RAINFALL DISTRIBUTION AND ITS IMPLICATION ON CROP PRODUCTION IN KANO STATE, NIGERIA

By

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BEING A DISSERTATION PRESENTED TO SCHOOL OF POSTGRADUATE STUDIES, BAYERO UNIVERSITY KANO IN PARTIAL FULFILLMENT FOR THE REQUIREMENTS OF MASTERS DEGREE IN GEOGRAPHY, DEPARTMENT OF GEOGRAPHY, FACULTY OF EARTH AND ENVIRONMENT, BAYERO UNIVERSITY, KANO NIGERIA.

JULY, 2016

DECLARATION

I hereby declare that this work is the product of my own research effort, undertaken under the supervision of Dr L.F. Buba and has not been presented and will not be presented elsewhere for the award of any academic certificate. All sources have been duly acknowledged.

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Zainab Waziri Dawha Date

DEDICATION

I dedicate this work to my beloved son Salim ADLER WANGIDA and my husband Ibrahim Isah WANGIDA Esq.

CERTIFICATION

This is to certify that the research work for this Dissertation and subsequent preparation of this Dissertation title ”Rainfall Distribution and its Implication on Crop Production in Kano State, Nigeria**”** by ZainabWaziri Dawha SPS/12/MGE/00035 has been read and approved for the award of Master’s Degree in Geography, Bayero University, Kano.

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DR L. F. BUBA **DATE**

APPROVAL PAGE

This research work has been examined and approved for the award of M.Sc. in Geography.

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SUPERVISOR DATE

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INTERNAL EXAMINER DATE

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ABSTRACT

Climatic data on rainfall for two decades (1994 – 2013) sourced from IAR while crop yield data were sourced from KNARDA were used. The aim of this study is to assess the impact of rainfall distribution on crop yield while the objectives are to: identify the trend and characteristics of rainfall distribution over the years, examine the relationship between rainfall and crop yield and to examine the trend and variation of crop yield over the years under review. Analytical techniques used include mean, standard deviation, coefficient of variation; correlation and simple linear regression were used. Results indicates that rainfall commences from April and terminates in October with coefficient of variability of 112.5% in April and lowest coefficient of variation of 29.3% in June and highest amount of rainfall occur in August. For the period under consideration, 2003 recorded the highest rainfall amount of 1429.5mm, while 2009 recorded the least amount of 726mm. The trend of crop yield over the years for all the crops indicates a rising trend. Rainfall accounts for only 0.03% of millet yield, 1.07% of maize, 10.41% of sorghum, 10.09% of rice, 1.25% of cowpea and 7.17% of ground nut. Recommendations include the regression of crop yield on environmental factors like soil fertility, use of genetically modified seeds, application of fertilizers to improve soil fertility and monitoring of climatic variables for occurrence of extreme weather events.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the study

Generally, there are many factors influencing crop production and these include soil, climate and diseases among others. In relation to climate, rainfall is the dominant controlling variable in tropical agriculture since it supplies soil moisture for crops and grasses for animals.

Hence, precipitation, solar radiation, wind, temperature, relative humidity and other climatic parameters affect and solely determine the global distribution of crops and livestock as well as their productivity. Climate plays a dominant role in agriculture having a direct impact on the productivity of physical production factors, for example the soil's moisture and fertility. Adverse climate effects can influence farming outputs at any stage from cultivation through the final harvest. Even if there is sufficient rain, its irregularity can affect yields adversely if rains fail to arrive during the crucial growing stage of the crops (Rudolf and Hermann, 2009), as cited in Mesika and Esekhade (2014).

Rainfall, among other factors, has always dictated how land is used in one way or another and it also affects the humidity condition of the atmosphere. Rainfall determines the vegetation cover of a particular geological zone and crop distribution.

Furthermore, rainfall determines the amount of moisture present in the soil which is ultimately made available to plants. Water plays a vital role in the growth of plant and it provides the medium through which nutrients are carried through the plant. According to Olaoye (1999), regular occurrence of drought as a result of erratic rainfall distribution and/or cessation of rain during the growing season reduce Nigeria's capability for increased crop production, as cited in in Mesika and Esekhade (2014). The work of Adakayi (2004) on the effect of climate change on food production in Northern Nigeria shows a strong positive relationship. The results showed that rainfall has significant relationship to crops production in northern Nigeria in which Kano state is no exception.

Agriculture which is the mainstay of local livelihoods and national Gross Domestic Product (GDP) in some African countries according to Mendelsohn, Dinar and Dalfelt, (2008)“Climate Change Impacts on African Agriculture, is the most vulnerable to climate variability and ch8lange. This is because in spite of recent technological advances, weather and climate are still the most important variables in agricultural production in Ayoade, “Introduction to Climatology for the Tropics,” (2004). As such, its production processes whether for food, fibre, beverages, energy, and industrial production or for live- stock, poultry or fisheries, will be heavily affected by climate variability and change. Increasing weather variability affects the suitability of land for different types of crops and pasture. The health of animals and their productivity as well as incidence of pests and diseases, loss scale farming households in the tropical and subtropical areas will be exposed to increased climate risks and will become more and more vulnerable to these risks in Igwebuike, Odoh, Ezeugwu, and Oparaku, (2010)“Climate Chang, Agriculture and Food Security,” . As a result, the production of the principal crops like rice, wheat, maize, and sorghum in the past few decades have continued to decline while the population increases in Adejuwon, “The Context of Food Security,” In: Adejuwon and Ogunkoya, Eds., Climate Change and Food Security in Nigeria,(2010) . This scenario increases the risk of hunger and food insecurity thereby placing a heavy reliance on food aid at the national and household levels.

Meeting this challenge requires drastic increase in the productivity of the principal staples especially maize which is a very important staple food crop in the Sub- Saharan African region, and Nigeria in particular. However, the yield of maize has continued to be very low particularly in Benue state which has a lot of potentials for crop production.

The low yield of crops particularly maize in Benue State can be attributed to several factors such as pressure on land due to population growth and attendant declining size of farm holdings, migrations, ethnic conflicts, inability of the peasant farmers to access fertilizers, conservative attitudes towards extension services, and market forces that are disincentives in Adejuwon J., “The Context of Food Security,” In: Adejuwon J. O. and O. O. Ogunkoya, Eds., Climate Change and Food Security in Nigeria, (2010). Others include field operations, timing of planting, pests and diseases, soil, and superimposed on these is climate in Babatunde, (2010) “An Analysis of the Effects of Agro-climatic Factors on Food Crop Yields in Ibadan Area of Oyo State. Of the climatic elements, rainfall, temperature and potential evaporation are the most critical in crop production in Ayoade, “Introduction to Climatology for the Tropics, (2004).

However, rainfall has more significant effect on inter-annual changes in crop yield in a tropical environment as it determines the supplies of water to plants in Adejuwon, “The Context of Food Security,” In: Adejuwon andOgunkoya, Eds., Climate Change and Food Security in Nigeria, (2010). Moreover, rainfall is the major limiting climatic factor in the growth and production of crops as it is particularly very sensitive to water deficit. Moreover, rainfall is the most variable of all climatic elements and determines the growing season in developing countries like Nigeria where agriculture is predominantly rain-fed. Almost every farmer is interested in what the expected rainfall would be, more than any other climatic element as it determines the success or failure of crops.

Rainfall has been seen as the most important factor in crop production in Nigeria. Some of the important factors guiding rainfall in relation to crops include number of rainy days, time of fall, total amount of fall and the type of soil. Rainfall usually determines the type of crop to be grown in different environment as well as the type of agricultural system to be practiced in different parts of the country.

Traditional small holders, who use simple techniques of production and the bush-fallow system of cultivation, account for around two thirds of Nigeria's total agricultural production. Nigeria's wide range of climate variation allows it to produce a wide variety of food and cash crops. However, food production could not keep pace with population increase. Food shortage is therefore linked with climate change (Adefolalu, 2004).

In relation to climate, rainfall is the dominant controlling variable in tropical agriculture. Since it supplies soil moisture for crops and grasses for animals. According to Ayoade (2004), agriculture largely depends on climate to function. Hence, precipitation, solar radiation, wind, temperature, relative humidity and other climatic parameters affect and solely determine the global distribution of crops and livestock as well as their productivity.

Estimation by FAO (2005) is that by 2100, Nigeria and other West African countries are likely to have agricultural losses of up to 4% due to climate change. Climate to some extent determines the choice of what plant to cultivate, how to cultivate it, the yields of crops and nature of livestock to keep. It can also be seen as one of the environmental factors that affects agricultural production. Supporting this, Ayoade (2002) confirms that many of the problems facing agricultural products are climate related.

Crop production is an integral part of agriculture, dealing with the cultivation, protection, harvesting and storage of cultivated plants for man’s use. It is the sum total of all activities involved in producing, preparing and processing of agricultural crops (Akanbi et al, 2004).

Grains and legumes are important food items to the livelihood of millions of people providing nourishment and generating income. However, Nigeria produces a wide variety of crops most of which are consumed as food, the major food crops include rice, maize, cassava, yam, sorghum, millet and cowpea and the minor ones are cocoyam, melon, sweet potato and plantain. Other arable crops which double as industrial and food crops to some extent also include groundnut, cotton and beni-seed (Akinyosoye, 2005). With climate change, food and water supply become unreliable and unsecure and the available arable land reduced causing population movements by making certain parts of the world much less viable place to live (Brown, 2008). Agriculture is by far the most significant user of water resource (UN Research, 2009). Agriculture has faced obvious challenges and the foremost problem of the sector in Nigeria is that it is still largely informal, subsistent, rain-fed and lacking mechanization.

The degree of reliance on rainfall by Nigerian farmers is absolute and it is posting more problems in area of food production, food security and sustainable agriculture. The agricultural practices depend on natural weather patterns, so also variations in rainfall levels result in large variations in total output and farm incomes and again changes in rainfall will also increase variability in groundwater recharge and river flow, hence affecting all water sources.

Rainfall is a major determinant of agricultural production in any agro-ecological zone anywhere in the world. Its seasonal and annual characteristics such as the onset and intra-seasonal rainfall distribution that promote good crop yields are, however, characterized by marked fluctuations. These fluctuations are not easy to forecast, yet a fore-knowledge will help the farmer to plan his farming activities strategically.

The regularity of drought periods has been among the most notable aspects of Nigerian climate in recent years, particularly in the drier regions in the north (Matthew, 2009). These Drought periods are indications of the great variability of climate across tropical Africa and the most serious effects of which are usually felt at the drier margins of agricultural zones or in the regions occupied primarily by pastoral groups. The high degree of spatial variability of Nigerian rainfall is associated with the intense randomness of the convective process, which is the dominant rain-producing mechanism in the country with the attendant effects on local features such as topography, vegetation and land-cover type among others (Omotosho et al., 2007).

The variability of the climate has been a topical issue in a sustainable environment as the crop yield and production is very important to the economy and livelihood of the people of Nigeria and the world at large. The sub-humid climatic zone of Africa permits the cultivation of a variety of crops in a pattern that emerged in earlier centuries in response to local conditions. It follows therefore that any change in climate may impact the agricultural sector in particular and other socio-economic activities in general. Climate change could have both positive and negative impacts and these could be measured in terms of effects on crop growth, availability of soil water, soil fertility and erosion, incidents of pests and diseases, and sea level rise (Semenov, 2009; Butterworth et al., 2009).

Spatial variability is evident in the irregular distribution of rainfall at both short-time scale and average conditions while the temporal variability tends to be greater in the Northern and Southern parts of the country (Omotosho et al., 2007).

Rainfall distribution throughout the cropping season is another important characteristic of rainfall that affects crop yields. A season with high total rainfall amount but poorly distributed cannot promote high crop yields. On the other hand, fairly good yields can be obtained with well distributed seasonal rainfall that may not be high in terms of total amount. In perhaps all rainfall prediction efforts, however, only forecasts of the seasonal total rainfall amounts are given with some probabilities. Forecasts on seasonal rainfall distribution are rare. Given this situation, farmers' desire for knowledge in this regard remains unsatisfied. A clearer insight into rainfall distribution and levels of variability associated with either the seasonal amounts or seasonal distribution may be obtained only through analysis of historical rainfall data.

Undoubtedly, rainfall distribution trends over a given season can be useful in the interpretation of observed crop performance. The challenge to successful rainfed crop production is the timely and precise prediction of the rainfall characteristics of a coming cropping season. These challenges need to be sufficiently addressed through scientific research in order to reduce high fluctuations of crop production in rainfed ecologies on both seasonal and annual time scales.

1.2 Statement of Research Problem

The main characteristics of Sudano - Sahelian Ecological Zones include poor rainfall (distribution and quantity), high temperatures, humidity, drought, high wind velocity and harmattan, etc. The onset, distribution and even total amount of rainfall in the zones have been erratic, resulting in crops failure (NAERLS, 1982) as cited in Ofor 2009 and that has been sustained. Farmers are faced with the challenge of readjusting to the changing pattern of rainfall to improve crop yields. Amidst these unpredictable and recurring challenges evolve the need to critically investigate rainfall and the crop production relation.

The dependence of farmers on rain-fed agriculture makes crop production vulnerable to rainfall variability. Agricultural production is largely undertaken by smallholder subsistence farmers who rely solely on high unpredictable and sporadic seasonal rainfall (Ndamani, 2015). The majority of the people in the area rely on crop production for their livelihood. Therefore extreme variation to agro-climatic condition as rainfall in the area could directly affect the survival of the people.

In view of the critical importance of rainfall, a comprehensive knowledge of its trends, inter-annual and amount is necessary for crop production planning and management. Although the relationship between climate variables and crop production has been investigated in various literatures, statistical analysis of crop production and rainfall at state level and rainfall with all the major crops produced in the area have not been thoroughly investigated. Therefore, a study of this nature is necessary to fill the gap existing in the knowledge of agro-climatology of millet, maize, sorghum, rice, cowpea and groundnut production in Kano state.

The impact of rainfall on crop production can be related to its total seasonal amount or its intra-seasonal distribution. In the extreme case of droughts, with very low total seasonal amounts, crop production suffered most. But more subtle intra-seasonal variations in rainfall distribution during crop growing periods, without a change in total seasonal amount, can also cause substantial reductions in yields. Generally, the effect of rainfall variability on crop production varies with types of crops cultivated, types and properties of soils and climatic conditions of a given area.

These challenges need to be sufficiently addressed through scientific research in order to reduce high fluctuations of crop yields in rainfed ecologies on both seasonal and annual time scales.

Agriculture is an important sector but the sharp decline in production followed by sharp increase depicts fluctuation in production. A number of factors could be attributed to the changes experienced. Nwafor (2007) noted that the impact of climate change on agricultural production in Nigeria has received limited attention despite the fact that over 60% of the active populations of Nigerians are farmers. Studies on climate change globally and in Nigeria have reviewed that the potential impacts of climate change will include every aspect of the four dimensions of food security; food availability (production and trade), food accessibility, food stable supplies, and food utilization (Nwafor, 2007).

Several studies Abdullahi (2015) focused his studies on precipitation effectiveness indices and rice yield Kano, Yamusa, Abubakar and Falaki (2015), focused their studies on rainfall variability and crop production in northwest semi-arid zone of Nigeria, using markov process to determine wet and dry days. Furthermore, Bello (2012), his studies on based on precipitation indices and millet yield in ton per hectare in two local government area of Kano. It is against this background that this study focuses on examining the impact of rainfall distribution on the major crops produced in Kano State with the view to suggesting appropriate adaptive management mechanisms to cope with the rainfall distribution.

Research problem came as a result of many farmers complaining about the impacts of rainfall on crop production, which is either the rainfall amount is too much or too low that its damage their crops which may lead to decline in crops production. Not minding the other factors of climatic and non- climatic variables.

1.3 Research Questions

i. What is the trend and characteristics of rainfall over the years?

ii. What are the relationships between rainfall distributions and crop production?

iii. What is the trends and variation of cereals and legume crop production over the years?

1.4 Aim and Objectives

The aim of this study is to ascertain the impact of rainfall distribution on crop production in Kano State. The specific objectives are to;

i. Identify the trend and characteristics of rainfall distribution over the years.

ii. Examine the relationship between rainfall and sorghum, millet, maize, rice, cowpea and ground nut production in Kano state.

iii. Examine the trends and variation of sorghum, millet, maize, rice, cowpea and ground nut production over the years under review.

1.5 Research Hypothesis

Ho: There is no significant relationship between crop production and the rainfall distribution.

H1: There is a significant relationship between crop production and the rainfall distribution.

1.6 Significance of the Study

Previous studies on crops production in the study area tend to focus more on variety selection, application of fertilizers, pest and diseases control and storage methods. Based on literature review, research in the study area covers some part of the state and one or two crops are used. However, this is a unique study on whole areas that produce millet, maize, sorghum, cowpea, rice and groundnut in the state.

This research will investigate and provide the knowledge regarding the rainfall distribution in relation to crop yields as a strategy for farmers in achieving food security. This research would serve as a source of enlightenment to farmers (agricultural purpose), policy makers and fellow researchers. How best agricultural production can be managed based on rainfall distribution in relation to crop production so as to reduce the decline in the amount of yield production in metric tons is also of utmost. Therefore, a study of this nature is necessary to fill the gap existing in the knowledge of agro-climatology of millet, maize, sorghum, rice, cowpea and groundnut production in Kano state. It is conceivable therefore, that given enough information on climatic parameters; it is possible to deduce a simple relationship between crop production and climatic parameters. Such information will be useful in selecting suitable crop variety for the various sites and determination of farm calendar. In addition, impact assessments need to quantify the uncertainty associated with the response of each crop type to a changing climate.

1.7 Limitation of the Study

This investigation would be conducted to determine the significance of the impact of climatic parameter (rainfall distribution) on crops yield for this period (1994 – 2013).Neglecting other parameters such as, soil characteristics, pests and disease. It is however, limited to the most staple crops produced in Kano State. These crops mainly include; Maize, Millet, Rice, Sorghum, Ground Nut, and Cowpea.

1.8 Location of the Study Area

Kano state lies approximately between latitudes 10^0 33'N and 12^0 23'N and longitudes 7^0 45'E and 9^0 29'E, with a population of 9,401,288 during the 2006 census (Federal Republic of Nigeria, 2010). It has an estimated land size of 21,276.872 km2 with 1,754,200 hectares of agricultural land and 75,000 hectares forest vegetation and grazing land (African Institute for Applied Economics, 2007).

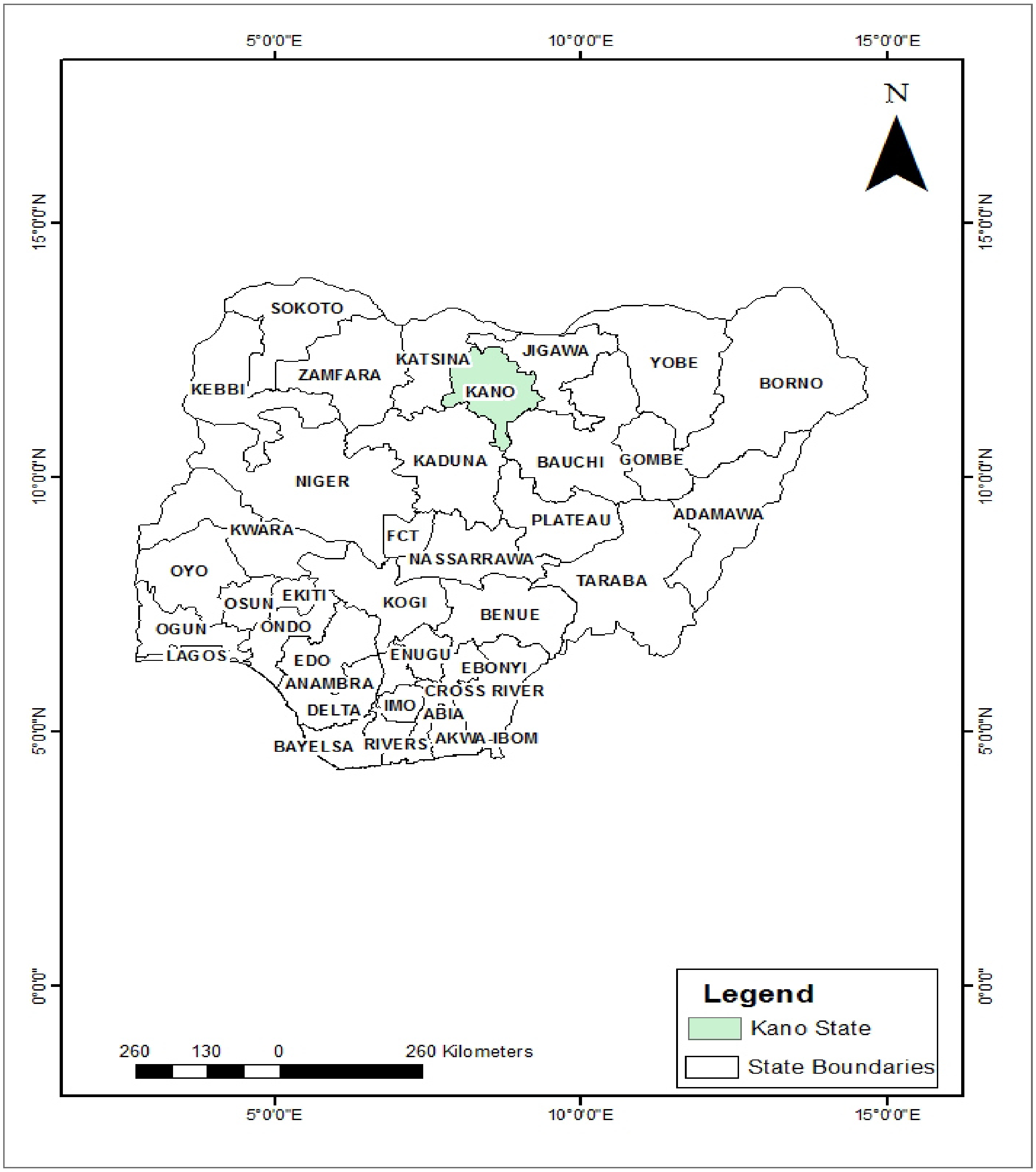

Figure 1: Nigeria showing Kano state

Source: Zonal Advanced Space Technology Applications Laboratory, BUK (2015)

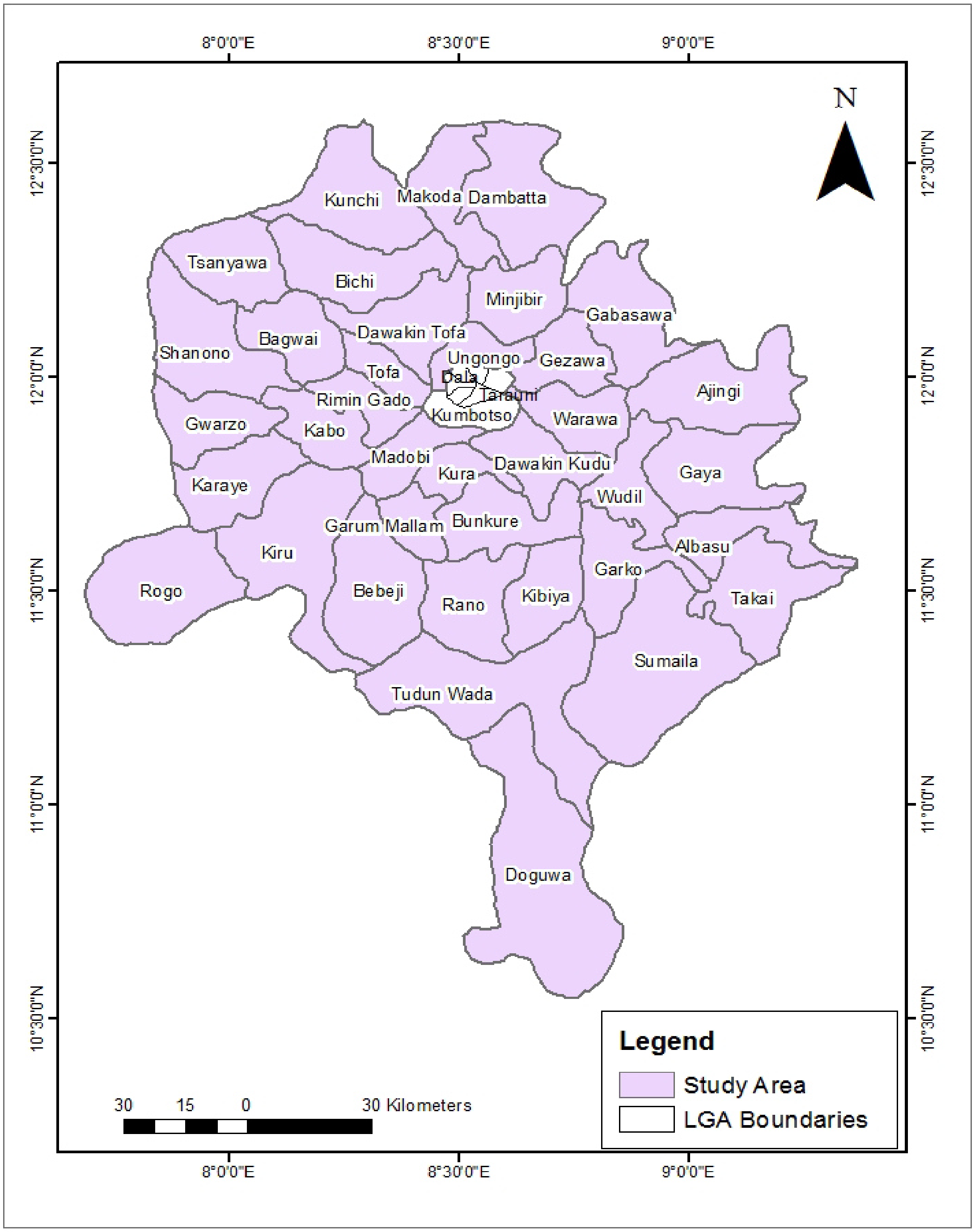

Fig. 2: Kano state showing the Study Area

Source: Zonal Advanced Space Technology Applications Laboratory, BUK (2015)

1.8.1 Geology

Geologically, more than four fifth of Kano State is underlain by quartzite, undifferentiated meta-sediments and basement complex rocks of the pre-Cambrian upper Cambrian origin. Prolonged weathering of the rocks produced deep clay rich regoliths, which have been subjected to laterization. The lateritic outcrops dot the inter-flute areas of the upland plain serving as caps for regolith hills e.g. Goron-Dutse and Dala hills. Well jointed younger granites of Jurassic origin occur in ring complexes in the extreme south. A narrow strip of the Chad Formation occurs to the east (Olofin 2008). In height, the relief ranges from lower plains (500 m) to highlands of more than 1,000m above sea level. The landforms include: the Rishi hills: plains with grouped hills: sandy plains; and alluvial channel complexes.

The area is characterized by rocks of the Basement Complex of pre-Cambrian age to the west and south, and the Chad formation to the northeast. The relief can be described under three types which are found in three zones. These are: the south and southeastern highlands, the middle and western high plains and the northeastern low Chad plains. The first two types are part of the High plains of Hausa land and the third is part of the Chad plains (Olofin, 2008).

1.8.2 Soils:

In their natural state, the soils divide into four main groups. The ferruginous tropical soils formed on crystalline acid rocks occupy about two fifth of the State to the south, southwest and south east; the brown and reddish brown soils and latosols occur in the northern half; the brown and reddish soils are in the northeastern corner; and the juvenile and hydromorphic soils occur along the alluvial channel complexes.

The soils largely reflect the influence of parent materials. Intensive use of the soils and addition of manure and chemical fertilizers have altered their character, profile, texture, structure and chemical characteristics.

1.8.3 Vegetation:

The natural vegetation consists of the Sudan and the Guinea savannah both having been replaced by secondary vegetation. Four fifth of the state is now composed of farmed parkland, dotted with patches of shrub. The savannah woodland, which is the second largest zone, is typified by the Falgore Game Reserve. There are few forest plantations of exotic trees.

1.8.4 Climate

The climate of the study area is the tropical dry-and-wet type, classified by Koppen's as Aw. The movement of the Inter-Tropical Discontinuity (ITD) gives rise to two seasons (wet and dry seasons). The wet season lasts from May to mid-October with a peak in August while the dry season extends from mid-October of one calendar-year to mid-May of the next. The annual mean rainfall is between 800 mm to 900 mm; and variations about the annual mean values are up to ± 30%. The mean annual temperature is about 26^0C (Olofin, 2008).

Mean annual rainfall ranges from over 1,000mm in the extreme south to a little less than 800mm in the extreme north. The rains last for three to five months. Mean temperature ranges from 26Â°C 33Â°C.There are four seasons: a dry and cool season, Kaka, (midNovember to February), marked by cool and dry weather plus occasional dusty haze: the dry and hot season, bazara(March/mid-May) when temperatures climb up to 40Â°C and which is a transition period between the harmattan and the wet season; the wet and warm season, damina (mid-May to September), is the proper wet season when the lowest diurnal temperature is recorded; and a dry warm season, rani (October to mid-November) marked by high humidity and high temperature next to bazara in hotness.

1.8.5 Drainage:

Rivers and Dams Kano, Challawa, Watari, Jatau and Dudurun Gaya join the Hadejia, which empties into the Lake Chad while Gari, Tomas and Jakara disappear into the sands of the Chad Formation further east. Several manmade lakes such as Tiga, Challawa Gorge, Gari, Jakara, Watari, Guzuguzu, KafinChiri, Dudurun Gaya, Bagauda have been constructed to improve portable water supply to towns and villages and to provide water for irrigation.

1.8.6 Ecological Problems:

Kano experiences great temporal variation in rainfall amount and duration. During the 1970/73 drought, Kano recorded only forty eight per cent of the annual mean of rainfall distribution. This phenomenon and occasional pest infestation pose major dangers to crop and animal lives and, consequently, human lives. Irrigation has led to the erosion of top soil, resulting in considerable loss of the fine soil particles which contribute to the high sediment yield of the main rivers. High sediment yield, especially from areas with basement complex rocks, has led to rapid reservoir siltation, thereby reducing the life span of most of the reservoirs.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Climate plays a dominant role in agriculture having a direct impact on the productivity of physical production factors, for example the soil's moisture and fertility. Adverse climate effects can influence farming outputs at any stage from cultivation through the final harvest. Even if there is sufficient rain, its irregularity can affect yields adversely if rains fail to arrive during the crucial growing stage of the crops (Rudolf and Hermann, 2009), as cited in Mesika and Esekhade (2014).

Ajadi et al. (2011) reported that there are three methods of establishing agriculture - climate relationships. The first method establishes the fundamentals of plant - climate relationship in terms of the solar radiation and moisture balance for various crops in various climatic environments. The second method involves studying agricultural products yield data and climate for a number of places within a given area for as long a period as constant record of both agriculture and climate allow, and deducing agro-climatological relationship from analyses of data, while the third method involves studying plant - climate relationship under controlled environment.

2.2 Crop-Climate Relationship Studies

Rainfall is among the five climatic factors that are of particular importance to crops production: rainfall, air and soil temperature, day length (photoperiod), radiation and wind. There are few studies that have been conducted on crop climate relationship. Among the few ones are Abdulhamid and Sawa (2011), who conducted a study on forecast models for the yield of millet and sorghum in the Semi-Arid Region of Northern Nigeria using Dry spell parameters. The results of the research show that sorghum is more responsive to dry spell occurrence than millet. Occurrence of dry spells at some phonological stages of development of sorghum is beneficiary and increases its yield. About 54.5% and 63.2% of the variation in the yield of millet and sorghum respectively are accounted for by the variation in occurrence of dry spells.

Maksimovic and BucSevic (2009) also studied the effect of weather variation on crop production in Serbia and Montenegro. The result shows that, corn yield were significantly higher in irrigation than in the variant of dry farming. However, extremely high temperature at the time of flowering pollination and grain filling affected yield performance of corn, not only in dry farming but also in irrigation. Lobell and Field (2007) studied the Global scale climate–crop yield relationship and impacts of recent warming. The result suggests that recent climate trends attributed to human activity have had a discernible negative impact on global production of several major crops. Abdulhamid *et al* (2011) studied the effect of climate on the growth and yield of sorghum (sorghum bicolor) in Wailo, Gajunwa Local Government Area, Bauchi State. The result shows differences in the effect of each element on sorghum yield at different stages of the growth.

Ajadi *et al* (2011) examined the impact of climate on urban agriculture: A case study of llorin city, Nigeria. In this study, the results obtained from the regressions and correlation statistics revealed that climate has little impact on crop productivity within the years under review. In other words, the result implies that, though there are variations in climate parameters within the years, such variation has little impact on the selected crops. Yamusa, Abubakar and Falaki (2015) examined rainfall variability and crop production in Northwestern Semi-arid zone of Nigeria. In this study, the results obtained from the correlation statistics revealed that rainfall has negative relationship with the yields of maize and cowpea. Tunde, Usman and Olawepo (2011), examined the effects of climatic variables on crop production in Patigi Local Government Area, Kwara State. The results obtained from the correlation and regression statistics revealed that climatic parameters have impact yields under the years of review.

Bello (2012), focused his study on precipitation effectiveness indices and millet yield in Kura and Danbatta Local Government Area of Kano State. His results revealed from the multiple regression and correlation statistics that rainfall and moisture stress are critical to the yield formation of millet.

2.3 The Studies of the Fundamentals of Plant-Climate Relationships

Palikhe (2008) studied relationship between pesticide use and climate change for crops in Hrihar Bhawal. The finding of the study shows that, climate and weather can substantially influence the development and distribution of insects. Most of the warming over the last 50 years is likely to have been due to man-made activities. Wolfram and Michel (2006) conducted a research on estimating the impact of climate change on crop yields. The test shows that the new estimate is significantly better at predicting yields than other approaches found in the literature. The flexible function form reveals that growth is highly non-linear and asymmetric in temperature. Ngujen (2004) examined the global climatic change and rice food security review. Omonona and Akintunde (2009) studied rainfall effects on water use and yield of Cocoa in Nigeria. Raja *et al* (2007) studied the effects of carbon dioxide, temperature and ultraviolet – B radiation and their interactions on Soya beans (Glycine Max L.) Lobel (2007) investigated changes in diurnal temperature range and national cereals yields. Stone (2001) examined the effects of heat stress on cereals yields and quality crop responses and adaptation to temperature stress. Olarewaju (2012) studied the effect of climate on Yam tuberization in the guinea savanna ecological zone of Nigeria, the case study of Kwara state. The result shows that yam tuberization in the guinea savanna ecological zone of Kwara state is favoured by rainfall that is well spread and with soil temperature at 5cm depth. Soil moisture at all depths shows a positive relationship with tuber formation.

2.4 Empirical Studies of Plant- Climate Relationships

Researches that were conducted on the empirical studies of plant-climate relationships are varied depending on the types of research and nature of the study area. Some of the few researchers are Abdulhamid *et al* (2011) these reported that, the result of the correlation between the climatic variables and yield of sorghum at Wailo. The result shows differences in the effect of each element on sorghum yield at different stages of growth. For the pre-sowing period rainfall has positive and significant correlation with yield. This shows that rainfall supply during the pre-sowing period is very important for good sorghum yield at Wailo. Apata (2008) investigated the effects of global climate change on Nigerian agriculture. Findings from this study indicated that agricultural impacts of climate change in Nigeria are uncertain. The total average impact may be positive or negative depending on the climate scenario. But in most scenarios it was shown that climate change will have an overall positive impact on Nigeria's agriculture.

Ben Mohamed et al (2002) reported that, the result of the study show that, the rainfall and the trend variables were significant ($P<0.01$) and conformed to the prior expectation of the signs of the coefficients. The significance and positive coefficient of the rainfall, means that as rainfall increases, production of millet increases while during drought years (when rainfall decreases), and Millet production declines.

Other studies have revealed an extreme sensitivity of maize plants to water deficit, during a very short critical period, from flowering to the beginning of the grain-filling phase (Bergonci et al., 2001). Maize crops have also the highest water requirement during the critical period, when the maximum leaf area index combines with the highest evaporative demand. Thus, maize crops are very sensitive to water deficits during its critical period (flowering to beginning of grain filling) for two reasons: high water requirement, in terms of evapotranspiration, and high physiological sensitivity when determining its main yield components, as number of ears per plant and number of kernels per year.

Aliyu (2009) conducted a research on the implication of the recent trends and variability in the duration of the growing seasons for food crop production in northern Nigeria and the author emphasized a downward trend in the duration of the growing season in some locations from 1978 -2007, with a significant variability in most of the stations north of latitude 9^0N of Nigeria. He did not however, relate the trend of the growing season and monthly rainfall with current trend yields of some major crops growing in these stations.

Climate has been undoubtedly identified as one of the fundamental factors that determine both crop cultivation and livestock keeping. Climate is a long-term average weather condition that directly or indirectly affects agricultural production. Climate determines the choice of what plant to cultivate, how to cultivate it, the yields of crops and nature of livestock to keep. Climate change is likely to adversely affect food security in many regions of the world, especially in developing countries where a large fraction of the population is already facing chronic hunger and malnutrition (Lobell *et al.*2008, Schmidhuber and Tubiello 2007).In such countries, the survival of the population will depend on the effective adaptation of agriculture to climate change. Better knowledge of climate impacts on crop yields is a pre-requisite for breeding more resilient crop varieties, or for adopting existing varieties more resistant to climate-induced stress—two different strategies to counteract the adverse effects of climate change on crop yields (Barnabás *et al.*2008).

For Africa in particular, the meta-analysis of the results of 16 studies over West Africa (Müller 2011, Roudier *et al.*2011) shows that although projected impacts on yield are most frequently slightly negative (−10%), there is a large spread between results. This variation indicates a low confidence in future yield projections, with projected impacts on crop yields ranging from −50% to +90%. More recently, Knox *et al.* (2012) estimated that mean yield change for all crops is −8% by the 2050s with strong variations among crops and regions. This diversity of impacts reflects the differences in these impact studies, which focus on different locations, and rely on different climate projections, crops and crop models, and downscaling techniques; the result is a large spread of crop yield projections (Sultan 2012). This low degree of confidence makes it difficult to aggregate and upscale such projections in order to provide a consistent assessment of future yield changes at regional or continental scale (Berg *et al* 2013).

There is thus a need to perform more consistent assessments of climate change impacts on crop yields at the regional scale in West Africa. In particular, it is necessary to account, as far as possible, for uncertainties in regional climate change scenarios. Indeed, the considerable spread in current climate model projections of regional climate change over West Africa, especially with respect to rainfall (Müller 2011, Roudier*et al.*2011), results in uncertainty in estimates of future crop yields; with the existing studies generally being based on too narrow a selection of climate projections. Several different approaches exist to derive large-scale climate change impacts on crop yields, such as the use of empirical relationships between crop growth and climate (Lobell *et al.*2008, Schlenker and Lobell 2010) or the recent development of large-scale vegetation models including an explicit representation of croplands (Müller *et al,*2009, Berg *et al* 2013,). Among these approaches are the up-scaling of simulations from plot-scale process-based crop models over a larger regional domain (Liu 2008) allows the diversity of responses to be assessed accurately, including the effects of different cultivars and/or management practices. The ability to identify the most suitable crop varieties, with the most robust characteristics for withstanding climate change, is crucial for formulating adaptation strategies in the region.

Ajadi (2011) explained that solar radiation, temperature, moisture and other climatic parameters determine the global distribution of crops and livestock as well as crop yield and livestock productivity. Reuben and Barau (2012) observed that rainfall distribution and the occurrence of moisture stress condition during vegetative period are critical for the yield formation of cassava crop at Kabba, Kogi State. In view of the foregoing, Odjugo (2010) stated that climate change is unequivocal and its impacts are here with us. Available pieces of evidence show that each day brings fresh proofs of climate change effects and these effects include increasing temperatures, decreasing rainfall in the continental interiors, drought, desert encroachment, melting ice, extreme weather, floods, sea level rise, sinking of Islands, water scarcity, health and agricultural problems.

The impact of climate change on agricultural production in Nigeria has received limited attention despite the fact that over 60% of the active populations of Nigerians are farmers. Studies on climate change globally and in Nigeria have reviewed that the potential impacts of climate change will include every aspect of the four dimensions of food security; food availability (production and trade), food accessibility, food stable supplies, and food utilization (Nwafor, 2007).

2.5 Rainfall and Crop Relationship

Rainfall regime is the most important climatic factor influencing crop cultivation activities, (Ayanlade et al. 2010). Rainfall can vary considerably even within few distance and different time scale. This implies that crop yield is exceedingly variable over space and time which will have a big effect in determining the kind of crop to be grown, farming system to be adopted and the sequence of farm operations (Adejuwon, 2005). Rainfall can also be seen as the supplier of soil moisture to crops, although, moisture do not depend on rainfall alone but also on various concerns such as the evapo-transpiration and surface runoff (Intergovernmental Panel on Climate Change, 2009).

Crops production depends almost entirely on rainfall as its moisture supply. Therefore the amount and distribution of rainfall are important factors in determining the ultimate productivity of the crop. In West Africa, the onset of the rainy season is highly variable while the end of the rains is sharp (Kowal and Kassam, 1978). Some of the agroclimatic features of rainfall distribution include:

- Total rainfall during a season;
- The onset of the rainy season;
- The termination of the rainy season;

The definition of Onset, Cessation and the length of rainy season has been a problematic one because of the intermittent nature of rainfall in the region. These three terms have been defined in various ways for different purposes by researchers. Onset refers to the time a place receives an accumulated amount of rainfall sufficient for growing of crops. It is not the first day the rain falls. Cessation means termination of the effective rainy season. It does not imply the last day rain fell, but when rainfall can no more be assured or be effective. The length of rainy season is the number of days between the onset and cessation dates.

'Rainy season' can be defined as the period of the year during which rainfall distribution characteristics are suitable for crop germination, establishment, and full development. It is the period of the year categorized as the rainy or wet season, the length of which varies spatially, temporally, and with crop type. In a typical tropical country like Nigeria, rain falls in different months of the year at different places, as the rain belt appears to follow the relative northward and southward movements of the sun. In this tropical situation of a marked seasonal rainfall regime, variability of the onset and retreat of rain is highly significant, and its estimation and prediction are necessary.

Rainfall is a major determinant of agricultural production in any agro-ecological zone anywhere in the world. Its seasonal and annual characteristics such as the onset and intra-seasonal rainfall distribution that promote good crop yields are, however, characterized by fluctuations. These fluctuations are not easy to forecast, yet a fore-knowledge will help the farmer to plan his farming activities.

Rainfall has been seen as the most important factor in crop production in Nigeria. Some of the important factors guiding rainfall in relation to crop include number of rainy days, time of fall, total amount of fall and the type of soil. Rainfall usually determines the type of crop to be grown in different environment as well as the type of agricultural system to be practiced in different parts of the country. According to Olaoye (1999), regular occurrence of drought as a result of erratic rainfall distribution and/or cessation of rain during the growing season reduce Nigeria's capability for increased crop production.

Climate, particularly rainfall is a limiting factor in agricultural production in the arid region of the tropics, northern Nigeria inclusive. A shift in the average climatic conditions of an area would, therefore, lead to a shift in the pattern of agricultural activities in the area. Global warming has and is still altering the global rainfall regime. Extremes of this climatic parameter are on the increase in some areas while its average is on the decrease at some. The Inter Government Panel on Climate Change (Intergovernmental Panel on Climate Chang, 2007) reported that by 2020, agricultural production including access to food in many African countries will be compromised by climate change. The area suitable for agriculture, the length of the growing season and yield potential, particularly along the margins of the arid and semi arid areas of Africa are expected to decrease. In some countries in Africa, yields from rain-fed agriculture could be reduced by up to 50%. Rainfall is the most critical factor in the estimation of the Hydrological Growing Seasons in the tropics. Kano state is rated among the top 5 states that produce millet, maize, ground nuts and sorghum, crops that are largely rain-fed in Nigeria. However, the production of these major grain crops today is faced with climatic challenges, one of which is the rainfall distribution.

Undoubtedly, rainfall distribution trends over a given season can be useful in the interpretation of observed crop performance. The challenge to successful rainfed crop production is the timely and precise prediction of the rainfall characteristics of a coming cropping season. These challenges need to be sufficiently addressed through scientific research in order to reduce high fluctuations of crop yields in rainfed ecologies on both seasonal and annual time scales. Considerable research works have been carried out on the effects of climate on agricultural production, but few works have been specific on the effects of rainfall distribution on millet, sorghum, maize, rice, cowpea and groundnut in Kano state.

Akinniran T.N., Ezekiel A.A, and Ganiyu.et al. (2013), studied the effect of rainfall variability on crop production, observation that crops yield were in general not strongly affected by seasonal rainfall variation in Oyo state is confirmed by the mean annual rainfall and the result of exponential functional analysis, both of which revealed that there is little variation in total seasonal rainfall distribution and consequently indicates little effect on crop productivity in the state.

Akenpenpuun and Timothy D. (2013),studied Climate and Grain Crops Yield in Kwara State, Nigeria, in this study, the result obtained from the regression and correlation statistics reveals that climate has little impact on crop productivity within the years under review. In other word, the result implies that, though there are variations in climatic parameters within the years, such variation has little impact on the selected crops. This suggests that variation in crop yield and climatic influence on agriculture in Kwara State could be as a result of other factors namely; soil or farm techniques in Kwara State, Nigeria.Reuben and Barau (2012) observed that rainfall distribution and the occurrence of moisture stress condition during vegetative period are critical for the yield formation of crops at Kabba, Kogi State.

2.6 Maize production and Rainfall Distribution

Maize is produced on nearly 100 million hectares in developing countries with almost 70% of the total maize production in developing world coming from low and lower middle income countries (FAOSTAT,2010). By 2050 demand for maize will double in the developing world and maize is predicted to become the crop with the greatest production globally and in the developing world by 2025 (Rosegrant, 2008). In large parts of Africa, maize is the principle staple crop accounting for an average of 32% of consumed calories in Eastern and Southern Africa rising to 51% in some countries. The world population is expected to surpass 9 billion by

2050, with population growth highest within developing countries. Harvest at current levels of productivity and population growth will fall far short of future demands. Projections of climate change will further exacerbate the ability to ensure food security and foster economic growth within much maize producing areas. The irregular distribution of rainfall, during the crop cycle, may explain a lot of the yield variability attributed to crop growing conditions. Berlato et al. (2005) showed relationships between maize yield and the El Niño Southern Oscillation, through the influence of this phenomenon on rainfall patterns in the State. Schultz et al. (2011) in a study on South Africa, Lesotho and Swaziland found climate change to be associated with potential increases in maize production, though they argue that it is likely to have little effect in marginal areas where yields are already low.

2.7 Sorghum and Rainfall Distribution

Of all the factors that affect agricultural production, the deleterious effects of climate are the most difficult to ameliorate. Add to this the variability and unpredictability of climatic factors and this becomes the main risk to production. Abiotic stresses such as drought or excessive rainfall, very high or low temperatures, low insolation levels, and so forth, can significantly reduce yields and restrict the latitudes and the soils where commercially important species can be cultivated. Of the climatic elements, water is the most important, its availability during the plant's growth cycle generally being the single factor that limits crop yield (Chiroma et al., 2006).

2.8 Millet and Rainfall Distribution

Millet production depends almost entirely on rainfall as its moisture supply. Therefore the amount and distribution of rainfall are important factors in determining the ultimate productivity of the crop. In West Africa, the onset of the rainy season is highly variable while the end of the rains is sharp (Kowal and Kassam, 1978). Poor soil moisture at sowing reduces seedling emergence leading to poor crop establishment. In addition there can be extended periods between the initial rainfall and subsequent rains. If a poor stand results, farmers often re-sow when rains re-occur. Therefore, it is important that agro-climatic information include information not only on the onset of the rains but also the expected weather during the period immediately following the onset of the rainy season.

High climatic variability (e.g. low and variable distribution of rainfall) represents a delicate balance between agricultural production and food security. Studies show that the changes in the agriculturally-relevant variables of climate (e.g. increasing temperatures and declining levels and distribution of rainfall), are likely to reduce yields of maize, rice, wheat and other food crops in semi-arid regions of the world (Lobell et al., 2009). The amount and distribution of rainfall affects many other aspects of agricultural production among smallholder farmers in Sudanion-Sahelian agro-climatological region, namely farm sizes, crop enterprises, cropping calendars, incidence and growth of weeds, crop pests and diseases (Yengoh et al., 2010). In earlier studies, Bewket (2009), has noted that in Sub Sahara Africa, rainfall is the most important climatic factor influencing the growth characteristics of crops. Rainfall provides the water that serves as a medium through which nutrients are transported for crop development. In view of this significant role, clearly, inadequate water supply has adverse effects on efficient crop growth, resulting in low productivity.

2.9 Cowpea and Rainfall Distribution

Cowpea (Vignauniguiculata) commonly known as beans is an important, versatile food crop. It is the most ancient human food. It belongs to family of fabaceae (Leguminoisae) and subfamily of papillnoideae. Cowpea has been intercropped for long time with various other crops such as maize, wheat, millet, sorghum (Johnson, 1970). It can be utilized in various ways ranging from the use of young green seedling as vegetables and also forage for livestock to its consumption as beans. It is an excellent source of protein which is enriched by amino acids, lysine and tryptophan. Cowpea is widely grown in sub Saharan Africa; it is widely planted under rain fed conditions in domestication which is associated with pear in South Africa. Economically, cowpea is utilized by man in different ways. Generally, cowpea grows in areas of low rainfall as high rainfall lead to crop failure. Cowpea, being a warm climate and drought tolerant crop is grown throughout the tropics particularly in the semi-arid and low rainfall regions. It provides food, fodder and also improves the soil fertility.

Major cowpea production in Nigeria is in the Northern part of the country, accounting for about 60 percent of the country's total cowpea produced. Due to its proximity to the Sahara Desert, Nigeria's north is particularly susceptible to drought, with the risk of increased drought growing along with the expected effects of global warming (Adejuwon, 2008). In Nigeria, the production trend of cowpea shows a significant improvement with about 441 percent in area planted and 410 percent in yield from 1961-1995 (Ortiz 1998). Several factors account for these impressive increase over the last two decades, the International Institute of Tropical Agriculture (IITA) has made significant advances in improving the productivity of cowpea in the sub-Sahara Africa.

2.10 Rice and Rainfall Distribution

The main systems of rice culture are: irrigated lowland, rainfed lowland, rainfed upland, irrigated upland, seasonally flooded wetlands and tidal wetlands. On a global scale, rice grown in flood-prone and tidal wetlands, and under rainfed upland, rainfed lowland and irrigation conditions, constitutes 10 per cent, 10 per cent, 25 per cent and 55 per cent of the cultivated rice area, respectively. Irrigated rice, rainfed lowland rice, rainfed upland rice and rice from flood-prone areas account for 75 per cent, 17 per cent, 4 per cent and 4 per cent, respectively, of global rice production. For any given region or season, prevalent cropping systems cannot be considered ideal for optimal crop productivity. The sections that follow will examine, for each of the main rice ecosystems, their climatological requirements, the weather vagaries that impair operations, and the agronomic measures that have been established to cope with weather anomalies. Rice is grown from about 50° N to 35° S and from below sea level to above 2 000 m, covering a mean temperature range of 17°C to 33°C, a growing-season rainfall range of 0 to 5 100 mm, and a solar radiation range of 300 to 600 calories/cm2/day in the various growing areas and different seasons. Many of the rice-growing areas are served by major rivers and have alternating wet and dry seasons. The varieties used and cultural practices adopted in rice cultivation vary widely and are influenced by local climatology (rainfall, temperature and solar radiation regimes) and times and certainty of availability of water for main or supplementary surface irrigation.

Rice is the only cereal that can stand water submergence, and this helps to explain the long and diversified linkages between rice and water. For hundreds of years, natural selection pressures such as drought, submergence, flooding, and nutrient and biotic stresses led to a great diversity in rice ecosystems. The plant's adaptation strategies include surviving submerged conditions without damage, elongating its stems to escape oxygen deficiency when water tables rise, and withstanding severe drought periods. Ecologists have distinguished five water related categories of rice plant: rainfed lowland, deep water, tidal wetland, rainfed upland and irrigated rice. Historically, rice cultivation has been a collective enterprise. The investment and shaping of the landscape that are needed for the pond system (terraces) require collective organization within the community. Water management also relies on collective interest: crop and water calendars must be organized for large blocks of fields in order to manage water efficiently and organize such work as land preparation, transplantation and drying for harvesting.

2.11 Groundnut and Rainfall Distribution

The agro-climatology of groundnut is that it is essentially a tropical plant and requires a long and warm growing season. The favorable climate for groundnut is well-distributed rainfall of at least 500 mm during the crop-growing season, accompanied by an abundance of sunshine and relatively warm temperature. Temperature in the range of 25°C to 30°C is optimum for plant development (Weiss, 2000). Once established, groundnut is drought-tolerant, and to some extent it also tolerates flooding. Rainfall of 500 to 1000mm will allow commercial production, although crop can be produced on as little as 300 to 400mm of rainfall. Groundnut thrives best in well drained sandy loam soils, as light soil helps in easy penetration of pegs and their development and their harvesting. The productivity of groundnut is higher in soils with pH between 6.0 and 6.5 that is soils with less acidity.

Groundnut is one the most popular commercial crops in Nigeria north of latitude 10N.Groundnut kernels, cake and oil account for such as 20 percent of requirements for edible nuts. The husks[shell] is used as fuel, roughages and litter for livestock, mulch and soil conditioner .The key areas are located in the Sudan savanna and Northern Guinea ecological zones, where the soil and agro-climatological conditions are favorable (Misariet et al 1980).Temperatures are moderately warm and relatively stable during the growing seasons at 20^{0}c-25^{0} c. The savanna zone in Sudan receives adequate rainfall for the production of groundnut. The crop is grown usually as a component of a variety of crop mixtures including sorghum ,millet, cowpea ,and maize (Misari et al.1988).There are two main varieties grown in Nigeria, long-season varieties maturing in 130 to 145 days and short- season varieties maturing in 90 to 100 days. As for production constrains, groundnut production in Nigeria faces problems that are numerous and complex .Drought, coupled with the groundnut rosette epidemic in 1975, results in a decline in groundnut production. This has led to a Southern ward shift of the suitable climatic zone for groundnut production. Heavier soil in the South compared with the sandy soil of the Sudan Savanna make harvesting difficult ,however .Diseases such as the rosette ,early leaf spot ,late leaf spot and rust have been on the increase. Leaf spot attack severely reduces yields.

Rainfall is the most significant climatic factor affecting groundnut production, as 70 per cent of the crop area is found in semi-arid tropical regions characterized by low and erratic rainfall. Low rainfall and prolonged dry spells during the crop growth period were reported to be main reasons for low average yields in most of the regions of Asia and Africa, including India (Reddy et al., 2003).

2.12 Summary of Literature Review

In general, precipitation is the climatic variable of primary importance in shaping the spatial and temporal variations of Agriculture in the tropics. The seasonal cycles of rainfall directly determine the tempo and rhythm of the growing seasons. A lot of literatures exist on the various studies of establishing weather climate agricultural relationships that were advocated by Ajadi et al. (2011) reported that there are three methods of establishing agriculture **-** climate relationships. The first method establishes the fundamentals of plant **-** climate relationship in terms of the solar radiation and moisture balance for various crops in various climatic environments. The second method involves studying agricultural products yield data and climate for a number of places within a given area for as long a period as constant record of both agriculture and climate allow, and deducing agro-climatological relationship from analyses of data, while the third method involves studying plant **-** climate relationship under controlled environment**.**

CHAPTER THREE

RESEARCH METHODOLOGY

3.0 Introduction

This chapter clearly highlights the procedures employed in achieving the objectives of this study. It vividly explains the descriptive and statistical analysis employed.

3.1 Types and Source of Data

For this study, rainfall data was obtained from the Institute for Agricultural Research (IAR) station, while sorghum, millet, maize, rice, cowpea and ground nut production in Metric/Tons were obtained from Kano State Agricultural and Rural Development Agency (KNARDA). Availability and reliability of the rainfall data were considered as these locations are longstanding operational synoptic stations, standard equipment and Personnel as set by the World Meteorological Organization (WMO).

3.2 Data Collection

Rainfall on a daily basis converted into monthly totals for a period of 20 years (1994 -2013) and crop data specifically yearly estimate of crops productions in (Metric/Tons) also for a period of 20 years (1994-2013). Crop data were sourced from the department of monitoring and evaluation under Kano Agricultural Rural Development Agency (KNARDA).

The study area is Kano state as a whole, specifically the 36 local government areas namely; Minjibir, Ungogo, Bagwai, DawakinTofa, Bichi, Gezawa, Danbatta, Tofa, RiminGado, Kabo, Shanono, Kunchi, Rogo, Madobi, Gwarzo, Tsanyawa, Makoda, Karaye, TudunWada, Doguwa, Bebeji, Takai, Sumaila, Kibiya, Rano, GaruMallam, Gabasawa, Garko, Bunkure, Ajingi, Dawakin Kudu, Albasu, Kura, Kiru, Warawa and Wudil. The studies focus mainly on the 36 Local Government Areas where the crops are basically grown there.

3.3 Technique of Data Analysis

The study employed both descriptive and inferential statistical techniques in data analysis. While simple correlation and linear regressions were used in showing the relationship between climatic parameters and crop yield and showing the trend and variation in crop yield over the twenty years in the study area. These statistical techniques were employed in the analysis of both crop yield data and climatic parameter because of their peculiarity in revealing the relationship and variation among variables.

Descriptive statistics of long term monthly rainfall were computed for the period under study. Mean monthly rainfall, standard deviation (a measure of dispersion) and coefficient of variation (measure of variability) were also computed for the period under study and presented in tabular forms. This enabled the researcher explain the trend and characteristic of rainfall distribution in the study.

3.3.1 Mean

The mean was employed in calculating the annual rainfall and crop production for the study area.

$$X = \frac{\sum_{j=1}^{n} xj}{n} = \frac{\sum x}{n}$$

Where X = mean or arithmetic means

$$\sum_{j=1}^{n} = summation\ (Sigma)$$

xj = the variable (observation)

n = total number of variables

3.3.2 Standard Deviation

$$s = \sqrt{\frac{\sum_{i=1}^{n}(\boldsymbol{x} - \overline{\boldsymbol{x}})^2}{\boldsymbol{n}}}$$

Where

S = Sample Standard Deviation

n = Total number of Variables

∑ = Summation of Square of all deviation from the arithmetic

j = 1 mean

3.3.3 Coefficient of Variation

The coefficient of variability is an expression obtained by converting the standard deviation into a percentage of the mean. Also in this study the coefficient of variability (%) showed the variation.

$$CV = \frac{S}{X}\, x\ 100$$

CV = Coefficient of variation

S = Sample standard deviation

X = Mean of the monthly and annual rainfall.

3.3.4 Correlation Analysis

Correlation analysis determined the existence of relationship between crop production and rainfall considered for the investigation. This was done for each of the crops variable and rainfall distribution separately.

$$rp = \frac{\sum(x - \bar{x})(y - \bar{y})}{\sqrt{\sum(x - \bar{x})^2 \sum(y - \bar{y})^2}}$$

$\sum(x - \bar{x})^2$ = Summation of the square of all deviation from the mean in the independent variable

$\sum(y - \bar{y})^2$ = Summation of the square of all deviation from the mean in the dependent variable

3.3.5 Regression Analysis

Simple linear regression analysis established linear trends in the behavior of climatic element (rainfall) and crops production in the area. Superimposition of regression line on the individual scatter plots provided further insight on the direction and strength of trends in the distributions. The coefficients of determination were computed, providing a basis for trends in the crop yields. All the statistics were done using Microsoft Excel 2007.

The simple regression analysis can be a means of estimating the dependence of once observed variables upon another or several variables; it involves numerical relationship between two or more variables, as in the formula below

$$Y = a + bx$$

Where

Y = Dependent Variable

$$a = y - bx$$

$$b = \frac{\sum(x - \bar{x})(y - \bar{y})}{\sum(x - \bar{x})^2}$$

x = Independent variable

x = Mean of Independent Variable

y = mean of dependent variable

Time series graphs, trend line and histograms were drawn to show the monthly and annual variation of rainfall in the study area. Pie chats were drawn to show the mean crop production for the period under study.

CHAPTER FOUR

DATA PRESENTATION AND INTERPRETATION

4.1 Introduction

The data analysis is intended to vividly follow the earlier stated objectives of this study and obtain meaningful results to be interpreted from the data sourced for this work. Attempts will also be made to interpret the results based on physical and applied climatology. The variation of rainfall over time will be looked upon, the relationship between crop production and rainfall will also be diagnosed, including the trend of crop production. Finally, the relationship between the variables will be looked at in the light of accepted conceptual framework.

4.2 Descriptive Statistics of Monthly Rainfall

Table 4.1: Descriptive Statistics of Monthly Rainfall Distribution

MONTHS	MEAN	STD	CV (%)
JAN	0	0	0
FEB	0	0	0
MAR	0	0	0
APR	11.36	12.77849	112.5
MAY	50.74	32.24212	63.5
JUN	156.265	45.85471	29.3
JUL	283.875	134.9174	47.5
AUG	333.77	116.3828	34.9
SEPT	153.31	67.59681	44.1
OCT	21.01579	20.04576	95.4
NOV	0	0	0
DEC	0	0	0

Table 4.1 presents the distribution of coefficient of variation (%) in the study area. The months with highest coefficient of variation is April (112.5%) which coincides with the time people are expecting the arrival of rains, but the high coefficient of variation means that no reasonable planning and rainfed agriculture can be done in relation to rainfall. It also implies that any prediction done on rainfall is likely to fail woefully and most especially farmers need to be careful. It also marks the second season March, April and May (MAM) when rain begins to fall. Likewise, October (95.4%) marks a sharp fall from months with less variation and more reliability of rainfall to months of high uncertainty and variation signed by insufficient moisture for agricultural pursuit. The months with lower coefficient of variation from May to September shows favorable condition for crop growth. It also shows that rainfall is more stable in June (29.3%), July (47.5%) and August (34.9%) and more variable in April (112.5%). Table 4.1. The study area has onset of rainfall in May and cessation by September. However in some years, onset of rainfall is experienced in June and cessation by September.

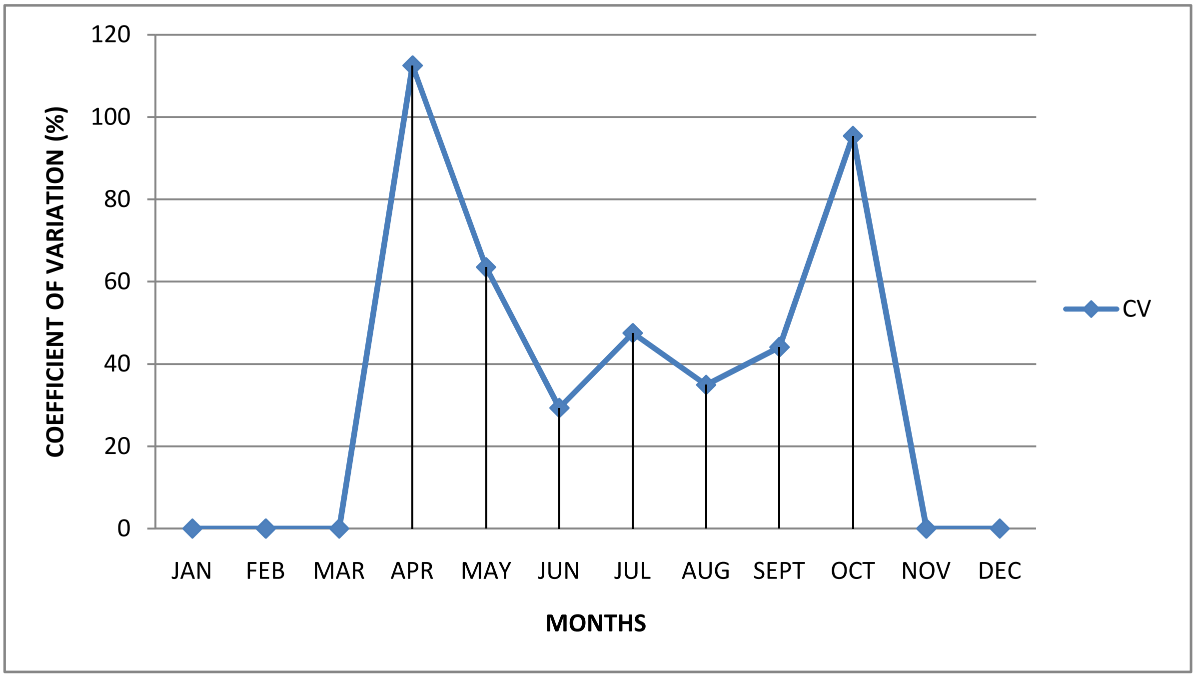

Figure 4.1: Coefficient of Variation in Monthly Rainfall for Kano State (1994 – 2013)

Figure 4.1 is a graphical representation of coefficient of variation in percentage of monthly rainfall distribution within the years under study. It shows that the variation is high in April with more than 100% variation and it also mark the month in which rain starts in Kano and as the rainy season continues the coefficient of variation drops to less than 70% in May, June, July, August with September having the lower coefficient of variation and that means it is more reliable for farming activities. Coefficient variation begins to increase again as in October marking the months of unreliable rain to rainless months. The implication is that apart from dry season farming, the onset and cessation of rains are periods that farmers need to know and begin to grow crops that will mature from May to September or June to September/October when rain is more reliable.

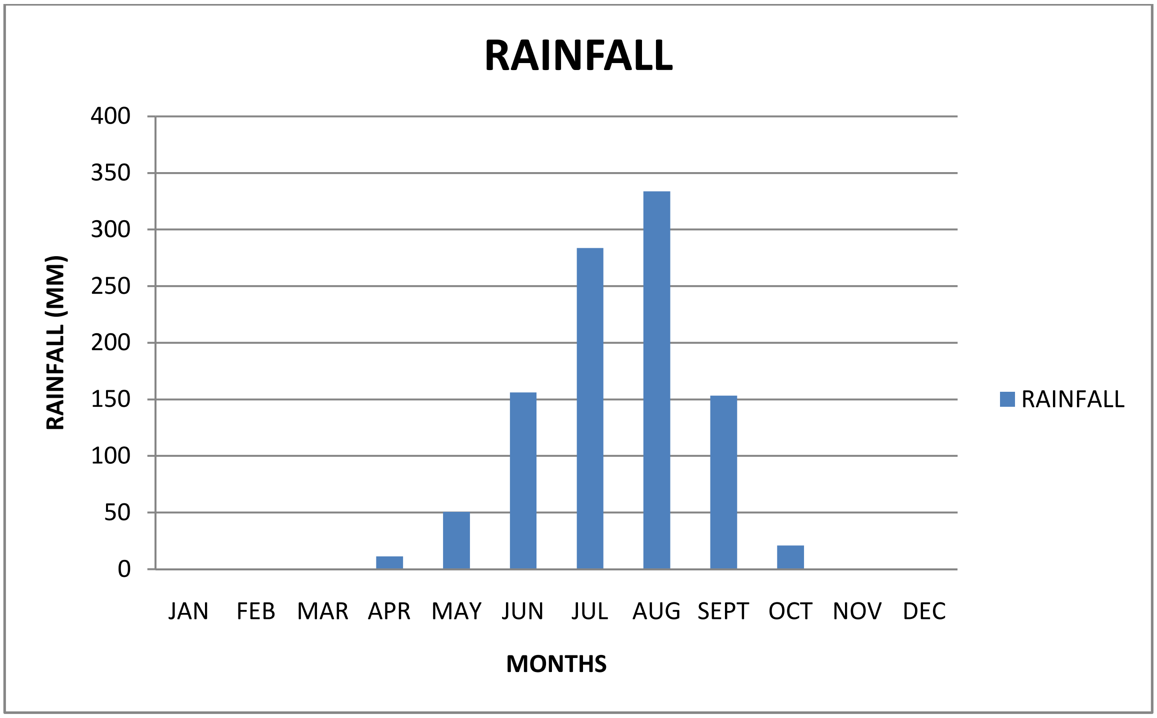

Figure 4.2: Monthly Rainfall Distributions in Kano (1994 – 2013)

Monthly rainfall variation within the years under study shows that, the rain starts in Kano in April and rises to its peak in August and then begins to decline to the rainless months. From figure 4.2, it is evident that the first season which is December, January and February(DJF) are rainless which is the main dry season, March, April and May (MAM) marks the inception of the rain at a scanty level while June, July and August (JJA) is the main rainy season when rainfed agriculture dominates the area. September, October and November (SON) is the transition zone between the main wet season and the dry season in Kano. It can be seen from figure 4.2 that the increase in monthly rainfall amount, from the onset until the peak is reached, is more gradual than the decrease from when the peak is attained to when the rains ceases. This is in line with the findings of Kowal and Kassam (1978), Buba (2010).

4.3 Annual Distribution of Rainfall in Kano State

Table 4.2: Descriptive Statistics of Annual Rainfall

YEARS	ANNRAINFALL	MEAN	STD	CV
1994	768.4	64.03333333	85.76695592	133.9411076
1995	699.5	58.29166667	80.32722236	137.8022399
1996	1134.2	94.51666667	138.542444	94.51666667
1997	1290.2	107.5166667	145.2077498	135.0560376
1998	1161.5	96.79166667	195.38916	201.865684
1999	1391.7	115.975	192.8585262	166.2931892
2000	1071.1	89.25833333	118.3589261	132.6026621
2001	1613	134.4166667	243.702059	181.3034536
2002	1053.7	87.80833333	134.4040547	153.0652611
2003	1429.5	119.125	171.0608777	143.5977987
2004	753	62.75	84.04427945	133.9351067
2005	908.7	75.725	103.8002814	137.0753138
2006	783.9	65.325	81.26896003	124.4071336
2007	818	68.16666667	105.9315416	155.4007945
2008	734.5	61.20833333	94.58035024	154.5220154
2009	726	60.5	93.05932614	153.817068
2010	1018.1	84.84166667	113.0291713	133.2236574
2011	881.6	73.46666667	97.46494941	132.6655391
2012	938.9	78.24166667	129.9480934	166.0855385
2013	874.1	72.84166667	125.4234896	172.1864632

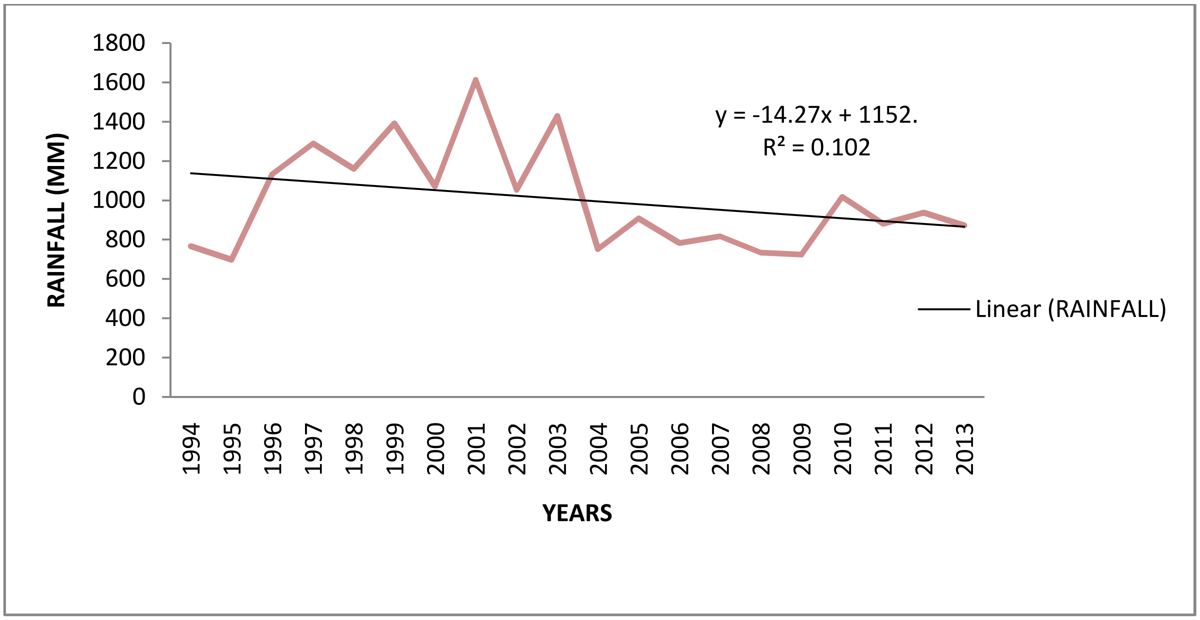

Fig 4.3: Annual and Trend of Rainfall Distributions in Kano (1994 – 2013)

There was increase in rainfall within the first decade and then there was sharp decrease in the second decade. The year 2001 within the first decade experienced the highest rainfall and there was slight decline from 2004 to 2009 in the second decade. 2010 marked the recovery in rainfall but a decline occurred in 2013.

The year with higher CV is 1998 (201.96%) and 2001 (181.30%) which marks the years with lower rainfall for crop growth. Then years with lower CV is 1994 (94.51%) and 2006 (124.40%) shows high rainfall. For the first decade from 1994 – 2003, the mean rainfall was 96.77mm, and the second decade 2004 – 2013 was 70.31mm while the whole period from 1994 – 2013 had a mean of 83.54mm.The mean rainfall of the second decade is below the mean total which is 83.54mm.This shows that rainfall is generally decreasing overtime.

4.4 Regression Statistics Trend Analysis of Crop Production and Years

The trend of millet, sorghum, maize, rice, cowpea and ground nut over the years seeks to establish the behavior of the different output of crops temporally to see how they fared. Different years have varying production due the various influencing conditions.

Table 4.3: Regression analysis for crop Production and Years

S/N	CROPS	REGRESSION(R^2)
1	Sorghum	0.474
2	Millet	0.013
3	Maize	0.064
4	Rice	0.579
5	Cowpea	0.048
6	Groundnut	0.197

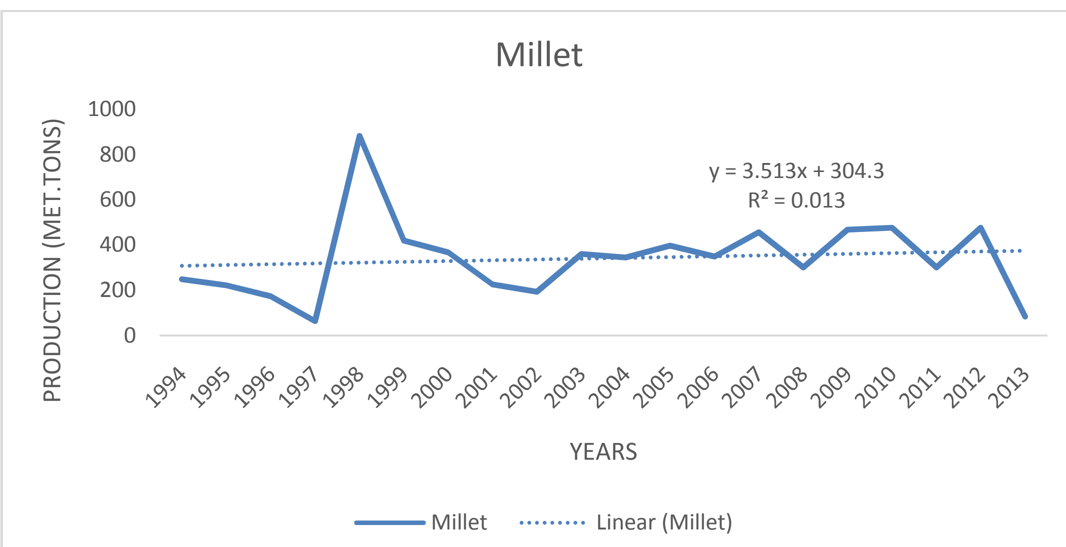

Fig 4.4: Trend of Millet Production (Metric Tons)

Figure 4.4 presents the fluctuation and trend of millet production over the years. It indicates that 1994 had a higher production but started diminishing and lowest production subsequently occurred in 1997, however, production skyrocketed the subsequent year (1998) and began to reduce again over the years. The general trend was increase as portrayed by the trend line and its equation over the years though with evidences of inter-annual variation in production.

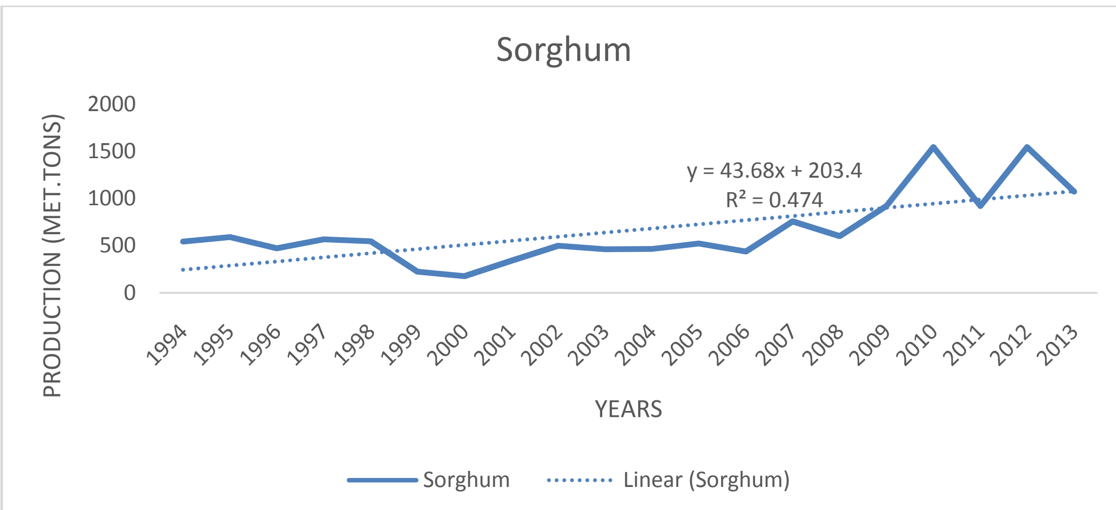

Fig 4.5: Trend of Sorghum Production (Metric Tons)

Sorghum production over the years is presented in figure 4.5. Sorghum production shows decline from 1999 but improved almost steadily until 2006when it showed sharp drop, but immediately improved the subsequent year and began to alternate again, there was higher increase in 2010 and also a sharp dropped in sorghum production in 2011 and followed by an increase in 2012.On a general note, sorghum production has shown tendency of improvement as indicated by the trend line over the years, though with evidences of inter-annual variation in production. There is likelihood that other conditions have improved to cause this positive change.

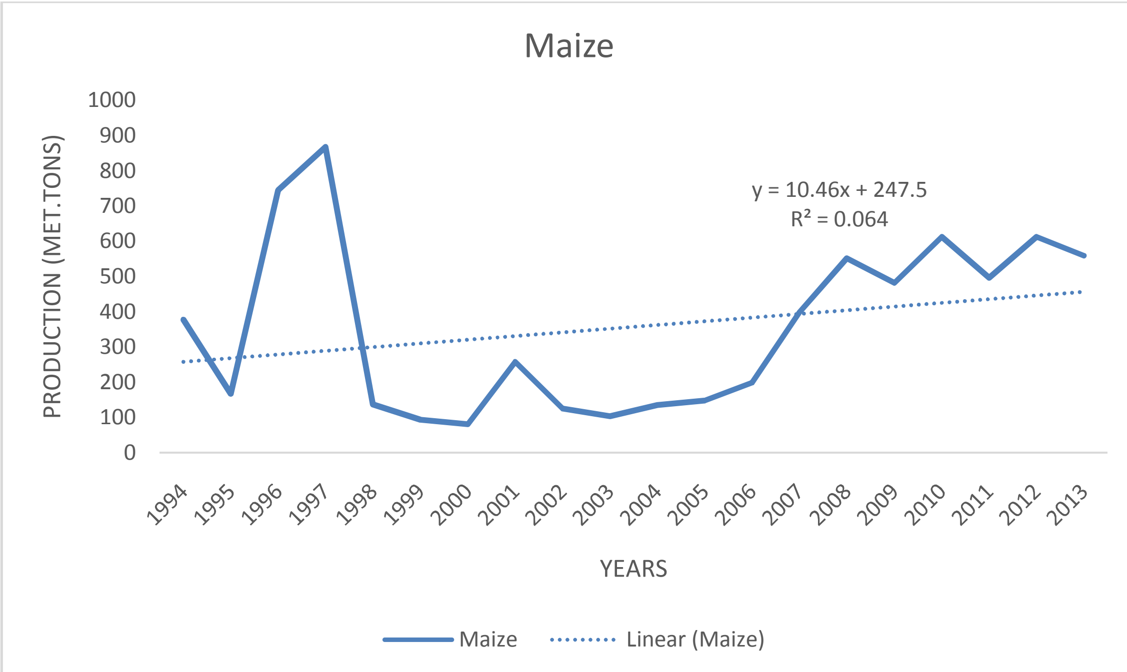

Fig 4.6: Trend of Maize Production (Metric Tons)

The production of maize over the years is indicated in figure 4.6. The year 1995 showed a recovery from years of low maize to increased production within 1996 to 1997 with a fall again in 1998 to 2000. The period, 2001 to 2002, showed years of increased production which continued thereafter. The general trend line shows an increased production over the years though with evidences of inter-annual variation in production.

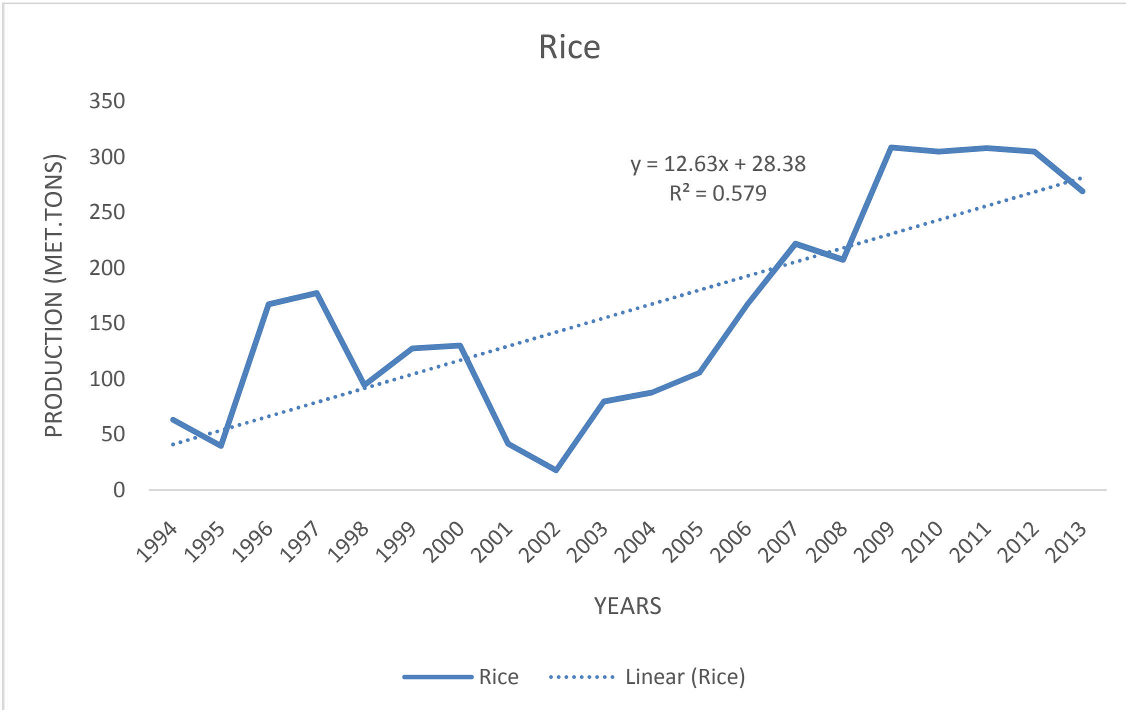

Fig 4.7: Trend of Rice Productions (Metric Tons)

Figure 4.7indicates rice production for twenty years in Kano State. Low crop production occurred in 1995 and significant improvement occurred in rice production from1996 with least production in 2002, followed by increase from 2003. Rice production has improved over the years as seen by the trend line. The general trend line shows an increased production over the years though with evidences of inter-annual variation in production.

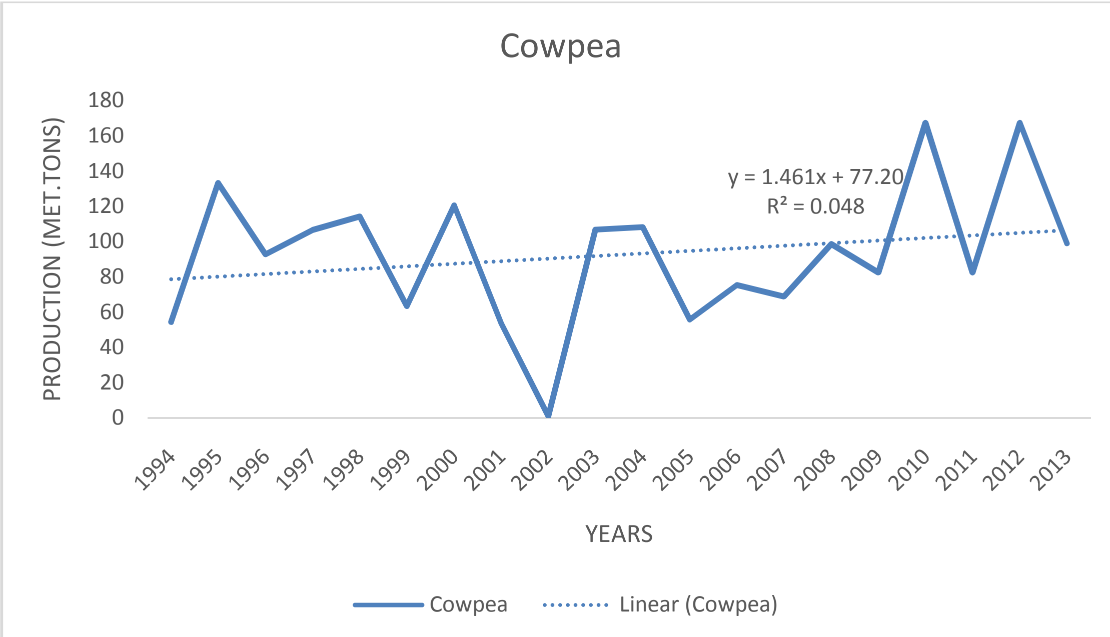

Fig 4.8: Trend of Cowpea Productions (Metric Tons)

It could be seen that 1994 was low in the production of cowpea within the years of consideration and above the mean until 2002 when it practically reduced to the minimum, then it showed significant improvement though with fluctuation below and above the mean. The trend indicates an improvement in production over the years. The general trend line shows an increased production over the years though with evidences of inter-annual variation in productions, which indicate that measures have been put in place for such improvement which should be improved upon.

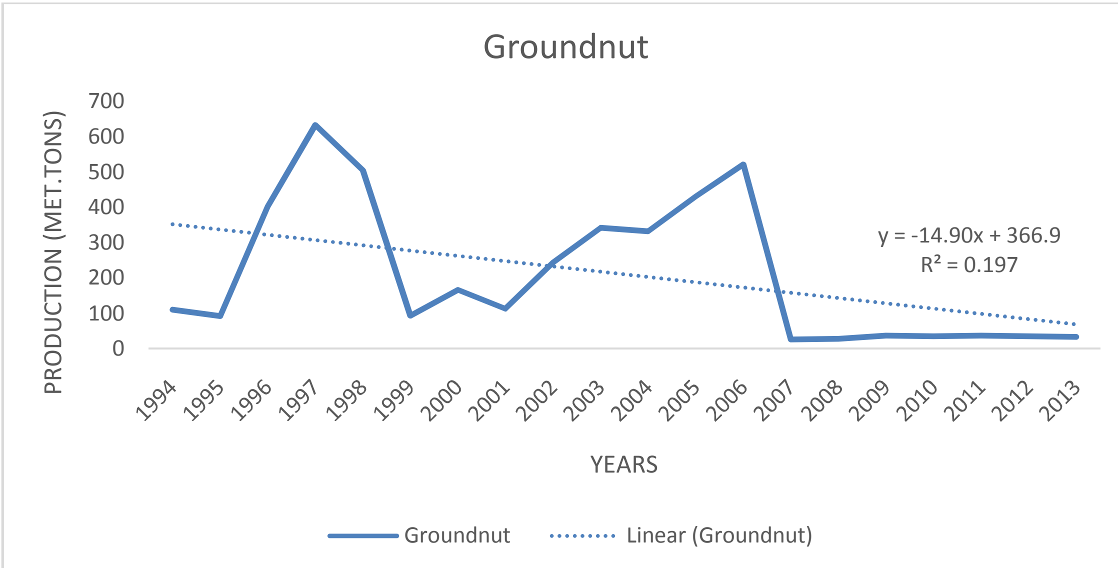

Fig 4.9: Trend of Groundnut Production (Metric Tons)

It is noted that Groundnut production was at its peak in 1997, but began to decline and recorded least production in 2007 and remain low for the rest of the years. The general trend line shows an increased production over the years though with evidences of inter-annual variation in production.

4.5 Variation in Crop Production in Kano State

Table 4.4: Crop Production (1994-2013)

SN	CROP	MEAN (Metric Tons)	STD	CV (%)
1	MILLET	341.216	178.213759	52.23
2	SORGHUM	662.162	375.2831257	56.68
3	MAIZE	357.503	244.204359	68.31
4	RICE	161.077	98.242889	60.99
5	COWPEA	92.54995	39.35596396	42.52
6	GROUNDNUT	210.43105	198.6618407	94.41

Table 4.5 presents the mean and standard deviation of different crop production over the years. The deviation from the mean is seen more in sorghum with the least occurring in cowpea.

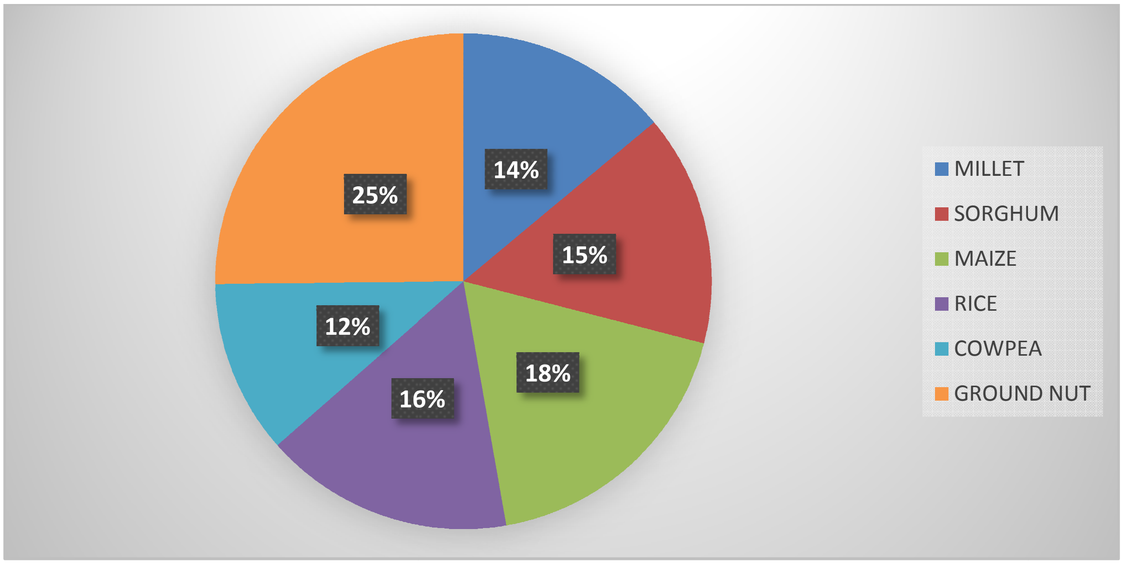

Fig. 4.10: Coefficient of Variability of Crop Production (Metric Tons) in Kano state (1994–2013)

The coefficient of variability for all crops considered is presented in figure 4.10. The coefficient of variability in crop yield production indicates that for the period under consideration, cowpea has been more reliable from year to year than any other crop with 12% even with the reduction and fluctuation in rainfall amount as indicated in the inter-annual rainfall variation in figure 4.2, followed by millet with 14% and sorghum with 15%. On the other hand, rice being a crop that is more susceptible to rainfall has shown high level of uncertainty with 16%, this clearly implies that for meaningful and sustainable rice production in Kano state, rain - fed agriculture must be sustained and be improved upon by both government and individual farmers. Groundnut has showed highest level of uncertainty with 25% this clearly implies that groundnut production has reduced in the study area basically as a rainfed crop with no alternative to complement. There is need to seriously improve the production by both government and the individual farmers and organization in the area. This can also be related to the fact that the climate (rainfall amount) in the area is reducing and as such crops like millet, sorghum, cowpea and maize will thrive better in the area.

4.6 Rainfall and Crop Production Relationship

Table 4.5: Rainfall and Crop Production Relationship (Correlation Analysis)

S/N	CROP	CORRELATION (r)
1	Millet	-0.018
2	Sorghum	-0.322
3	Maize	-0.103
4	Rice	-0.317
5	Cowpea	-0.111
6	Groundnut	0.267

The relationship between annual rainfall amount and crop yield production is presented in table 4.6. From the correlation (r) values, it is explicitly clear that there is a negative relationship between rainfall and the different crop in terms of crop production, except for groundnut where a very weak relationship seems to manifest. From the correlation analysis, the result shows that annual rainfall amount is negatively correlated with millet, sorghum, maize, rice and cowpea. This may be because the average rainfall variation does not go below the crop water requirement in the study area. And for rice may be because of the fadama land present in the study area. Hence, rainfall is not too significant for cultivation of rice. Rainfall has weakly positive correlated with groundnut. This implies that increase in rainfall amount in the study will lead to increase in the yield of groundnut. This findings is contrary with the results by (Yamusa, Abubakar and Falaki, 2015), Rainfall variability and crop production in the North western semi-arid zone. This shows that rainfall is positively correlated with maize and cowpea. And also with the findings of (Tunde, Usman and Olawepo, 2011), their results indicates rice and groundnut are negatively correlated while maize highly and millet and sorghum are weakly correlated. Another findings by (Bello 2012), precipitation effectiveness indices and millet yield in two L.G.A of Kano State, indicate that total rainfall is positively correlated with millet. The differences in results may be due to the methods used and the others characteristics of rainfall other than annual rainfall amount like the onset, cessation and hydrologic indices

However, when tested at 0.05 two sample for paired means, it indicated that there is no significant relationship between all the crops considered in this research and rainfall.

4.7 Linear Regression between Rainfall and Crop Production

The simple linear regression between rainfall and crop production seeks to investigate the influence of the independent variable which in this case is rainfall on the dependent variables which in this case are sorghum, millet, maize, and rice, cowpea, groundnut production in metric tons.

Table 4. 6: Regression Analysis of Rainfall and Crop Production in Percentage

S/N	CROPS	REGRESSION (R^2)	REGRESSION IN PERCENTAGE (%)
1	Sorghum	0.1041	10.41
2	Millet	0.0003	0.03
3	Maize	0.0107	1.07
4	Rice	0.1009	10.09
5	Cowpea	0.0125	1.25
6	Groundnut	0.0717	7.17

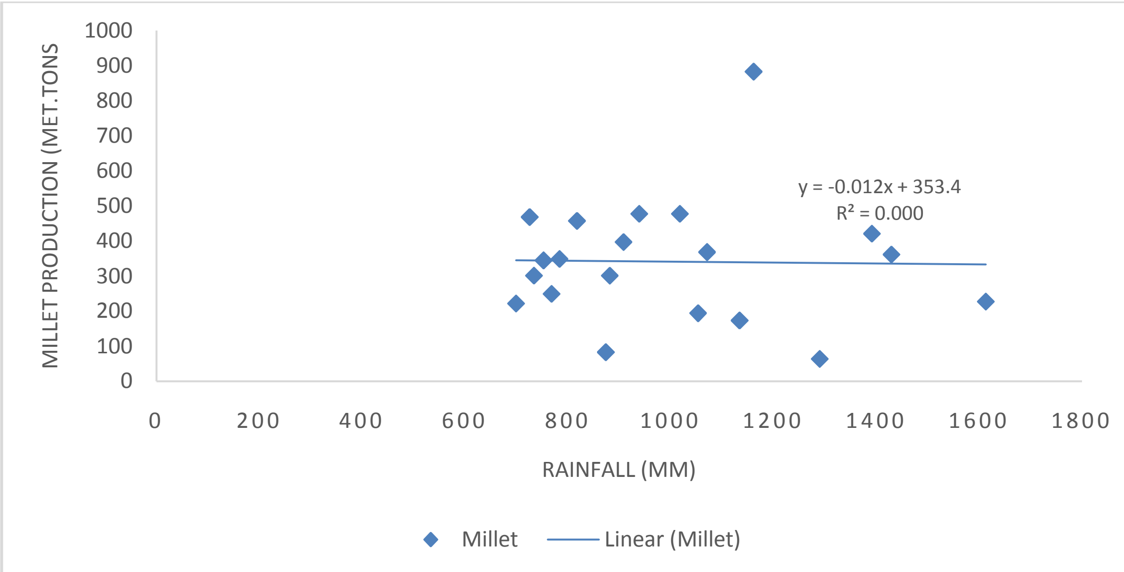

Fig. 4.11: Linear Regression for Rainfall and Millet Production.

The regression relationship between rainfall and millet indicates that rainfall account for only about 0.03% of millet yield which indicates that rainfall is not needed in much quantity, evident by the production even when rainfall is low. This result is contrary with the findings of Bello (2012), in precipitation effectiveness indices and millet yield in Kura and Danbatta in Kano State. His result indicates that rainfall distribution is critical to millet yield and is positively correlated.

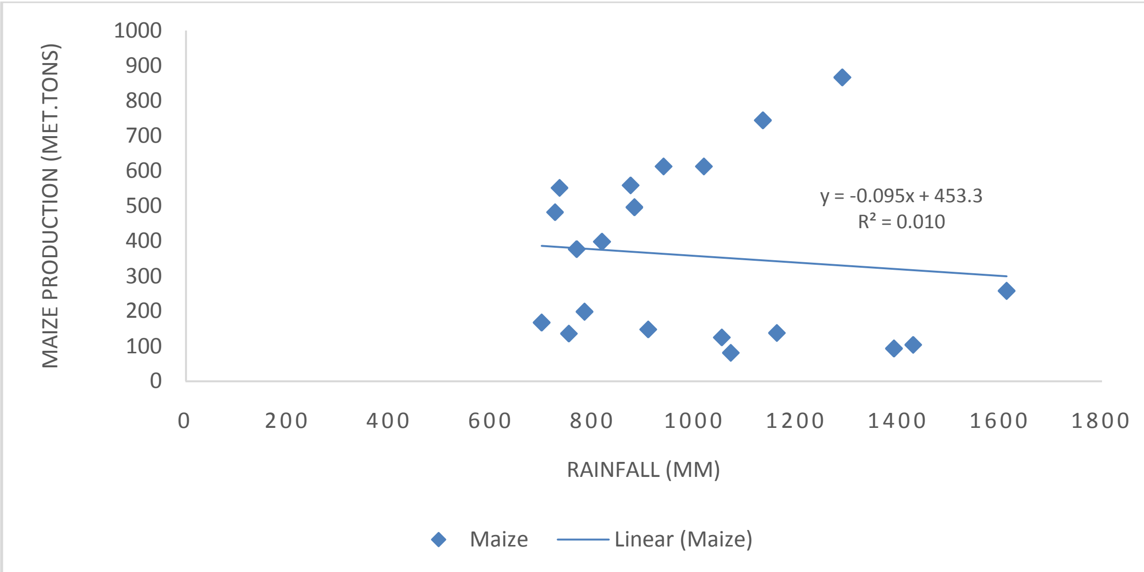

Figure 4.12 Linear Regressions between Maize Production and Rainfall

The relationship between maize and rainfall is also weak, with rainfall accounting for 1.07% yield of maize. This also indicates that with low rainfall amount, maize has been able to cope within the years under consideration and though important from the result, other factors also abound. This result is also contrary to the findings of Emmanuel and Fanan (2013), Effect of variability in rainfall characteristics on maize yield in Gboko. His correlation findings showed maize production has strong positive correlation with rainfall amount. The differences in results may due to the differences in agro-ecological zone. This findings is also contrary with the results by (Yamusa, Abubakar and Falaki, 2015), Rainfall variability and crop production in the North western semi-arid zone, which shows that rainfall is positively correlated with maize.

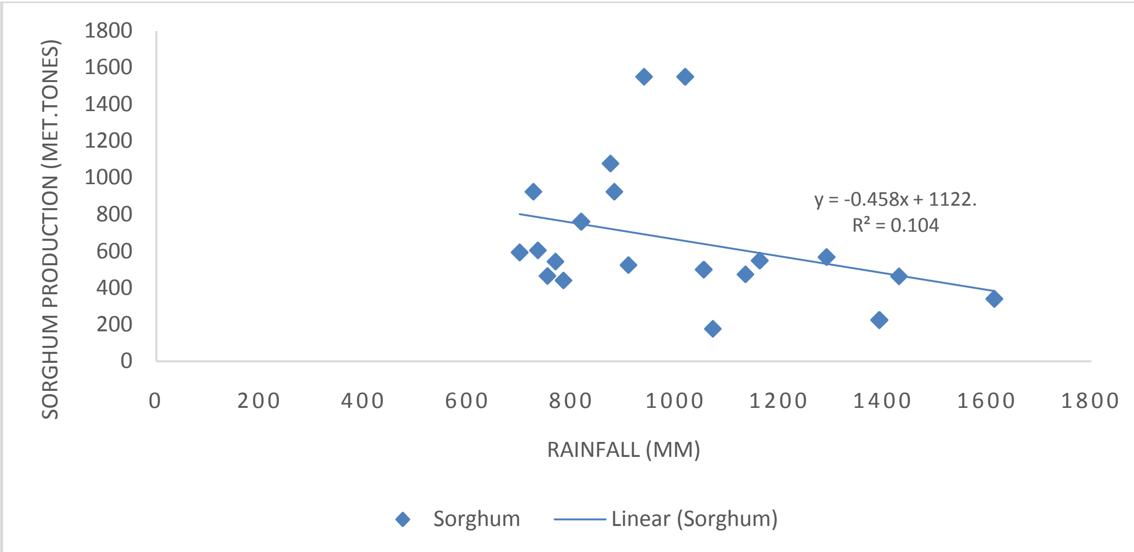

Figure.4.13 Linear Regression between sorghum Production and rainfall

Regression between rainfall and sorghum shows that rainfall accounts for 10.41% of sorghum production and goes to also indicate that less rainfall is needed for sorghum production necessitating the need to improve other factors like soil nutrients and others factors.

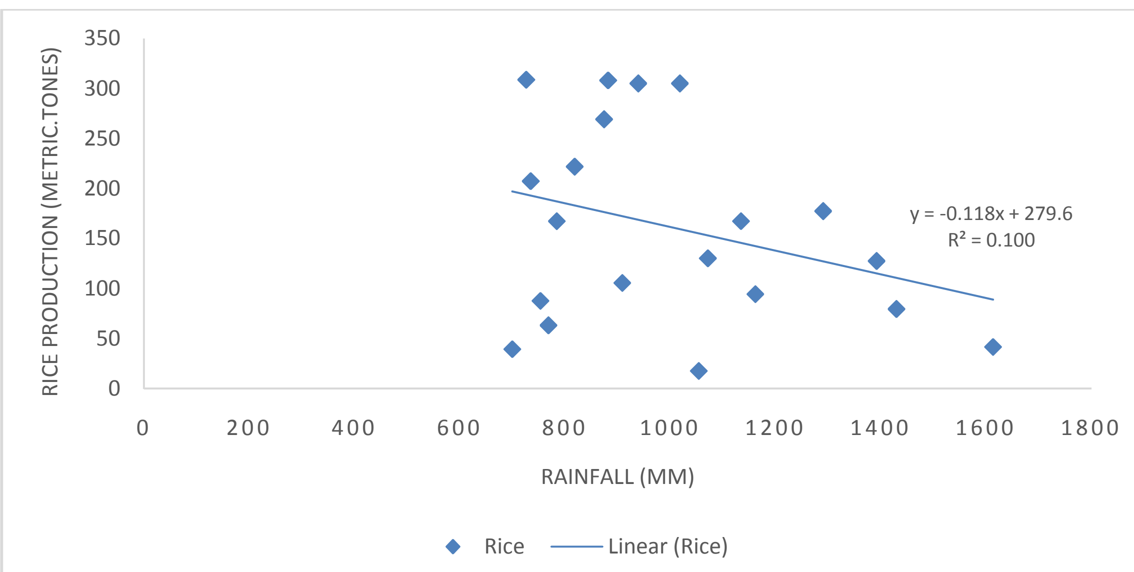

Figure.4.14 Linear Regression between Rice Production and Rainfall

The regression relationship between rainfalls is weak with about 10.09% rainfall responsible for rice yield in Kano state. Surprising as it may be anyway, rice production here is solidly accounted for by the diverse complementing efforts of government organizations responsible for providing dams for irrigation. No doubt in areas of rice production in Kano state, it is visible to acknowledge the presence of water sources available for irrigation purposes for sustaining rice yield in the state. This result is in line with the findings of Abdullahi (2015), productivity of rice as influenced by weather parameters in Kano river irrigation project. His result indicates that rice production is not affected by rainfall due to the other source of moisture in area.

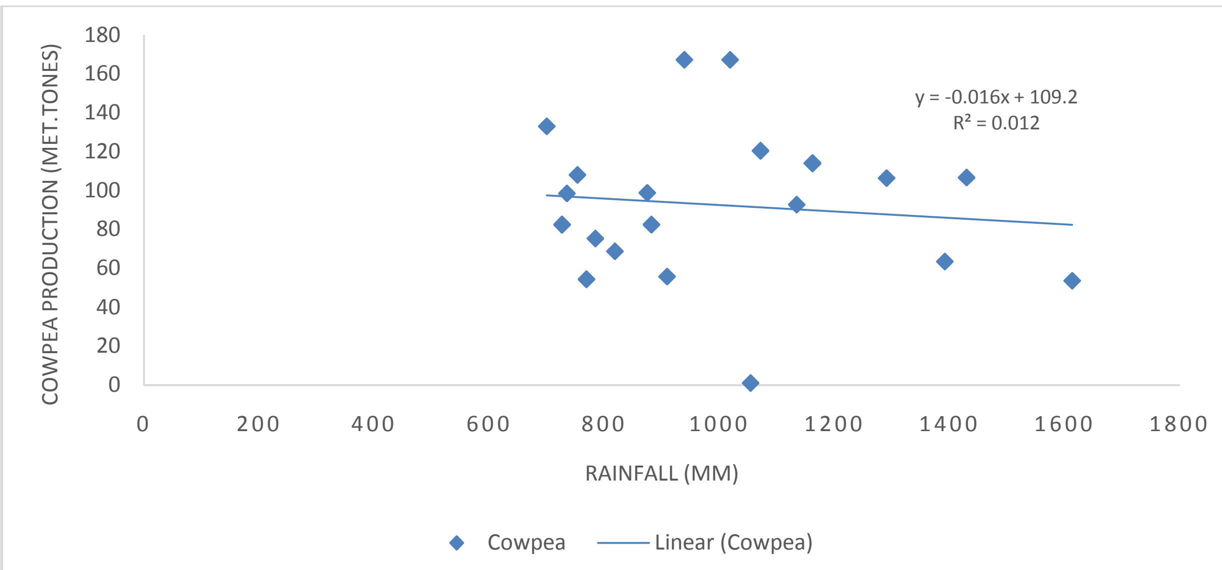

Figure.4.15 Regression between Cowpea Production and Rainfall

The low regression value of rainfall that accounts for a particular crop occurs in the case of cowpea where rainfall accounts for only 1.25% of its production. This goes to show that since with that relationship and cowpea still do well, then it means that cowpea which is not irrigated to complement for short term rain and yet does well, requires just a small amount of rain which makes it do well in this part of the country.

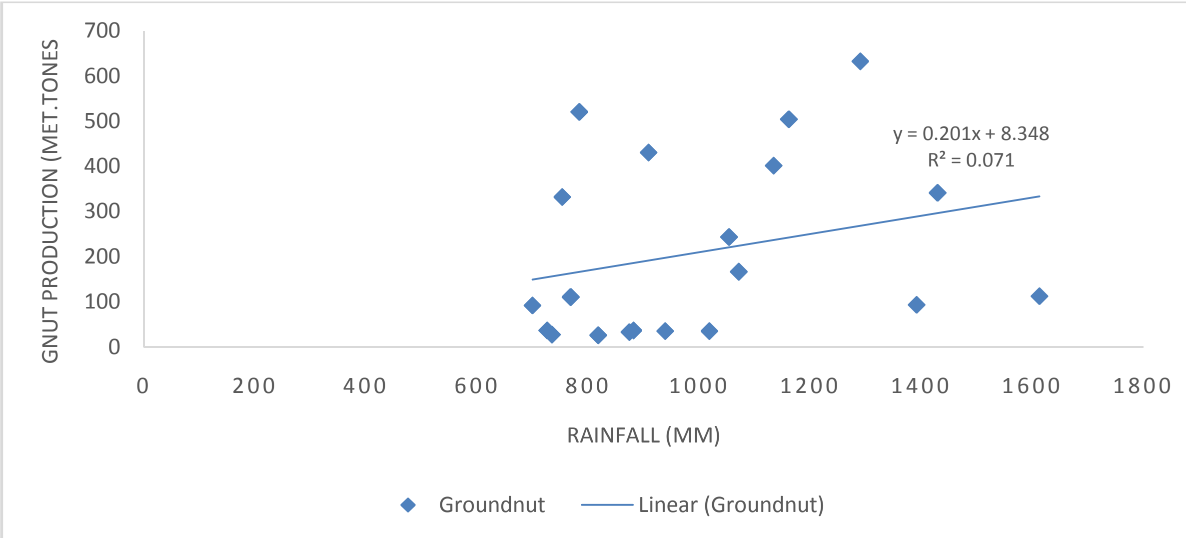

Figure 4.16.Regression between Groundnut Production and Rainfall

The regression value between rainfall amount and groundnut is 7.17%, indicating that rainfall highly accounts for groundnut yield in Kano state. This positive relationship implies that with sufficient rainfall, groundnut yield is expected to be high, whereas with below average rainfall, ground nut yield will be expected to be low.

These results are in line with Akepenpuun and Timothy D. (2013)who analyzed climate and Grain Crops Yield in Kwara State, Nigeria, with result obtained from the regression and correlation statistics revealing that climate has little impact on crop; productivity within the years under review and suggested other factors like soil and farming techniques in Kwara State, Nigeria. Muhammad (2014),Relationship between climatic variability and crop production in Bauchi state, the result of correlation and regression revealed that rainfall has little impact on crop production in the study area under the years reviewed.

From the above, it can be deduced that climate variable of total annual rainfall amount alone have low impact on crop yield. The study has also revealed that what matters more in crop yield is the spread of rainfall during rainy days rather than the total amount of rainfall received annually. As confirmed by (Ifabiyi and Omoyosoye 2011), where they discovered that annual rain days and annual amount had the greatest effect on maize yield. This result is also in line to the findings of Emmanuel and Fanan (2013), Effect of variability in rainfall characteristics on maize yield in Gboko. His findings showed that the distribution of annual rainfall amount over rainy days has 5 times more influence on maize production in the area. Thus, the higher the amount of rainfall spread over the number of rain days in a year the higher the yield of maize per hectare in an area. The work of Adakayi (2004) on the effect of climate change on food production in Northern Nigeria shows a strong positive relationship. This difference in result could be as a result of difference in the sources and nature of climatic parameters considered.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

This chapter contains the general summary of the research work, conclusion and recommendations.

5.1 Summary of Findings

Climatic variation in northern Nigeria is not altogether new because this part of Nigeria contains a significant portion of the Sudan-Sahel ecological zone of West Africa. However, since the early 1970s, climatic anomalies in the form of recurrent droughts, frightening dust storms and rampaging floods have overprinted their rhythms, creating short-duration climatic oscillations as against the normal cycles of larger amplitudes. Thus the last 40years have witnessed four severe droughts, numerous dust storms and three killer floods. Indeed, the climate of the region has become highly unpredictable, making many people to wonder what has happened to the climate. Most of the drought that occur in this region have been found to be associated with a late start of the rainy season and early cessation of rains, resulting in drastic reduction of the length of raining season.(Ekpoh, 2010).

The main aim of this study is to ascertain rainfall distribution and its implication on crops production in Kano state for the period 1994-2013. The analysis considered time series of rainfall with total annual crop yields of some crops in the state.

Variation in rainfall characteristics was established. A noticeable monthly variation in rainfall was detected with the month of August having highest mean monthly total of 333.77mm and

April with the lowest mean monthly of 11.36mm.Average monthly rainfall variation of 35.60% is however lower than average yearly variation of 147.17%.

The coefficient of variation in the crops production in the study area has groundnut with 94%, maize yield and rice account for 68% and 60% respectively. Sorghum, millet and cowpea production are the least with less than 60% of the crops produced in the study area. This shows that they are more reliable in terms of rainfall distribution in study area.

Relationship between climatic variables (rainfall) and crop yields was established using linear regression and correlation analysis at 0.05 level of significance. Millet, sorghum, maize, Rice and cowpea were negatively correlated with rainfall at (-0.018), (-0.322), (-0.103), (-0.317) and (-0.111) respectively, while groundnut (0.267) have a weakly positive relationship with rainfall. This implies that increase in rainfall will increase the yield of millet, sorghum, maize rice and groundnut in the study area. And all the crops have positive linear regression relationship with rainfall. This also implies that with the decreasing annual rainfall amount and the distribution of rainy days, still shows the crops has increased in production which means the annual rainfall amount has not yet decrease below the water requirement of the selected crops within the years under consideration. The productivity of crops in tropical regions is highly vulnerable to inter-annual and sub-seasonal climate variability (Challinor et al., 2004). The results of this study showed that crop production and amount of rainfall varied significantly from year to year. (Figures 4.11 to4.16).

The trends of the inter-annual (figure 4.3), and seasonal rainfall variation is an indications that the rainfall amount was the most variable climatic index in the study area during the wet seasons. This present study agrees with the observations made by (Olaniran 2001). The inter-annual variability of rainfall was high and this may often result in climate hazards, especially floods, with devastating effects on food production and associated calamities and human sufferings. The non-linearity of the crop-yield plots and relatively low correlation coefficients ($r=<- 0.5$) in most cases except in groundnut with ($r= 0.267$) could be attributed to several confounding factors (such as farm management practices, soil fertility, pests, seed type and quality and planting period) that were not necessarily climatic.

The production for the grains (maize, millet, rice and sorghum) do not follow the same trend in some years, but they have peaks occurring in the years (2008, 2012and 2013), which recorded even rainfall distributions (Figures 4 – 9). This suggests that similar environmental factors may probably be involved in the grains production.

The coefficient of determination R^2 is low in all cases with rainfall, less than 10% except in the regression between rainfall and sorghum production which is 10.41% ($R^2 = 0.1041$) and rice production which is 10.09% ($R^2=0.1009$).This implies that rainfall amount alone is not sufficient to explain the crop yields in the area.

5.2 Conclusion

In this study, the result obtained from the regression and correlation statistics reveals that climate has little impact on crop productivity within the years under review. In other word, the result implies that, though there are variations in climatic parameter within the years, such variation has little impact on the selected crops. This suggests that variation in crop production and climatic influence on agriculture in Kano State could be as a result of other factors namely; soil or farm management techniques ,seed variety, and other environmental factors in Kano State, Nigeria.

Also, a reasonable results was obtained, particularly the temporal change in rainfall amount has been established. The low computed correlation coefficient ($r \leq 0.5$) for all crops production with rainfall amount implies that crop production may largely depend on combinations of number of interacting factors which are of both climatic and non- climatic components. Although crop production could be climate dependent, other variables such as farm management practices, soil fertility, pests, seed type and quality and planting period may contribute significantly to variations in crop yield.

5.3 Recommendations

i. Agricultural Extension Officers (AEOs) should be deployed to guide farmers through routine visits, sensitization programmes on variability in rainfall characteristics, use of farm inputs and monitoring of crop- climate relationship in the area in other to achieve improved crop yield

ii. Improved and/or genetically modified crop species that require less consumptive use of moisture and have shorter growing period should be made available to farmers with other incentives and they should be encouraged to grow them; and application of insecticides to reduce the effects of pests on crops.

iii. In view of the positive correlation and rainfall amount with groundnut production, the need for appropriate land use management practices that will ensure moisture availability in the area has become crucial for sustainable crop production. To this extent, soil conservation and age old farm practices such as land till- age, mulching, planting cover crops, controlling and checking erosion to help protect the soil from deterioration or degradation should be adopted; and, application of fertilizer to improve soil fertility and productivity.

iv. Application of irrigation and growth of crops in dams and fadama areas to supplement the water needs crops at the critical stages of growth. The reliance on rain-fed agriculture in this 21st century by majority of the farmers exposes the neglect by government in meeting the challenge of food security and use of modern agricultural techniques to boost crop production

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APPENDIX I

CROP PRODUCTION ESTIMATE OF KANO STATE FROM 1994-2013 IN (MET. TONS)

Years	Millet	Sorghum	Maize	Rice	Cowpea	Groundnut
1994	249.45	543.45	377.34	63.18	54.36	110.33
1995	221.9	592.88	167.41	39.37	133.14	91.82
1996	173.86	473.43	744.92	167.23	92.82	401.63
1997	63.94	567.17	867.22	177.26	106.46	632.61
1998	883.28	547.89	137.61	94.24	114.09	504.21
1999	421.15	224.61	93.35	127.43	63.44	93.08
2000	368.54	176.78	80.93	130.03	120.509	166.381
2001	227.23	340.01	257.82	41.46	53.59	112.39
2002	194.2	499.28	125.09	17.6	0.94	243.33
2003	361.4	462.4	103.7	79.48	106.7	341.4
2004	344.9	464.9	135.65	87.58	108.14	331.96
2005	397.25	524.4	147.72	105.6	55.72	430.6
2006	349.2	440.3	198.39	167.13	75.33	520.82
2007	457.78	760.3	398.08	221.69	68.72	25.64
2008	301.5	603.89	551.8	207.27	98.5	27.23
2009	468.71	923.3	482.12	308.5	82.49	36.37
2010	477.57	1549.28	612.78	304.83	167.33	34.88
2011	301.59	923.35	496.57	307.82	82.5	36.38
2012	477.57	1549.28	612.78	304.83	167.33	34.88
2013	83.3	1076.34	558.78	269.01	98.89	32.68

Source: KNARDA