. However, the years 1992, 1993, 1996, and 1997 experienced very wet years. From the year 2001 to 2005, the study area experienced dry years, while from 2006 to 2012, wet years were experienced with the exception of 2008 which reveals a dry year. The year 2013 and 2014 also experienced dry conditions while, 2015 experienced a near normal rainfall condition in the study area. In the month of October, which marks the cessation of rainfall in the study area, fluctuation between dry and wet years were experienced with wet years in the years 1991, 1994, 1995 and 1999. While from the years 2000 to 2004, dry years were experienced with the exception of 2002. However, from the year 2005 to 2011, the study area experienced wet years, whereas, the years 2012 to 2014 experienced dry years.

Annual rainfall anomaly in the study area was also examined. In the first decade, extreme dry years was observed from 1991 to 1994, while from 1995 to 1999 wet years occurred with 1997 having an extreme wet year. This indicates that the study area experienced high amount of rainfall in 1997. This agrees with the study of Akinsanola and Ogunjobi (2014) which revealed abundant amount of rainfall (wet years) in the country, with the exception of Jos and Katsina having dry tendencies in the third decade of their study period. However, there was discontinuity in 1998 as it is a dry year.

From 2000 to 2005, rainfall amounts declined in the study area which implied that, dry years occurred during this period. This disagrees with the study of Ifabiyi and Ojoye (2013), which revealed an upward amount of rainfall, which accounted for the flooding episodes in the sudano-sahelian zone of the country during this period. However, it is in tandem with the study Abaje et al(2010), as it revealed dry years at Kafanchan during the period. Between the year 2006 and 2012, wet years were experienced in the study area. This corroborates the study of Balogun, Sojobiand Oyedepo (2016), which revealed wet years in Ogun state. However, between 2013 to 2015, dry years were experienced. This corroborates the study of Balogun et al (2016), which attributed the abrupt changes (fluctuation) in rainfall to changes in regional circulation pattern.

It is clear from Figure 4.15, that rainfall declined in the study area, as the occurrence of dry years are more than wet years. This decline does not show a distinct trend because there were fluctuations in the study period. However, the decline in annual rainfall anomaly, is as a result of the substantial decline in the monthly

anomalies. This corroborates the study of Abaje et al (2010) which revealed that the substantial decline in annual rainfall yield was predominantly as a result of the decline in July to October rainfall at Kafanchan. The study further reiterate that these months are the critical months for annual agricultural cycle.

Maize yield was significantly low in 1997 and high in 1994. This may be attributed to the dry year which occurred in 1994 and the wet year which occurred in 1997. Maize yield was low in 2001 and high from 2010 to 2014. This may also be attributed to the fluctuation in dry and wet years around the period. The annual average yield of maize, 1.34 tons/ha is below the findings of FARA (2009) which revealed the average yield of maize found in Nigeria is 1.6 tons/ha. However, the percentage of variation in maize yield (14%) is above the percentage increase (7%) in Africa,and within the range (36%) of African's contribution to global maize yield as reported by FARA (2009).

The low yield of sorghum in 1992 and the high yield in 1999 and 2000 can be attributed to the dry and wet years experienced in the years within the first decade of the study period. The high yield of sorghum from 2013 to 2015 can also be attributed to the decline in rainfall amounts, as these years experienced dry conditions. The low yield in sorgum during wet years and its high yield during dry years can be attributed to the fact that sorghum resist drought by having a short life cycle(Winch, 2006). The average yield of sorghum 1.61 tons/ha is above the findings of Idrissa (2005), which revealed the yield of sorghum is less than 1.0 ton/ha in Africa and the study of Sekoli and Morojele (2016), which revealed average yield of sorghum for Lesotho is 1.0

ton/ha. The high average yield of sorghum in Moro Local Government Area, could be attributed to its tolerance of wide variety of climatic conditions.

The low yield of cassava in 1997 and the relatively high yield revealed in 2014 may be attributed to the dry and wet years experienced in this period, its physiology which allows it reach soil moisture deeper in the soil (El-Sharkawy, 2007), and to its vulnerability to excessive water(Blanc, 2011). The average yield of cassava, 13.56 tons/ha is below the findings of COSCA for Nigeria, but above that of Ghana, Tanzania, Cote d'ivoire, The Congo, and Uganda. This agrees with the report of FAO and IFAD (2005), which revealed the increase in cassava yield in Africa is because of the planting of high yielding varieties and the adoption of better agronomic practices.

Figure 4.19, indicates high yield of yam, with a low variation. High yield was recorded in 2014, while low yield was recorded in 2013. The low yield is attributed to the dry conditions experienced in these years. The average yield of yam 12.45 tons/ha is above the findings of CBN (2012) for Nigeria, Cote d'ivoire, and Benin republic, but agrees with the findings that higher yields continued in Nigeria and attributed it to the combined effort of National Root Crops Research Institute and IITA, Ibadan. Nwosu and Okoli (2010), also attributed increase in yield of yam in Nigeria to large area planted, than to increase in productivity, as they found that production trippled over the past 45 years from 1961 to 2006.

Rainfall anomalies showed insignificant positive relationship with maize, cassava and yam. This implies that, as rainfall anomalies increase, the yield of maize, cassava, and yam increased, if all other conditions remain the same. Rainfall

anomalies showed a negative relationship with sorghum yield. This implies that as rainfall anomalies increase, the yield of sorghum decreased, if other conditions remain the same. This is in tandem with Ajadi et al(2011), and Bewket (2009) which revealed that, as rainfall increased, sorghum yield reduced.

However, even though there exists an insignificant relationship between rainfall anomalies and crop yield, the relationship is very weak as the correlation between crop yield and rainfall anomalies shows less than 0.5. This agrees with Ndamani and Tsunemi (2015), Akpenpuun and Busari (2013)Awotoye and Mathew (2010) and Ayanlade et al(2010), as the studies revealed weak relationship between rainfall variation and crop yield.

The hypothesis postulated that there is no significant relationship between rainfall anomalies and crops yieldat 95% significant level, showed no significant relationship. Therefore, the null hypothesis is accepted and agrees with Ndamaniand Tsunemi (2015), that revealed, the effect of rainfall on crop is not statistically significant.

The coefficient of determination (R^2) between rainfall anomalies and crop yield revealed that rainfall anomalies accounts for only 0.1 % of variation on the yield of maize, 3.8% on the yield of sorghum, 4.9% on the yield of cassava, and 0.4% on the yield of yam in Moro Local Government Area. This implies that the effect of rainfall anomalies on crop yield variation over the years under review is low and therefore suggests that variation in crop yield could be attributed to other climatic and non-climatic factors. This agrees with Ndamani and Tsunemi (2015) and Ajadi et

al(2011), which revealed the importance of other factors such as soil fertility, farm techniques, labour, fertilizer, and insecticides, influencing annual crop production.

It is observed that rainfall anomalies will be negative up to 2019, indicating dry years. These dry years will decrease in magnitude as the years go by, as 2019 will be a slightly dry year and subsequently, a near normal rainfall to an extremely wet condition will be experienced from 2020 to 2025 in Moro LGA. This agrees with Adejuwon and Ogunkoya (2006), who revealed, there will be a trend towards wetter conditions during the 21st century in the Northern guinea savanna zone. In the same way, the yield of maize, sorghum, cassava, and yam will be on the increase in the coming years, as maize yield will be 1.28 tons/ha in 2025. The yield of sorghum will be 1.44 tons/ha in 2025. Cassava yield was 9.21 tons/ha in 2016 and will increase to 12.48 tons/ha in 2025. Yam yield was 11.36 tons/ha in 2016 and will increase to 12.17 tons/ha in 2025. It is noteworthy that the projection result represent only the maintenance of the same pattern observed today.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 INTRODUCTION

This chapter presents the summary, conclusion, and recommendations based on the findings of this research.

5.2 SUMMARY OF FINDINGS

This study analyzed the effect of anomalous rainfall on the yield of some selected crop which are dominantly cultivated in Moro Local Government Area of Kwara state, Nigeria. This was carried out using rainfall data in (mm) and yield data in (tons/ha) on maize, sorghum, cassava, and yam for a period of twenty-five (25) years, collected from the Kwara state Agricultural Development Project (KWADP) office, Ilorin.

Anomalous rainfall was derived using rainfall anomaly index (RAI) developed by Van Rooy (1965). This was used to determine the monthly and yearly

anomalous rainfall records within the study period with result presented in histogram. Time series analysis was used to determine the trend of crop yield in order to show the direction of change. Pearson product moment correlation was used to determine the relationship between rainfall anomalies and the selected crop yield, after the data has been harmonized in to a common base (see Appendix IV). This was carried out using $\log_{10}$method by means of MINITAB software. Simple linear regression analysis was utilized to determine the strength of the effect of rainfall anomalies on the yield of the selected crops, and to project the trend of anomalous rainfall and crop yield in ten (10) years' time from 2016 to 2025.

The result showed thatfew wet years were experienced in the months of January, February, November, and December, even though they are dry season months which has little or no impact on crop yield. In the months of March to October, fluctuations between dry and wet years were observed, with more occurrence of dry years. It was observed in the annual rainfall anomalies, that 1997 experienced an extreme wet condition, while 1994 experienced an extreme dry year in the first decade of the study period. In the second decade, 2000 to 2005 experienced decline in rainfall amounts as dry years were observed during this period, while from 2006 to 2012, wet years occurred in this period. From 2013 to 2015, dry years also occurred in the study area. However, it is observed that decline in annual rainfall anomalies is as a result of the decline in monthly rainfall anomalies.

The result also showed an increased trend in the annual yield of all the selected crops. However, these increase fluctuates between low and high yield, which is attributed to the dry and wet years experienced in the study area. Result shows that

rainfall anomalies has a positive relationship with the yield of maize, cassava, and yam, but, shows a negative relationship with sorghum yield. This implies that as rainfall anomalies increase, the yield of maize, cassava, and yam increase, while it decreases with sorghum yield. Though relationship exist between rainfall anomalies and crop yield, it is very low and not significant, as the null hypothesis postulated that no significant relationship between rainfall anomalies and crop yield at 0.05 significance level is accepted.

The coefficient of determination between rainfall anomalies and crops yield showed that rainfall anomalies accounted for only 0.1% of variation on the yield of maize, 3.8% on the yield of sorghum, 4.9% on the yield of cassava, and 0.4% on the yield of yam. This implies that the effect of rainfall anomalies on crops yield variation in the study area is low and suggests, it could be attributed to other climatic (variations in onset and cessation of rainfall, length of rainy season, rainfall intensity, soil temperature) and non-climatic factors such as,timely fertilizer and insecticides application, soil fertility, pest and disease outbreak, low access to loans, changes in government policies on farming input provisions etc.

Based on the predictions, it is observed that rainfall anomalies will be negative from 2016 to 2019, indicating dry years which will decrease in magnitude and will be positive from 2020 to 2025, indicating wet years which will increase in magnitude in the coming years. However, the crops yield (maize,sorghum, cassava, and yam) will be on the increase in the coming years, assuming the pattern observed is maintained.

5.3 CONCLUSION

Based on the findings of this research, it is concluded that rainfall anomalies increased in magnitude especially the negative anomaly, indicating more dry years which is evident from the inconsistent decline in the monthly positive anomalies. However, there will be discontinuity in the dry years, as it is evident from the projections that Moro Local Government Area will have a trend towards wetter conditions. The trend of crop yield increased, which is attributed to increase in rainfall amount. The relationship between rainfall anomalies and the yield of crops is weak and not significant. This suggests other climatic and non-climatic factors such as onset and cessation of rainfall, length of rainy season, rainfall intensity, soil temperature, soil fertility, poor fertilizer application, shortage of insecticides, pest infestation and diseases, have influence on crop yield in Moro Local Government Area.

5.4 RECOMMENDATIONS

Based on the findings of this research, the following recommendations were made;

1. Since it is evident that there is high occurrence of dry years in the study area, farmers should introduce crops varieties that can tolerate short rainy period in order to boost production in the area.
2. The dry years specifically require farmers to implement measures such as adopting mixed cropping system, mixed farming and planting drought resistant crops.

3. Farmers should also adopt cropping system that allows planting crops which require more moisture, since the study area will experience wetter conditions.
4. Since it is evident that the relationship between rainfall anomalies and crops yield is weak and not significant, farmers should concentrate on other factors such as onset dates for appropriate farming period, proper application of fertilizer, prompt weeding, etc. for maximum yield.
5. Finally, more research of this nature should be carried out in the same area using other climatic parameters such as precipitation effectiveness indices and taking other production factors into consideration.

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APPENDIX I

Derived Monthly Rainfall Anomalies from 1991 to 2015

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1991	6.68	-3	-3	-6.04	3.63	-0.26	2.06	-5.86	-9.33	1.55	-3.02	-3
1992	-3	-3	-1.12	-1.41	0.65	-3.39	0.50	-1.38	4.85	-5.54	-1.49	-3
1993	-3	3.19	0.47	-3.90	-0.39	-2.72	-1.03	0.74	3.26	-1.49	0.99	-3
1994	1.12	1.83	-1.08	-0.77	-2.58	-0.02	-0.38	-1.27	-0.75	6.30	-2.79	-3
1995	-3	-3	1.11	-0.95	0.14	-0.97	1.17	2.04	-0.44	2.14	3.27	1.72
1996	-3	-3	1.50	-1.42	1.66	-0.02	-3.19	2.45	1.66	-0.75	1.22	-3
1997	8.78	-3	7.08	5.66	3.33	3.76	-0.32	-0.33	3.67	-0.02	4.77	-3
1998	-3	-3	-1.70	-1.55	2.52	1.32	-3.64	1.11	-0.95	-0.64	-3.02	-3
1999	-3	4.26	4.53	-0.58	-0.91	0.13	0.38	1.15	-0.67	2.53	1.71	-3
2000	-3	-3	-2.03	-3.22	-1.31	-1.43	-6.06	2.16	1.89	-4.42	-3.02	-3
2001	-3	-3	6.09	-1.33	-1.74	-4.93	-2.38	-0.05	-0.99	-5.11	-2.41	-3

2002	-3	-3	-0.58	1.82	-4.23	-3.18	-0.67	2.10	-2.66	1.16	-0.94	-3
2003	-3	1.07	-1.30	-0.86	-2.85	5.82	-4.72	-3.13	-3.46	-1.08	-2.01	-3
2004	-2.46	0.96	-2.99	-3.26	-3.74	1.25	-0.37	-3.59	-2.73	-3.97	3.97	-3
2005	-3	3.22	-3.62	2.35	0.28	-0.07	2.76	-4.78	-1.40	1.51	0.82	13.5
2006	1.47	-0.01	4.01	-1.48	1.76	1.13	0.67	-2.05	0.25	3.69	-3.02	-3
2007	-3	-3	-3.02	0.62	6.82	2.59	0.47	-0.25	6.79	0.99	-3.02	-3
2008	-3	-3	0.67	4.18	-0.69	0.79	4.30	5.25	-1.87	0.27	-3.02	-3
2009	18.51	-3	-2.23	4.38	-1.28	-1.40	1.50	6.09	4.25	1.44	4.48	-3
2010	-3	4.23	1.59	-2.23	-4.22	-7.19	0.30	2.95	0.51	4.23	4.01	15.4
2011	-3	5.70	-4.88	-0.67	0.51	-0.39	-1.21	1.73	1.35	4.08	-0.48	-3
2012	-3	-2.44	-2.44	3.16	4.83	2.31	6.05	3.12	1.78	-2.43	-3.02	-3
2013	-3	4.26	-1.89	3.49	-3.85	-1.24	-0.92	-3.89	-3.16	-3.83	-3.02	8.2
2014	1.08	1.28	0.41	4.86	4.28	0.37	-3.76	1.39	-4.07	-2.15	2.81	-3
2015	-3	-0.46	2.95	-5.53	-4.14	-4.55	-3.09	-2.71	0.02	0.13	-3.02	-3

Source: Author's Computation (2018)

APPENDIX II

Derived Annual Rainfall Anomaly from 1991 to 2015

Year	Mean	Anomaly
1991	72.5	-3.80
1992	89.9	-1.03
1993	71.1	-4.03
1994	94.5	-0.29
1995	103.9	1.15
1996	100.1	0.57
1997	141.2	6.81
1998	91.0	-0.85
1999	104.9	1.29
2000	78.9	-2.78
2001	75.6	-3.31
2002	85.7	-1.69

2003	82.6	-2.19
2004	70.87	-4.08
2005	95.37	-0.16
2006	103.3	1.06
2007	123.1	4.06
2008	115.1	2.85
2009	130.2	5.14
2010	97.1	0.11
2011	104.4	1.22
2012	134.8	5.84
2013	75.0	-3.41
2014	94.28	-0.33
2015	73.3	-3.68
Mean	96.35	

Source: Author's Computation (2018)

APPENDIX III

AGRICULTURAL PRODUCTION SURVEY RESULTS IN CROP YIELD (TONS/HA)

Year	Maize	Sorghum	Cassava	Yam
1991	1.22	1.21	10.10	11.82
1992	1.10	1.10	10.73	11.16
1993	1.09	1.21	9.43	11.18
1994	1.55	1.38	10.27	12.96
1995	1.19	1.19	11.17	13.40
1996	1.19	1.19	11.16	13.40
1997	0.88	1.29	8.78	11.76

1998	1.14	1.30	12.90	10.98
1999	1.25	1.62	13.40	11.00
2000	1.28	1.62	12.45	11.86
2001	1.16	1.63	10.79	12.96
2002	1.30	1.70	12.94	12.33
2003	1.47	1.27	12.56	10.86
2004	1.25	1.42	12.21	11.70
2005	1.35	1.27	12.46	11.63
2006	1.58	1.32	15.28	11.85
2007	1.37	1.53	16.99	11.66
2008	1.43	1.40	17.14	12.46
2009	1.50	1.54	15.97	12.46
2010	1.47	1.58	16.48	12.53
2011	1.49	1.52	16.80	13.83
2012	1.58	1.52	16.98	13.83
2013	1.59	3.87	17.48	14.45
2014	1.63	3.19	17.76	15.26
2015	1.55	2.34	16.89	13.84
Mean	**1.34**	**1.61**	**13.56**	**12.45**
SD	**0.196**	**0.636**	**2.916**	**1.181**
CV	**14.6**	**39.5**	**21.5**	**9.49**

Source: Kwara State Agricultural Development Project Office (2017)

APPENDIX IV

Harmonized Data of Rainfall and Crop Yield

Year	Rainfall Anomaly	Maize yield	Sorghum yield	Cassava yield	Yam yield
1991	-3.80	0.8636	0.082785	1.00432	1.07262
1992	-1.03	0.041393	0.041393	1.0306	1.04766
1993	-4.03	0.037427	0.082785	0.97451	1.04844
1994	-0.29	0.190332	0.139879	1.01157	1.1126
1995	1.15	0.075547	0.075547	1.04805	1.1271
1996	0.57	0.075547	0.075547	1.04766	1.1271
1997	6.81	-0.05552	0.11059	0.94349	1.07041
1998	-0.85	0.056905	0.113943	1.11059	1.0406

1999	1.29	0.09691	0.209515	1.1271	1.04139
2000	-2.78	0.10721	0.209515	1.09517	1.07408
2001	-3.31	0.064458	0.212188	1.03302	1.1126
2002	-1.69	0.113943	0.230449	1.11193	1.09096
2003	-2.19	0.167317	0.103804	1.09899	1.03583
2004	-4.08	0.09691	0.152288	1.08672	1.06819
2005	-0.16	0.130334	0.103804	1.09552	1.06558
2006	1.06	0.198657	0.120574	1.18412	1.07372
2007	4.06	0.136721	0.184691	1.23019	1.0667
2008	2.86	0.155336	0.146128	1.23401	1.09552
2009	5.14	0.176091	0.187521	1.2033	1.09552
2010	0.11	0.167317	0.198657	1.21696	1.09795
2011	1.22	0.173186	0.181844	1.22531	1.14082
2012	5.84	0.198657	0.181844	1.22994	1.14082
2013	-3.41	0.201397	0.587711	1.24254	1.15987
2014	-0.33	0.212188	0.503791	1.24944	1.18355
2015	-3.68	0.190332	0.369216	1.22763	1.14114

Source: Author's computation (2018)

APPENDIX V

Model for Rainfall Anomaly and Yield of Crops

	Unstandardized Coefficients		Standardized coefficients		
Model	B	Std. Error	Beta	t	Sig.

Maize	**Constant**	0.124	0.014		9.102	0.0001
	Anomaly	0.00002	0.004	0.001	0.001	0.9999
Sorghum	**Constant**	0.184	0.026		7.101	0.0001
	Anomaly	-0.008	0.008	-0.194	-0.951	0.3520
Cassava	**Constant**	1.123	0.019		59.072	0.0001
	Anomaly	0.007	0.006	0.221	1.087	0.2880
Yam	**Constant**	1.093	0.008		132.79	0.0001
	Anomaly	0.001	0.003	0.065	0.314	0.7570

Dependent Variable: Maize, Sorghum, Cassava and Yam
Source: Author's Computation (2018)

Predicted rainfall Anomaly and crop yield

Year	**Anomaly**	**Maize**	**Sorghum**	**Cassava**	**Yam**
2016	-7.955	1.102	0.967	9.210	11.36
2017	-4.435	1.122	1.020	9.573	11.45
2018	-2.307	1.142	1.074	9.936	11.54
2019	-0.762	1.162	1.127	10.30	11.63
2020	0.459	1.182	1.181	10.66	11.72
2021	1.469	1.203	1.234	11.02	11.81
2022	2.328	1.223	1.288	11.39	11.90
2023	3.082	1.243	1.341	11.75	11.99
2024	3.759	1.263	1.395	12.11	12.08
2025	4.360	1.283	1.448	12.48	12.17

Source: Author's Computation (2018)