RAINFALL DISTRIBUTION AND THE LENGTH OF GROWING SEASON IN NORTHERN NIGERIA

BY

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CERTIFICATION

This project work entitled "Rainfall Distribution and the Length of Growing Season in Northern Nigeria" by Christopher Eragbae Ikharo, meets the regulation governing the award of the degree of Bachelor of Water Resources Management and Agrometeorology of Federal University Oye-Ekiti and is approved for its contribution to scientific knowledge and literary presentation.

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ABSTRACT

This study examines the rainfall distribution and the length of the growing season in Northern Nigeria using the daily rainfall data from the selected stations Gasua, Kaduna, Kano, Katsina, Maiduguri, Potiskum, Sokoto, Yelwa, Zaria. The data were collected from the archives of the Nigerian Meteorological Services, Oshodi, Lagos. The length of the growing season was determined using the cumulative percentage mean rainfall method. The growing seasons in Gasau, Kaduna, Kano, Katsina, Maiduguri, Potiskum, Sokoto, Yelwa, Zaria and Northern Nigeria extend over 4 months (third dekad of May to the end of the second dekad of September), 5 months (the middle of the second dekad of May to the end of the third dekad of September), 4 months (end of the third dekad of May to the beginning of the second dekad of September), 4 months (end of the third dekad of May to early October), 4 months middle of the first dekad of June to the end of the second dekad of September), 4 months (middle of the first dekad of June to the beginning of the third dekad of September) , 4 months (end of the third dekad of May to the end of the second dekad of September), 5 months (middle of the second dekad of May to late September), 5 months (end of the first dekad of May to the beginning of the third dekad of September) and 4 months (end of the third dekad of May to the beginning of the third dekad of September) respectively.

Keywords—Rainfall amount, raindays, rainfall onset, cessation, length of growing season, crop production, Northern Nigeria.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the study

Rainfall is the determining factor of agricultural production in the tropical region. It determines agricultural activities like land preparation, crop selection, planting and also the time of harvesting, (Amekudzi et al). The study of Yayock and Owonubi (1986) stated that the availability of sufficient water at appropriate times is the most crucial factor determining the type and productivity of crops. While Davey *et al.* (1976) observed that water is the most important nutrient of a crop, which does not just need water to grow, but requires it as a vehicle in which other nutrients are transported. Crops are usually planted during the rainy season, in the tropical region, implying that crop productivity is largely a function of rainfall. In 1989, Mortimore reported that irregularities in rainfall reliability and spread have therefore contributed significantly to the poor yields and high variability in crop production from year to year.

Growing 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 and temporally, with crop type (Odekunle, 2004).

In Nigeria, just like any other tropical country, rain falls in different months of the year with varied distribution in different places. As observed by Olaniran (1983) and Jackson (1989), the rain belt appears to follow the relative northward and southward movements of the sun. In this tropical region with a marked seasonal rainfall regime, variability of the onset and retreat of rain is highly significant, and its estimation and prediction are therefore necessary because a delay of 1 or 2 weeks in the onset is sufficient to destroy the hopes of a normal harvest.

The variability in the rainy season onset and cessation could pose socio-economic and developmental challenges as they threaten food security and induce poverty (Cooper, 2008; Lacombe, 2012). This is so because erratic and significant delays in rainfall affect the country's overall production of food.

In 1967, Walter observed that the start of the rains, is seldom abrupt, but is usually foreshadowed by a succession of isolated showers of uncertain intensity with intervening dry periods of varying durations. The main concern of an agriculturist is the start, end and length of the rainy season, the distribution of rainfall amounts throughout the year and the risk of dry spells. These factors have been observed to affect the growing season. Variations in agricultural production have been related to deviation from normal seasonal climate best described by the term growing period (Edoga, 2007).

1.2 Problem of study

Rainfall characteristics vary from year to year and from place to place. Its distribution has been observed over the years to be markedly varied which have led to an alteration in the onset and cessation dates and invariably the length of growing season over the country. The marked variations in rainfall greatly affect agricultural practices; therefore adequate study is necessary to understand rainfall distribution over the years so as to better understand future changes.

The studies of Oguntoyinbo and Odingo, (1979) and that of Odekunle, (2004) noted that in 1973, the onset was earlier in Nigeria, which encouraged early planting and animal migration. However, this was a false onset, resulting in both crop and animal loss. Very often than not, the onset is usually foreshadowed by a succession of isolated showers of uncertain intensity accompanied by dry periods of varying duration (Walter, 1968). Omotosho *et al.* (2000) noted that the variations in the onset date could be up to 70 days (10 weeks) from one year to another at a single station. Thus, the rainfall distribution characteristics during the course of a year in a typical wet-and-dry climate region like Nigeria dictate the schedule of agricultural activities from the land preparation, through the crop variety selection and planting, to the time of harvesting. The study of Omotosho et al. (2000), further stated that, reliable prediction of rainfall onset and cessation times, and thus the length of the growing season, will greatly assist on-time preparation of farmlands, mobilization of seed/crops, manpower, and equipment and will also reduce the risk involved in planting/sowing too early or too late.

1.3 Scope of the study

The scope of this study will cover the collection, analysis and interpretation of rainfall data from selected northern states in Nigeria.

1.4 Justification for the study

Inadequate knowledge of rainfall distribution and the length of growing season in the study area are capable of causing widespread crop and animal loss, loss of farmland and an increase in the level of economic decline. There is therefore the need to carry out in depth analysis of rainfall distribution in order to determine the length of growing season and also to evaluate its impact on agricultural productivity in the study area.

This present work will examine and analyze rainfall pattern with the aim of determining onset and cessation dates, length of growing season and rainfall distribution in selected northern states.

1.5 Aim and objectives

The aim of this study is to analyze rainfall and its distribution and length of growing season in Northern Nigeria.

The specific objectives are as follows:

i. Analysis of monthly, seasonal and annual rainfall distribution.
ii. Determination of the onset and cessation dates in the study area.
iii. Determination of the length of the growing season.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

Rainfall is a climate parameter that affects the way and manner man lives. It affects every facet of the ecological system, flora and fauna inclusive. Hence, the study of rainfall is important and cannot be over emphasized (Obot and Onyeukwu, 2010). Aside the beneficial aspect of rainfall, it can also be destructive in nature; natural disasters like floods and landslides are caused by rain (Ratnayake and Herath, 2005).

Many studies have proven that rainfall distribution and the length of growing season has a great effect on the cropping system or rather crop production. Therefore, it is imperative for agriculturists/farmers to have adequate information about the distribution of rainfall and the length of growing season and at the same time understand the period of the onset and cessation of rains so as to plan for various seasonal agricultural activities.

Husak (2006) suggested that in order to improve the ability of African decision makers to prepare for and deal with the consequences of precipitation anomalies, it is important to provide them with a more complete understanding of the range and likelihood of rainfall totals a location could possibly receive. Models of rainfall probability distributions over various timescales are useful tools for gaining this kind of understanding. Modelling rainfall variability in Africa presents an imposing problem for many reasons, including the need to summarize rainfall data for many years at many sites and the difficulty in finding a single method to represent such a variety of rainfall regimes.

The schedule of agricultural activities, right from land preparation, through crop selection and planting, to the time of harvesting for a developing country like Ghana, is rainfall dependent, (Ati, 2002; Cooper, 2008; Laux, 2009; Lacombe 2012). The variability in the rainy season onset and cessation could pose socio-economic and developmental challenges as they threaten food security and induce poverty. (Cooper, 2008; Lacombe, 2012) This is so because erratic and significant delays in rainfall affect the country's overall production of food and, in particular, cereals (maize, millet, soya bean and rice), which form the main staple food in the country. In addition, rainy season onset and cessation dates affect the transmission of vector-borne diseases, as the life cycle of the disease transmission vectors is sensitive to the variability and changes in temperature and rainfall. For example, the mosquito population is likely to increase rapidly during the warmer humid conditions, (Tompkins, 2013).

Odekunle (2004, 2006) showed that, even at a single synoptic station, the annual variation in the onset dates could be up to 70 days (10 weeks). Therefore, defining the onset date of the rainy season can sometimes be very challenging, as the onset characteristics can vary drastically with isolated showers or heavy rainfall of varying intensity being accompanied by extended dry spells.

The problems associated with poor agricultural practices, food security and human health in a developing country like Ghana could be attributed to the high variability in the onset and cessation of the rainy season, Amekudzi (2015).

2.2 Rainfall Distribution

The gross features of rainfall patterns in this region, Northern Nigeria, as in other parts of the country are usually in association with what is often called the Inter Tropical Discontinuity (ITD) (Nicholson, 1981; Kanote, 1984; Hayward and Oguntoyinbo, 1987; Oladipo, 1993). The movement of the ITD northwards across the country between January and August, and its retreat from the southern fringe of the Sahara desert, after August, cause much of Nigeria to experience seasonal rainfall (Olaniran and Summer, 1989). The ITD itself is the boundary at the ground between the dry Tropical Continental (cT) air of northern origin and the moist Tropical Maritime (mT) air of southern origin. Hulmes and Tosdevin (1989), argued that the convergence of trade wind and monsoonal airflow, in the region of the ITD, is unable to produce sufficient vertical motion (and depth of clouds) to induce rainfall. The relevance of the ITD therefore lies in its provision of a framework for following the south / north motion of the rain bearing maritime air mass (mT), (Ati et al, 2009).

Within the mT, air mass is enclosed a number of rainfall producing systems, such as the disturbance lines (especially the easterly waves), squall lines and the two tropospheric jet streams. It is the magnitude of these systems that influences the amount and seasonal distribution of rainfall over the region (Kamara, 1986; Hayward and Oguntoyinbo, 1987; Muller and Oberlander, 1987; Ayoade, 1988; Hastenrath, 1991).

Aondover Tarhule and Ming-Ko Woo (1998), observed that total annual rainfall at a location is influenced by several variables including the frequency of rain events, the duration of the rainy period and the intensity of rainfall of individual events. Inhomogeneity in the annual rainfall therefore reflect changes in these contributory variables. Adejuwon *et al.* (1990) fitted linear trends to the annual rainfall series of several locations in Nigeria for the entire period of available data which, in some cases, began in 1922. Olaniran (1988, 1991) analyzed the fluctuations in the series of rain days of three rainfall categories (low, moderate and heavy intensity).

In 2015, Chinago saw that many factors are responsible for the changes in distribution and characteristics of rainfall in Nigeria, and indeed all over the globe. These include natural factors such as change in orbital elements (eccentricity, obliquity of the ecliptic precession of equinoxes), natural internal processes of the climate such as the El Nino-Southern Oscillation (ENSO) or anthropogenic forcing (for example increasing atmospheric concentration of carbon dioxide and other greenhouse gases (GHGs), the effects of deforestation, urbanization and interference or limited infiltration due to tilling, pavement and inter logging of surface. However the general dispersions of climatic variables are just variations (being primary characteristics of natural system), but as a steadily and slow changes due to human inadvertent incursion into nature by ways of social-economic activities that result to developmental initiatives, population growth, agricultural activities as well as growth in science and technology.

The gaseous and material injections that the above activities inject into the atmosphere, the continuous clearing of green vegetal cover and other land use purposes practically inhabits transpiration and evaporation from land and vegetal surfaces. The stage is thus set for a change in the rainfall of such vicinity after decade or decades and centuries of such human intervention (Goudie,1980; Gribbin and Kelly, 1996; Sorte, 1999; Afangideh and Ekanem, 2005; Odjugo, 2007). This dynamic and natural variation occurs on seasonal, decadal, centennial and even longer time scales. Each "up and down" fluctuation can lead to conditions which are warmer or colder, wetter or drier, more stormy or quiescent (NOAA, 2007, Abaje et al, 2010).

Obot et al (2010) noted that several studies have been carried out globally on rainfall. For examples;

Jayawardene et al. (2005) observed different trends across Sri Lanka using 100 years data. Some parts recorded decreasing trend, some increasing trend while some locations showed no coherent trend. They also showed that the trend characteristics vary with the duration of the data analyzed. Smadi and Zghol (2006) examined the trend analysis of rainfall over Jordan for a period of 81 years (1922-2003) and they observed different trends for different seasons across selected for the study. One of the stations showed a decline in both the rainy days and the total amount of rainfall after the mid-1950s. In 2006, Partal and Kahya examined the trend within a 64 year period (1929-1993) of rainfall for 96 stations in Turkey. The overall result indicated that the trend in precipitation is downward, while few stations showed increasing trend.

2.3 Onset, Cessation and Length of growing season

Amekudzi (2015) examines the onset and cessation dates of the rainy season over Ghana using rain gauge data from the Ghana Meteorological Agency (GMet) over the period of 1970–2012. The onset and cessation dates were determined from cumulative curves using the number of rainy days and rainfall amount. In addition, the inter-annual variability of the onset and cessation dates for each climatic zone was assessed using wavelet analysis. A clear distinction between the rainfall characteristics and the length of the rainy season in the various climatic zones was noticed. The forest and coastal zones in the south had their rainfall onset from the second and third dekads of March. The onset dates of the transition zone were from the second dekad of March to the third dekad of April. Late onset, which starts from the second dekad of April to the first dekad of May, was associated with the savannah zone. The rainfall cessation dates in the forest zone were in the third dekad of October to the first dekad of November, and the length of the rainy season was within 225–240 days. The cessation dates of the coastal zone were within the second and third dekad of October, and the length of rainy season was within 210–220 days. Furthermore, the transition zone had cessation dates in the second to third dekad of October, and the length of the rainy season was within 170–225 days. Lastly, the savannah zone had cessation dates within the third dekad of September to the first dekad of October, and the length of rainy season was within 140–180 days. The bias in the rainfall onset, cessation and length of the rainy season was less than 10 days across the entire country, and the root mean square error (RMSE) was in the range of 5–25 days. These findings demonstrate that the onset derived from the cumulative rainfall amount and the rainy days are in consistent agreement.

The wavelet power spectrum and its significant peaks showed evidence of variability in the rainfall onset and cessation dates across the country. The coastal and forest zones showed 2–8- and 2–4-year band variability in the onsets and cessations, whereas the onset and cessation variability of the transition and savannah zones were within 2–4 and 4–8 years.

Amekudzi and others established from their findings that inter-annual variability of the onset and cessation dates has adverse effects on rain-fed agricultural practices, disease control, water resource management, socio-economic activities and food security in Ghana.

In 2015, Akinseye and others determined the onset dates of the rain using long-term daily rainfall records from 22 meteorological stations that spread across agro-ecological zones (AEZ) in Mali. The mean onset dates were statistically compared with the farmer's planting window for the selected weather stations to determine the suitable dates of onset of growing season (OGS) and length of growing season (LGS). The hypothesis considered a time lag minimum of 7 days between the mean onset date and traditional farmer sowing dates for the crops. Then, the preferred method was used to estimate OGS based on early, normal and late dates respectively across the stations. Also, the estimated LGS according to each zone was evaluated using probability distribution chart with duration to maturity for varieties of the same crops. The results showed that Def_4 was found appropriate for Sahelian and Sudano-Sahelian zones; Def_3 satisfied the criteria and exhibited superior capacity into farmer's average planting date over Sudanian and Guinea Savannah zones. These results have an important application in cropping systems in order to prevent crop failure and ensure a better choice of crop variety according to LGS under climate variability and change being experienced across Mali.

Onset definitions as considered by Akinseye;

Def_1 Defined the onset date as the date after 1st of May when rainfall accumulated over three consecutive days was at least 20 mm and when no dryspell within the next 30 days exceeded 7 days (Sivakumar 1988).

Def_2 Defined onset of rain as a receiving total of 30 mm within 10 days, after which there is no dryspell longer than seven (7) days within the next 30 days (Kasei and Afuakwa 1991)

Def_3 Defined as a total rainfall of at least 20 mm at least two rainy days in a 7-day period followed by 2–3 weeks, each with at least 50 % of the local crop water requirement (Omotosho et al. 2000). This definition was modified to fit in into the model used as the start of the first two rains totalling 20 mm or more within 7 days with at least two rainy days, and no dry spell within the next 21 days exceeded 7 days.

Def_4 Defined as the first occasion after May 1 that the 10- day total exceeds half the evaporation assuming a daily evaporation of 5 mm (FAO 1978).

Mugalavai (2008) observed the presence of a relationship between the onset and cessation dates and between the length of the season and the onset and/or cessation dates are very relevant for planning activities in the season. They studied the two rainy seasons in western Kenya and analyzed them with the aim of determining the patterns of rainfall onset, cessation and length of growing season and subsequently establish the relationships between these characteristics.

Sivakumar (1988) carried out an analysis of long-term daily rainfall data for 58 locations in the southern Sahelian and Sudanian climatic zones of West Africa. The study showed that a significant relationship exists between the onset of rains and the length of the growing season.

Oladipo and Kyari (1993) investigated the fluctuation in the onset, cessation and length of the growing season in Northern Nigeria and reported also that the length of the growing season is more sensitive to the onset of the rains than to the cessation. Reliable prediction of rainfall characteristics, especially the onset, is needed to determine a less risky planting date or planting method, or sowing of less risky types varieties of crops in responsive farming (Stewart, 1991).

Amekudzi (2015) extensively studied the variability of rainfall onset, cessation and growing season over the country using the rainfall amount and rainy days approach. Similarly, researchers like Olaniran (1983, 1984), Adejuwon (1990) and Odekunle (2005) determined the onset and cessation of the rainfall season using gauge data. Le Barbe (2002), also studied the onset of rains over West Africa with annual oscillations of the weather zones characterizing the West African climate. Cocheme *et al.* (1967) and Benoit (1977) determined the onset and cessation of the growing season from the relationship between rainfall and evapotranspiration. Alternatively, Omotosho (2002) used the Theta-E technique, which depends on the equivalent potential temperature. Although numerous onset and cessation studies have been carried out, very few utilized an integrated network of gauge and regional climate models (RCMs). RCMs, in rainfall analysis over West Africa, have the potential to enhance prediction of onset, cessation and duration of the rainy season. For example, RegCM4 allows for the capturing of detailed climate variations over shorter spatial scales. As a result, it may be able to simulate the movement of the rain belt, as well as, the position and strength of the Inter Tropical Discontinuity (ITD), with other associated changes which affect the rainy season. An added advantage is the ability of RegCM4 to capture complex terrain and land-use cover, allowing for the integration of regional topographic and vegetation effect within the model simulation. This makes RegCM4 a useful model for simulating rainfall events over West Africa.

Omotosho (2000), noticed that "the onset dates are the most critical. Reliable prediction of onset time will greatly assist on-time preparation of farmlands, mobilisation of seeds/crops, manpower and equipment and will also reduce the risks involved in planting/sowing too early or too late. Predicting the start of the rains in West Africa is a very challenging task because of the irregularities in the rainfall distribution, both in time and in space. Prediction methods have been proposed, some based on rainfall data alone (Ilesanmi, 1972; Obasi and Adefolalu, 1977; Stern, 1982; Fasheun, 1983; Nnoli, 1996). These rainfall models cannot address the year-to-year variations in the onset dates. Other schemes are based on upper winds (e.g. Beer, 1977; Omotosho, 1990, 1992). Omotosho's (1990) scheme, now in operational use at the African Centre of Meteorological Applications for Development (ACMAD), is capable of addressing the year-to-year variations in the atmospheric conditions and, hence, in precipitation. Omotosho (1992) also proposed a long-range onset prediction method based on upper wind direction changes alone. However, even after crops/seeds have been planted/sown, they will still require favourable rainfall conditions during the early stages in order to eliminate crop failure. In addition, appropriate decisions with regard to irrigation needs and their timings, as well as water conservation strategies for dams and hydro-electric power utilisation, are all dependent on reliable estimates of monthly and seasonal precipitation prospects or amounts. Furthermore, a reasonable knowledge of the date of rainfall cessation enables the prediction of the length of the growing or rainy season, which is most useful for the selection of crop varieties, crop matching and cropping sequences (Kowal and Knabe, 1972). Therefore, in order to ensure maximum and sustainable agricultural productivity, as well as efficient water resource management practices, reliable predictions of the monthly and annual precipitation, the cessation date and the length of the rainy season are all equally very important. Early methods for estimating annual precipitation were inter-tropical discontinuity (ITD)-rainfall models (e.g. Ilesanmi, 1972; Kowal and Knabe, 1972), which gave same rainfall estimates every year at each station or latitude. Omotosho (1992) proposed a scheme based on the accumulated moisture (specific humidity departures) within the boundary layer in the early stages of monsoon development. This method possesses the inherent ability to account for the annual variability in rainfall amounts. However, a major disadvantage of the schemes of Omotosho (1990, 1992) is the sparse network of the required upper-air data over the entire West African region. At present, there are also sea surface temperature (SST) models, which can predict rainfall amount (e.g. Lamb and Peppler, 1992; Eltahir and Gong, 1996; Fontaine and Janicot, 1996; Janicot, 1998 and other models), but whose skills are still rather low (correlation coefficients of 0.3–0.4) and which only give estimates for the peak rainy season, i.e. July–September. Similarly, all existing cessation models, except that of Omotosho (1992), are rainfall-based and give the same dates of cessation of rainfall every year, which is certainly far from reality. Omotosho's (1992) method, which is based on the vertical wind shear associated with the mid-tropospheric Africa easterly jet (AEJ), is also capable of treating each year independently; however, the sparse upper-air network again limits its application. In addition, the model can only be used several weeks after the onset of rainfall, by which time all planting and sowing have already been completed. Furthermore, the authors know of no method presently being used that gives estimates of monthly precipitation values or prospects. Obviously, there is a strong need for new and long-range schemes based on more readily available data and which will consequently have wider applicability. The present study is, therefore, an attempt to provide some solutions to the above critical problems. Because West African precipitation is strongly dependent on the monsoon flow, its unique characteristics of seasonal, monthly and daily variability is, therefore, utilised to develop empirical prediction schemes for the onset, cessation, monthly and annual amount of rainfall over Kano in Nigeria. As the direction and intensity of these moisture and temperature variations of the flow over West Africa are adequately monitored by the equivalent potential temperature (θ_e), a very conservative parameter with respect to both saturated and unsaturated (dry) atmospheric process, the parameter is employed in the simple schemes presented in this paper. Obasi (1964) and Adefolalu (1972) used the parameter to investigate rainfall variability over Lagos during the so-called 'little dry season' (July–August) of the coastal areas of West Africa. More recently, Omotosho (1989a) proposed the use of the anomalies of the parameter (i.e. θ'_e) as predictors of the onset, persistence and clearance of dust haze over Kano. Later, using energetics analysis, Omotosho (1989b) further suggested that the observed negative anomalies

($\theta'_e < 0$) are essentially the result of the horizontal transport of drier and, to a lesser degree, colder air."

In 2004, Odekunle observed from the literature that "the length of the growing season can be determined in a variety of ways. Among them are Thornthwaite (1948), Thornthwaite and Mather (1955), Cocheme and Fraquin (1967) and Benoit (1977), that have employed a rainfall–evapotranspiration relation model to determine the onset and cessation of the growing season. Others have based their prediction method on upper wind data (e.g. Beer, 1977; Omotosho, 1990, 1992). In 2000, Omotosho *et al.* attempted the use of daily mean values of surface pressure, temperature, and relative humidity for the determination of onset and cessation of rainfall while Theta-E technique, which is dependent on the equivalent potential temperature was used by Omotosho (2002) to determine onset and cessation of rainfall. However, most workers (Dagg, 1965; Walter, 1968; Ilesanmi, 1972; Igeleke, 1973; Kowal and Adrews, 1973; Olaniran, 1983, 1984; Adejuwon *et al.*, 1992; Bello, 1995; Nnoli, 1996; Ati, 2002) have employed rainfall alone to determine the onset and cessation of the growing season. Rainfall totals are more widely used mainly because they are more readily available (Olaniran, 1983). He further stated that the use of rainfall data is a more direct approach rather than the use of some other related factors from which to make inferences. Although Thornthwaite and Mather (1955) employed rainfall and temperature (both of which are readily available data) to estimate the climatic water budget for agriculture, the model has not found wide use in West Africa for three main reasons. First, it has been found that temperature is not a good indicator of the available energy for evaporation or potential evapotranspiration, since it lags behind solar radiation (Ojo, 1977). Second, the model does not take into consideration the effect of advection (Ojo, 1977). Third, in the tropics, temperatures are relatively uniform and seasonal variations are small, thereby allowing a wide range of suitable crops in relation to temperature conditions (Nieuwolt, 1982). Thus, as noted by Nieuwolt (1982), temperatures are not a critical factor in tropical agriculture. Therefore, rainfall is the principal controlling element in tropical agriculture (Nieuwolt, 1982; Stern and Coe, 1982). In the use of rainfall data alone, there are two main approaches found in the literature: an absolute definition, based on a certain threshold value; and a relative definition, based on a certain proportion relative to the total rainfall (Adejuwon, 1988). The most widely accepted is the relative definition method (Ilesanmi, 1972). However, rainfall probability, especially daily rainfall probability, which is the most direct method of rainfall reliability estimate, has been relatively neglected in the determination of the length of the growing season. No matter how variable the rainfall distribution characteristics of a given region at the onset and cessation periods are, there is a certain period of the year during which it would be adequate for crop germination, establishment, and development in any given year. Such a period would not exhibit significant variation from year to year. It is exactly this kind of period that the daily rainfall probability is meant to detect. Even the recent prediction models proposed by Omotosho (2000) and Omotosho (2002), which are meant to address year-to-year variation in the rainfall onset and retreat periods, still turned out to fail in some years (27% of the cases tested). In fact, in the years of failure, the error terms are as high as 24–37 days. This study aims at determining the length of the growing season in Nigeria, and also assesses the relative efficiency of the daily rainfall probability and the relative definition methods."

Odekunle (2005) in his paper 'determining rainy season onset and retreat over Nigeria from precipitation amount and number of rainy days', finally concluded that; "This study has examined the relative efficiency of the use of rainfall amount and rainy days in the determination of rainfall onset and retreat dates in Nigeria. The method employed in the determination of the rainfall onset and retreat dates is the percentage cumulative mean rainfall value. The results obtained show that both methods (the use of rainfall amount and rainy days) are equally efficient with respect to the mean rainfall onset and retreat dates. With respect to the rainfall onset and retreat dates of the individual years however, the use of rainy days is more efficient as it generates rainfall onset and retreat dates that are more realistic than those generated using the rainfall amount method. This study recommends the use of rainy days, rather than rainfall amount, in the determination of rainfall onset and retreat dates of the individual years."

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Locations and description of study area

The study area is Northern Nigeria, located within the boundaries of Nigeria, 3–15°E, 4-14°N. Nigeria is bordered in the northern, eastern, western, and southern parts by the Republic of Niger, Cameroon, the Republic of Benin, and the Gulf of Guinea respectively. The total land area is about 923 300 km^2. The specific locations where rainfall data were collected are Gusua, Kaduna, Kano, Katsina, Maiduguri, Potiskum, Sokoto, Yelwa and Zaria. The nine locations were selected as being representative of Northern Nigeria.

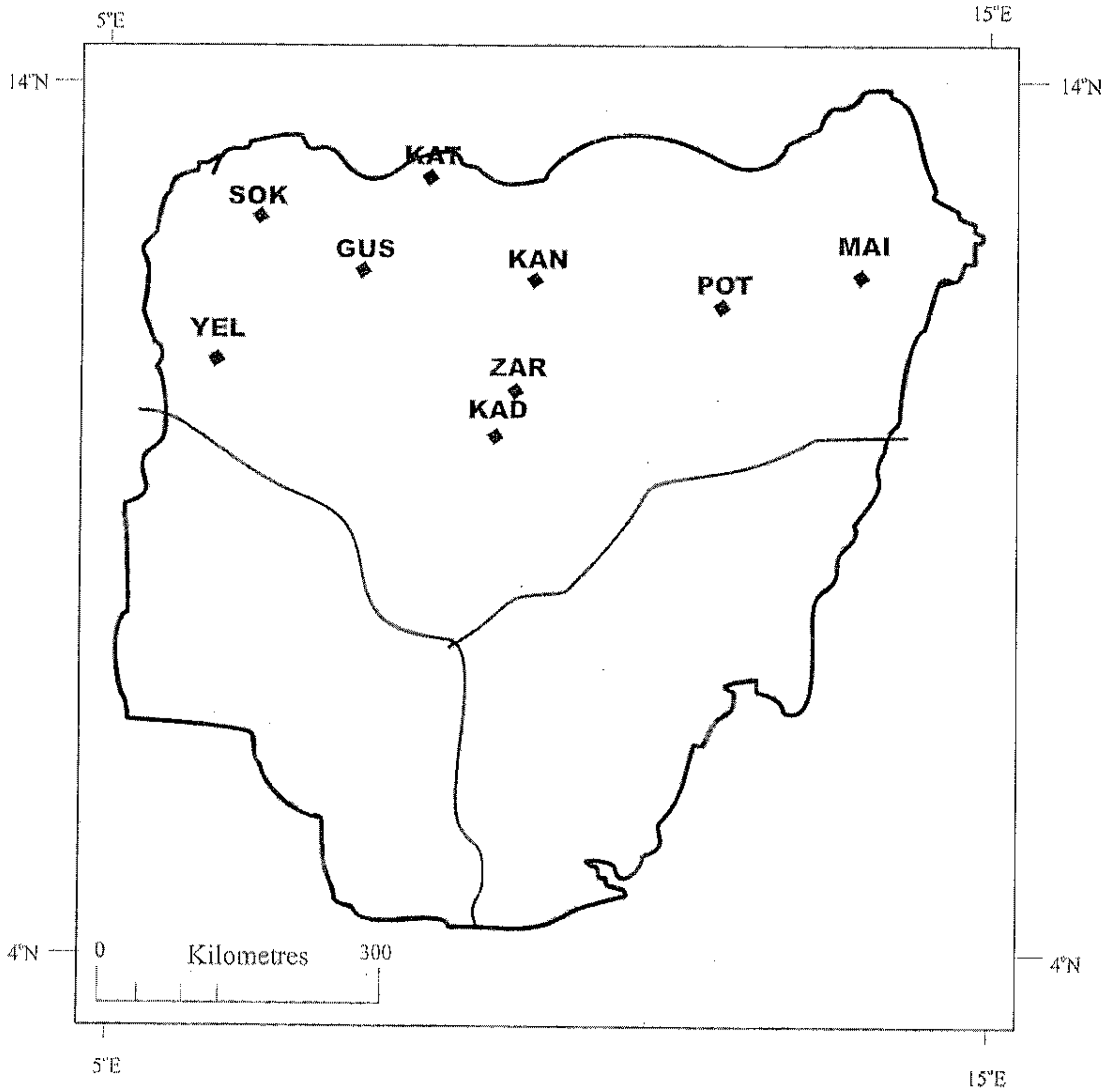


Fig 1: Map of Nigeria showing the study area

Northern Nigeria has a land area of 692,826 km^2; it is the largest geographical region in Nigeria. Nineteen out of the thirty six States of Nigeria are found in the northern region (NPC, 2010). Geographically the area is located between latitudes 7^0 and 14^0 North and longitudes 3^0 and 15^0 East. The climate of the area is marked by two distinct seasons, the short wet season that last from May to September and the prolonged dry season. Temperature is high all year round and the average annual rainfall is about 500 mm. The climate of the area is conducive for the production of several varieties of crops and animals and because of that the people are predominantly subsistence farmers. The vegetation of the area is sparse cut across three agro ecological zones; the guinea savannah is the most extensive, followed by the Sudan savannah and the Sahel. Population of the area was projected to be over 73 million (NPC, 2010).

3.2 Data collection and challenge(s)

The data used for this study is the daily rainfall data collected from archives of the Nigerian Meteorological Agency (NIMET), Abuja, Nigeria. Data for all the rainfall stations in this study are available for the period of 1981 to 2015 (35 years).

The rainfall data were collected using the British Standard rain gauge and a Dines' tilting siphon rainfall recorder. Data collected using these instruments are samples in space, and so are subject to errors, including instrumental and observer errors, and problems of data homogeneity.

Furthermore, the confidence placed in the data reliability cannot be determined. However, there are reasons to believe that the data will be of adequate quality. For instance, the seasonal distribution of the data should reflect well known tropical rainfall phenomena, such as the single maximum rainfall regime of northern Nigeria.

3.3 Methods of data analysis

The rainfall onset and cessation dates, as well as the length of the rainy season were determined by adopting the percentage mean cumulative rainfall and/or the rainy days method(s) described in Odekunle (2004). The method has the advantage of directly using the rainfall data or rainy days, rather than inferring the rainfall amount from other related parameters, making it appropriate for this study. Odekunle (2004, 2006) and Olaniran (1984) indicates that at any time and location where the method appear, to be less accurate in the determination of the onset and cessation dates of rainfall, the dry spells involved and frequency of those dry spells must be very short (mostly less than 5 days) and very low. According to Odekunle (2004), points of maximum curvature, corresponding to the onset and cessation of rainfall, are expected to be 7%–8% and over 90% of the annual rainfall, respectively.

3.3.1 Rainfall distribution

IPCC (2007) proposed a statistical approach to climate and climate change studies and this forms the focal point of this study as an attempt was made to study rainfall distribution in the Northern part of Nigeria.

Thirty five-year monthly rainfall values from nine selected stations in Northern Nigeria were collected from the archive of the Nigerian Meteorological Agency (NIMET) and the annual values over each station were calculated using this equation:

$$A = \sum_{i=1}^{12} Ri$$

Where R is the monthly rainfall amount at each station, *i* is the months of the year, and A is the annual rainfall amount at that station.

Graphs of the group data where plotted using Microsoft Excel. The result shows the trend in rainfall distribution over the study period.

A first step in the use of this method is to define the threshold value of rainfall amount required for a day to be counted as rainy. The Nigerian Meteorological Services Oshodi, Lagos usually employs two thresholds 0.3mm or 1mm. However, several thresholds have been investigated by Garbutt et al. (1981) and 0.85mm was found appropriate for agricultural purposes in West Africa. Therefore, a threshold value of 0.85mm is employed in this study. This implies that, all days with rainfall below this threshold value are not included as rainy days, (Odekunle 2006).

3.3.2 Rainfall Onset and Cessation Dates

The proponents of the method of percentage cumulative mean rainfall for determining rainfall onset and retreat dates include Ilesanmi (1972a; 1972b), Rao (1976), Adejuwon (1988) and Adejuwon et al. (1990). The first essential step of this method is to derive the mean annual rainfall that occurs at each 5-day interval of the year. This is followed by computing the percentage of the mean annual rainfall that occurs at each of the 5-day intervals throughout the year. The next step involves cumulating the percentages of the 5-day periods. Finally, when the cumulative percentage is plotted against time through the year, the first point of maximum positive curvature of the graph corresponds to the time of rainfall onset, while the last point of maximum negative curvature corresponds to the rainfall retreat. These points of maximum curvature which correspond to the onset and retreat of rainfall are respectively 7–8 percent and over 90 percent of the annual rainfall. In this study, the graphical method is used to determine the mean proportion, which is then used to estimate the rainfall onset and retreat dates for each year.

3.3.3 Length of Growing Season

In this method, the mean onset date of rainfall was defined as the first point of maximum positive curvature of the graph; the cessation date of rainfall was defined as the last point of maximum negative curvature and the duration of the rainy season was defined as the difference of the onset and cessation dates of rainfall (length = cessation = onset + 1)

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Monthly Rainfall Distribution

Monthly rainfall pattern over Northern Nigeria takes its conventional mono –modal distribution as shown in Fig. 2a-10g and agriculturally sufficient rainfall would not start over the study domain until May/June. It peaks in August.

Comparison between monthly rainfalls received in each station in the study area shows little irregularities but with the distinct peak month of August.

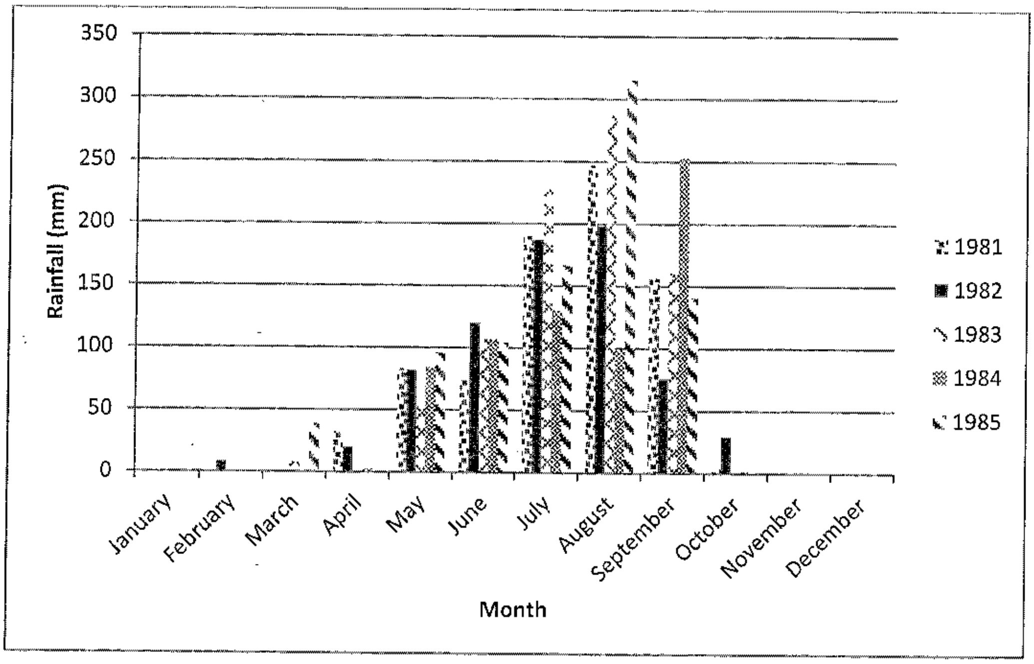


Fig 2a Comparison of monthly rainfall over Gasua (1981-1985)

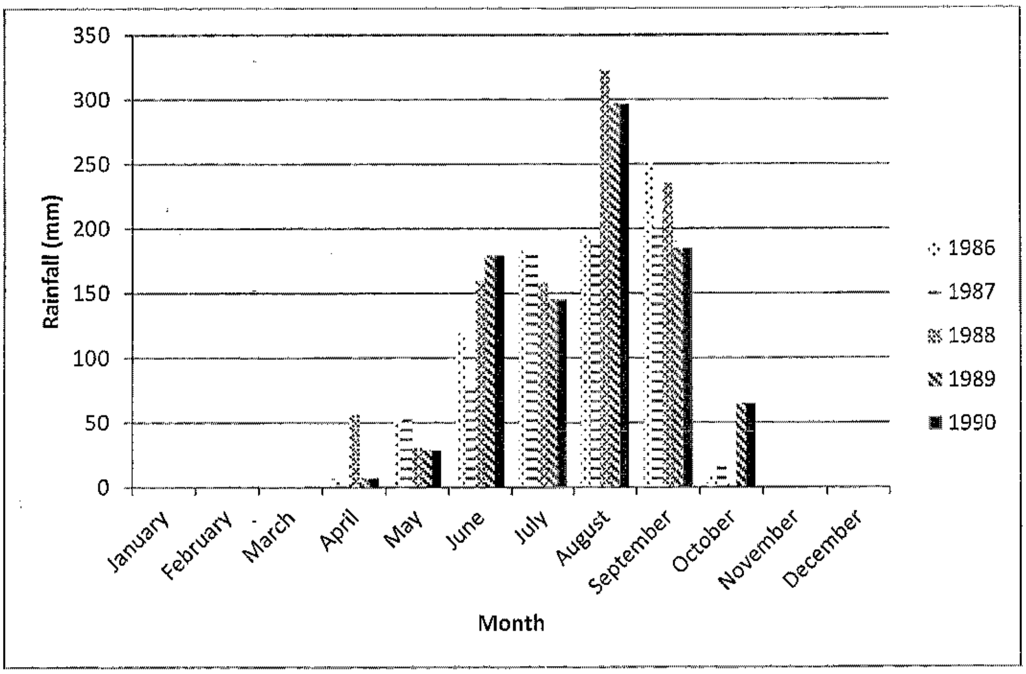


Fig 2b Comparison of monthly rainfall over Gasua (1986-1990)

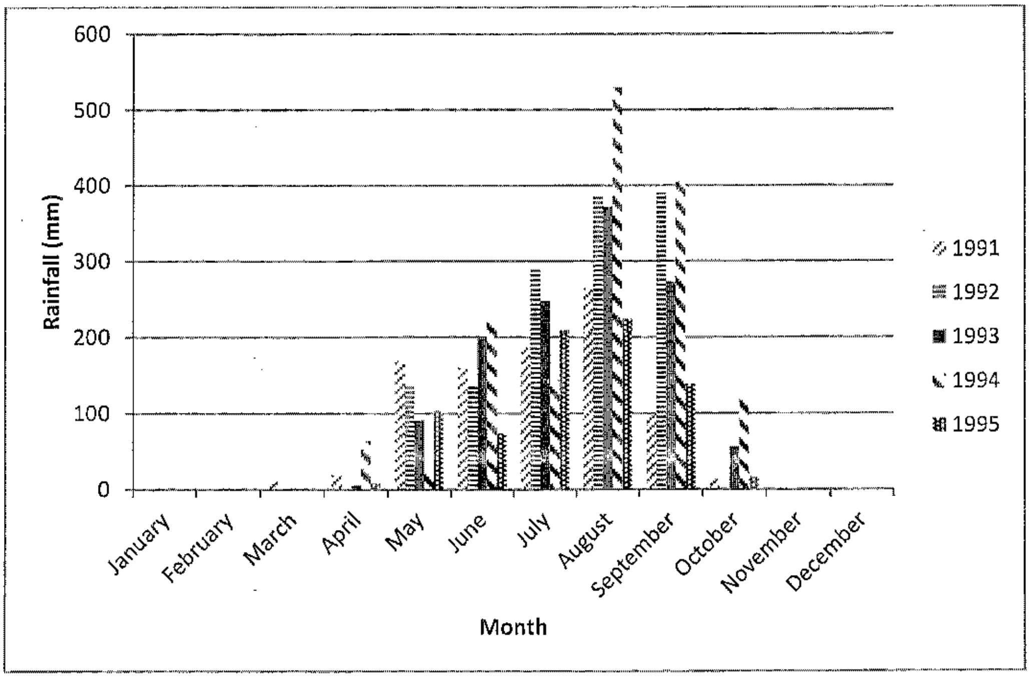


Fig 2c Comparison of monthly rainfall over Gasua (1991-1995)

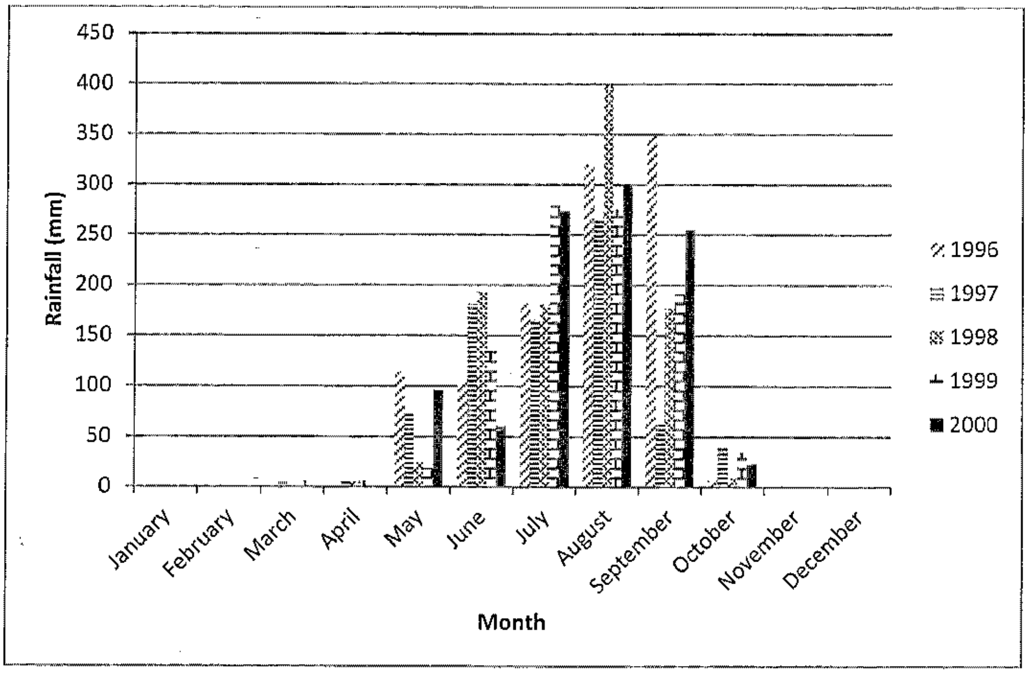


Fig 2d Comparison of monthly rainfall over Gasua (1996 – 2000)

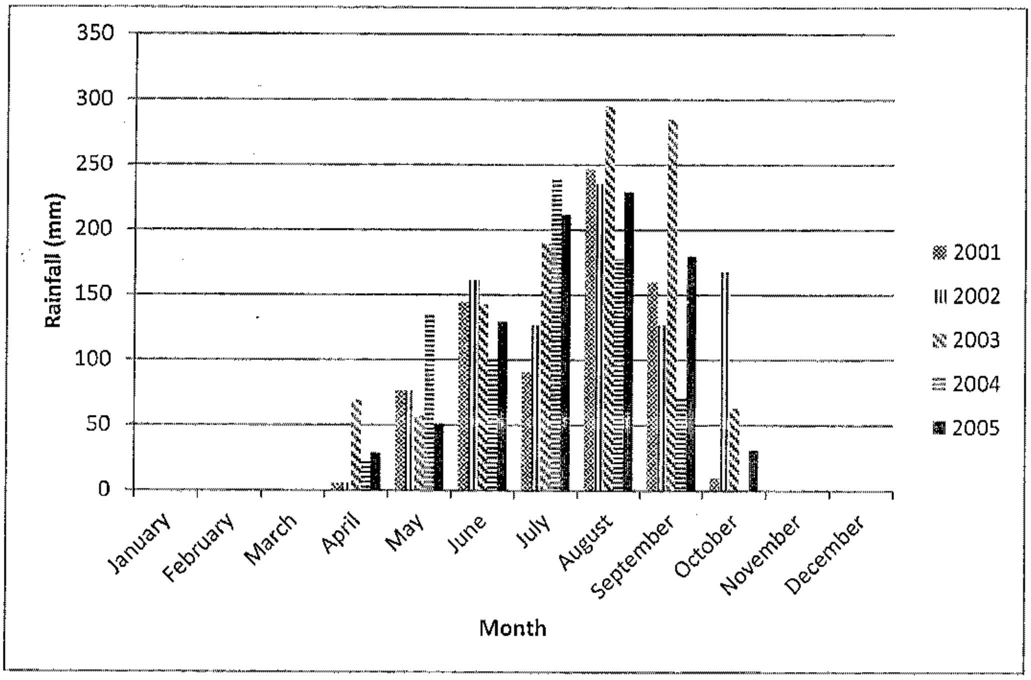


Fig 2e Comparison of monthly rainfall over Gasua (2001 – 2005)

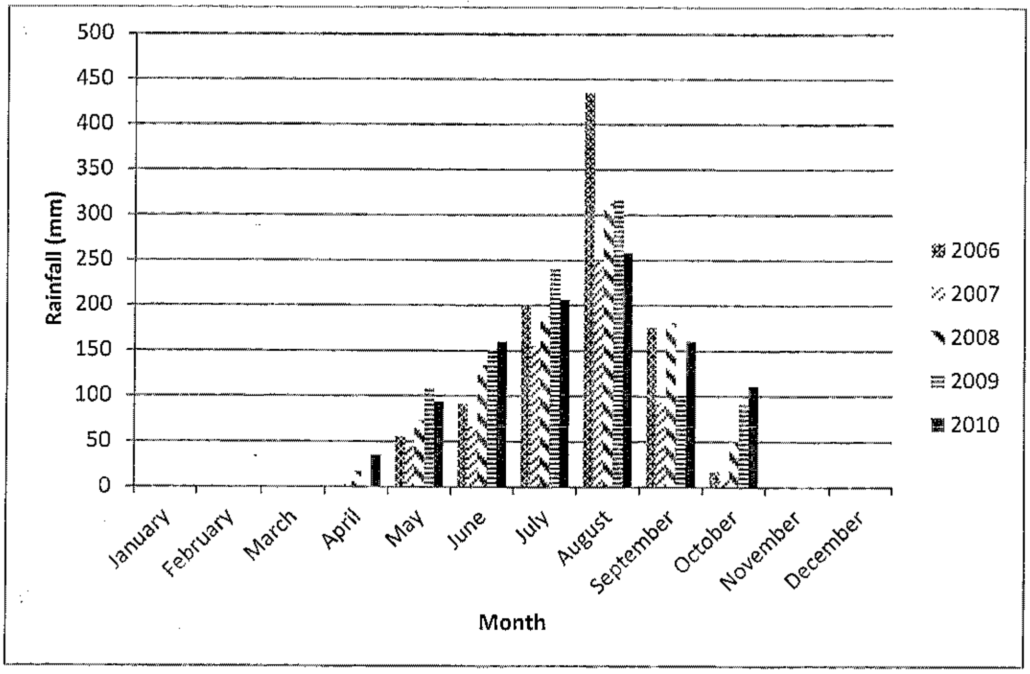


Fig 2f Comparison of monthly rainfall over Gasua (2006 – 2010)

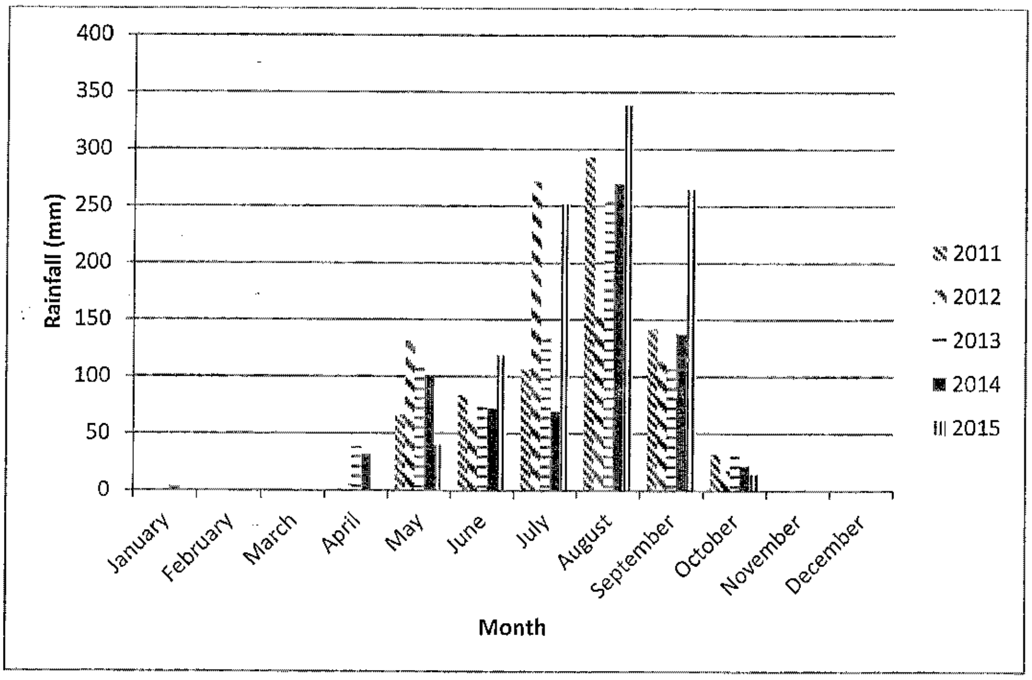


Fig 2g Comparison of monthly rainfall over Gasua (2011-2015)

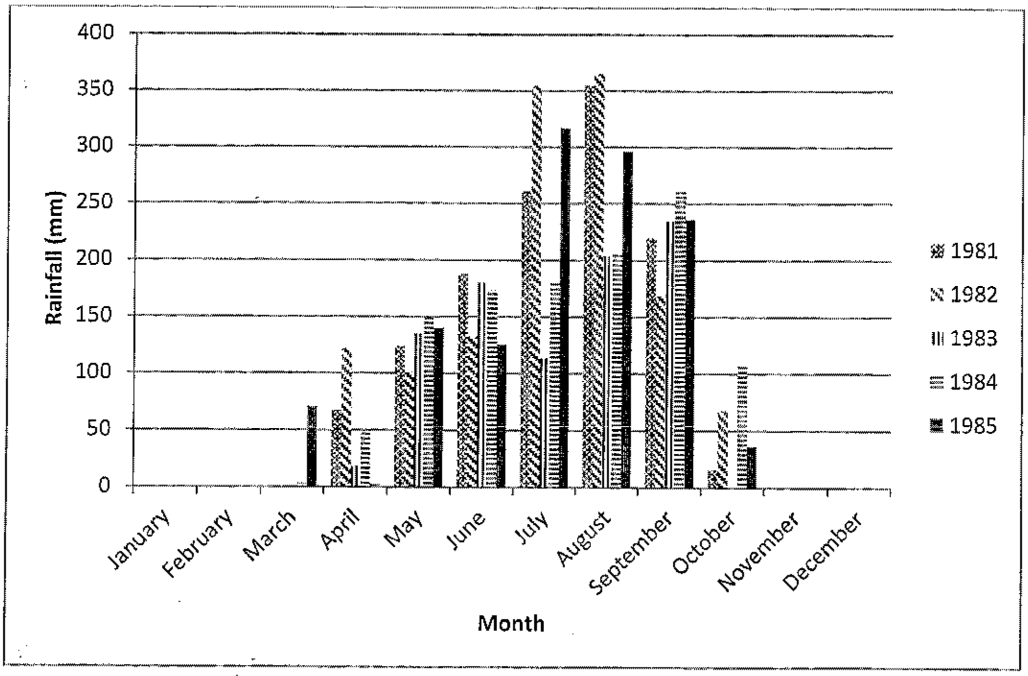


Fig 3a Comparison of monthly rainfall over Kaduna (1981 – 1985)

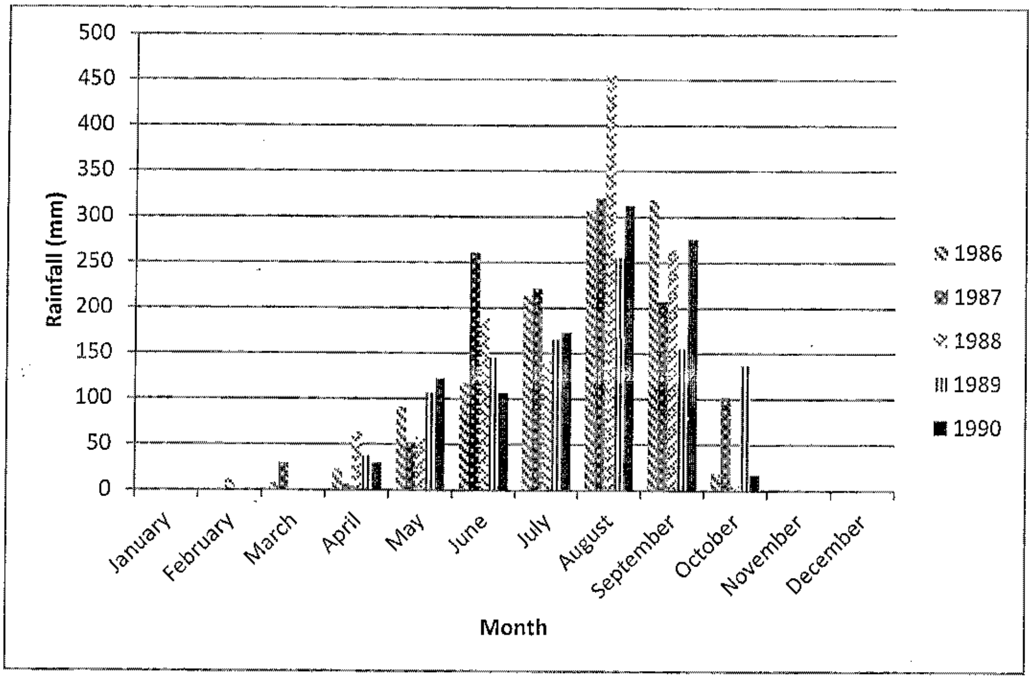


Fig 3b Comparison of monthly rainfall over Kaduna (1986 – 1990)

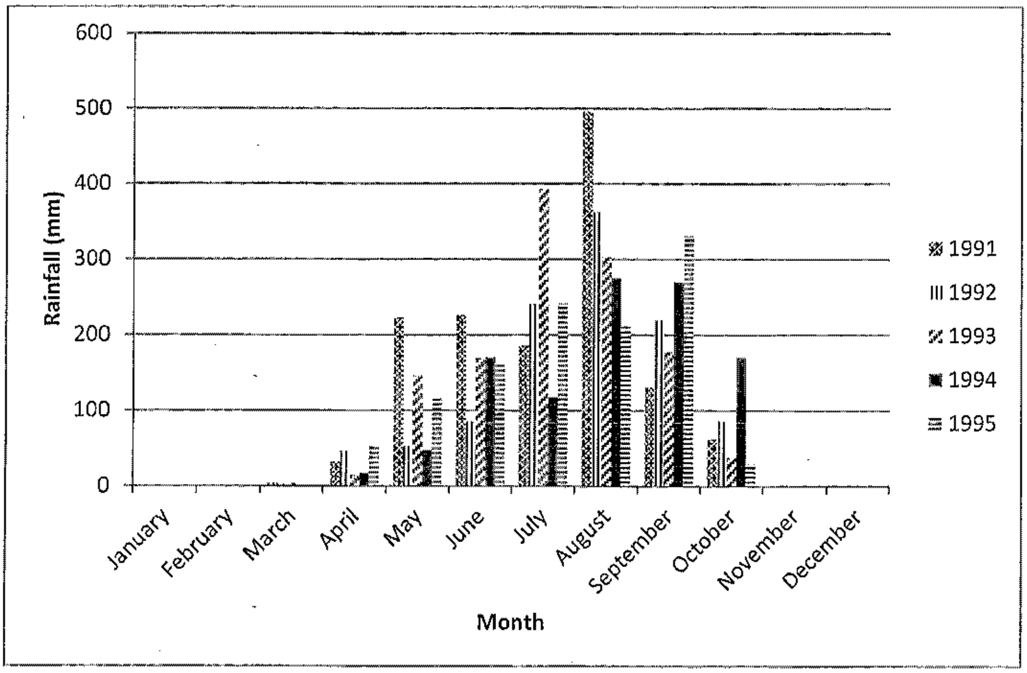


Fig 3c Comparison of monthly rainfall over Kaduna (1991 – 1995)

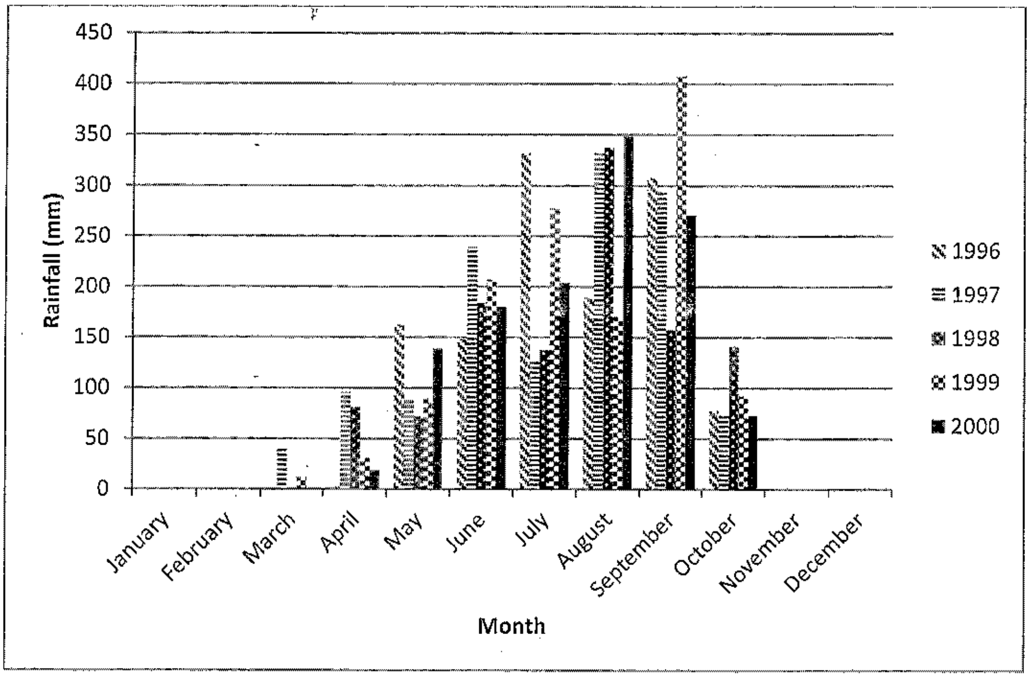


Fig 3d Comparison of monthly rainfall over Kaduna (1996 – 2000)

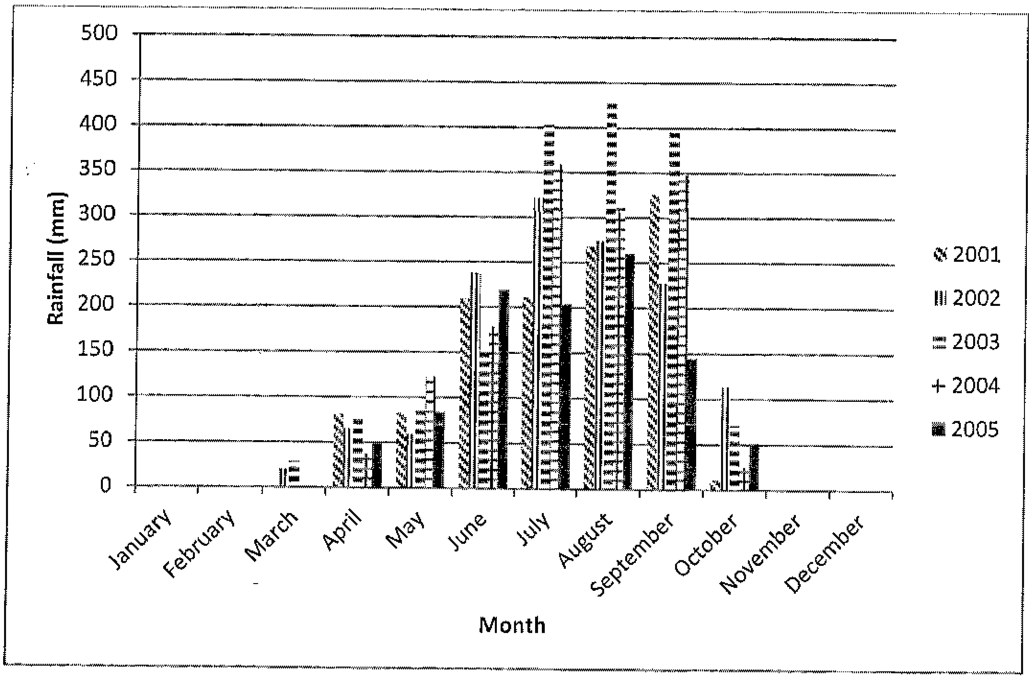


Fig 3e Comparison of monthly rainfall over Kaduna (2001 – 2005)

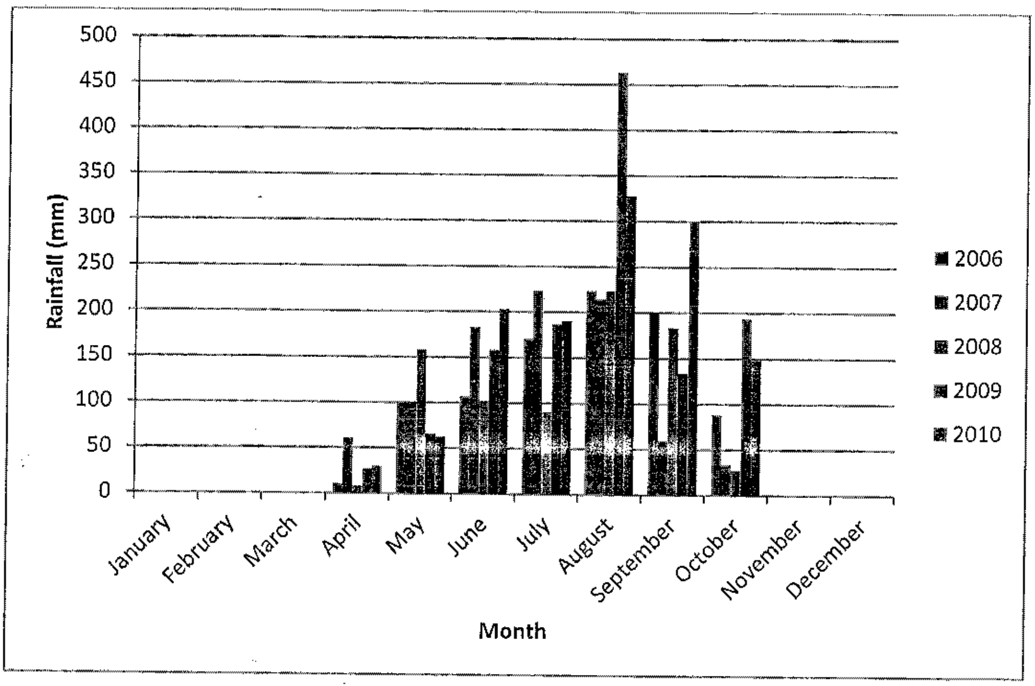


Fig 3f Comparison of monthly rainfall over Kaduna (2006 – 2010)

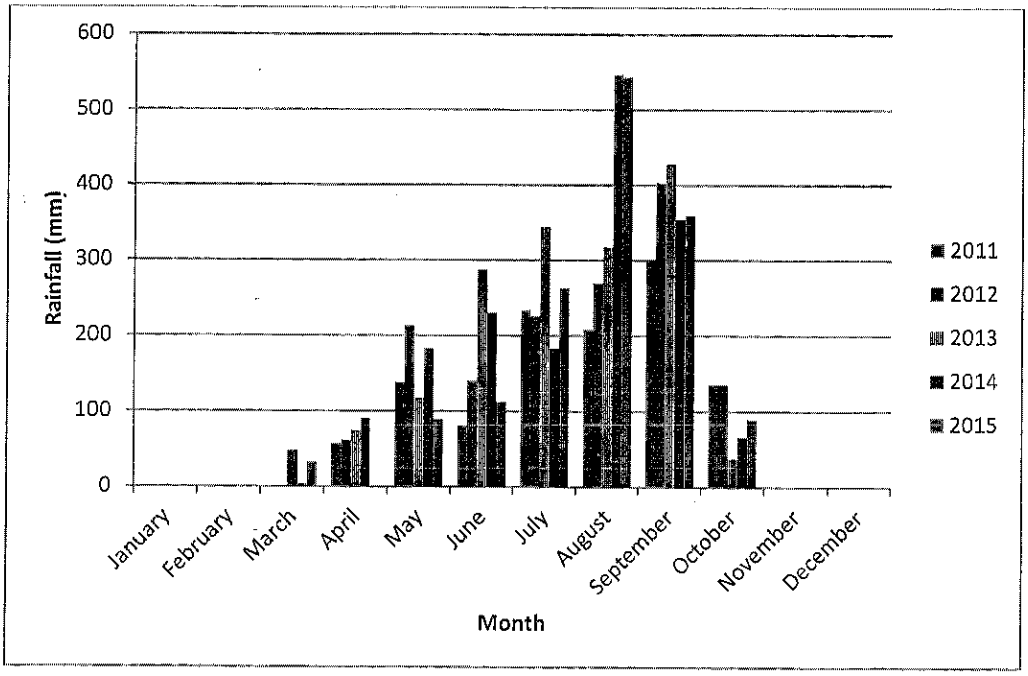


Fig 3g Comparison of monthly rainfall over Kaduna (2011 – 2015)

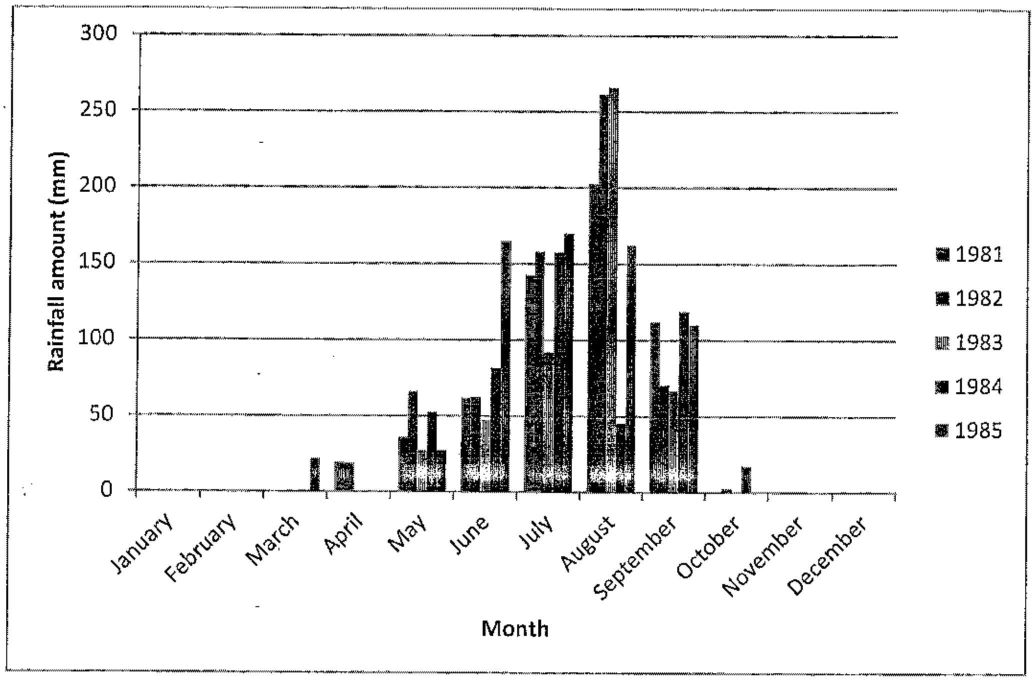


Fig 4a Comparison of monthly rainfall over Kano (1981 – 1985)

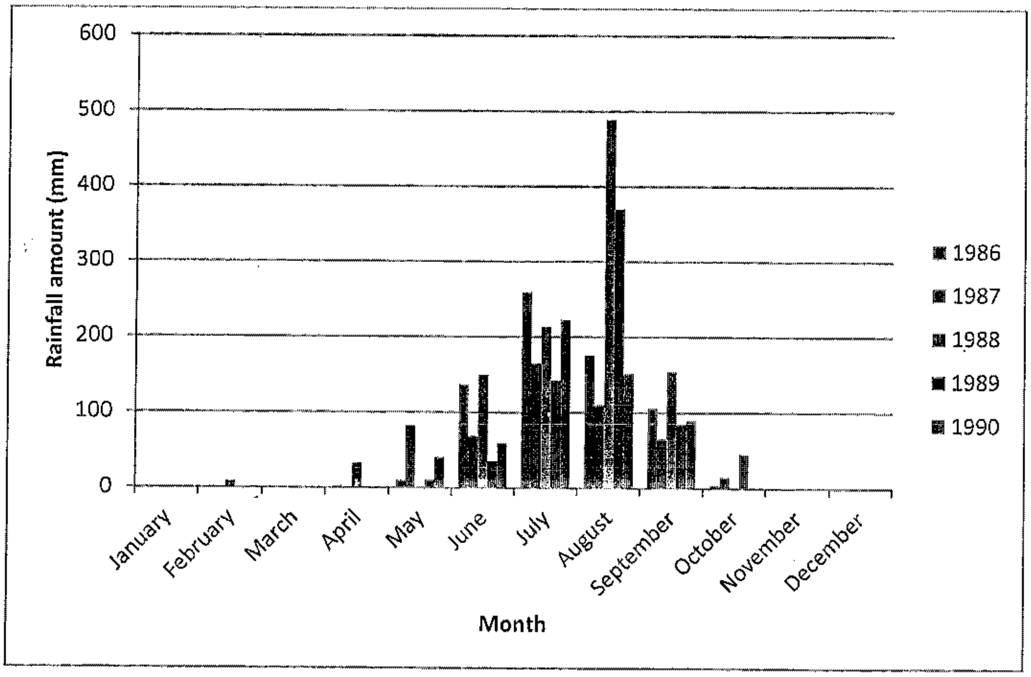


Fig 4b Comparison of monthly rainfall over Kano (1986 – 1990)

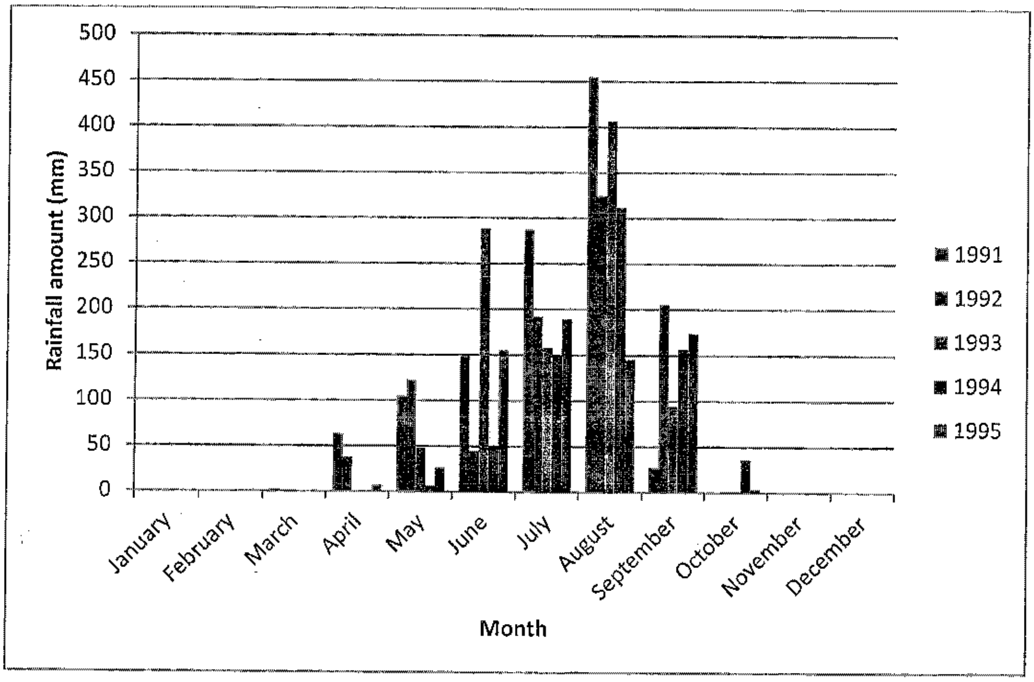


Fig 4c Comparison of monthly rainfall over Kano (1991 - 1995)

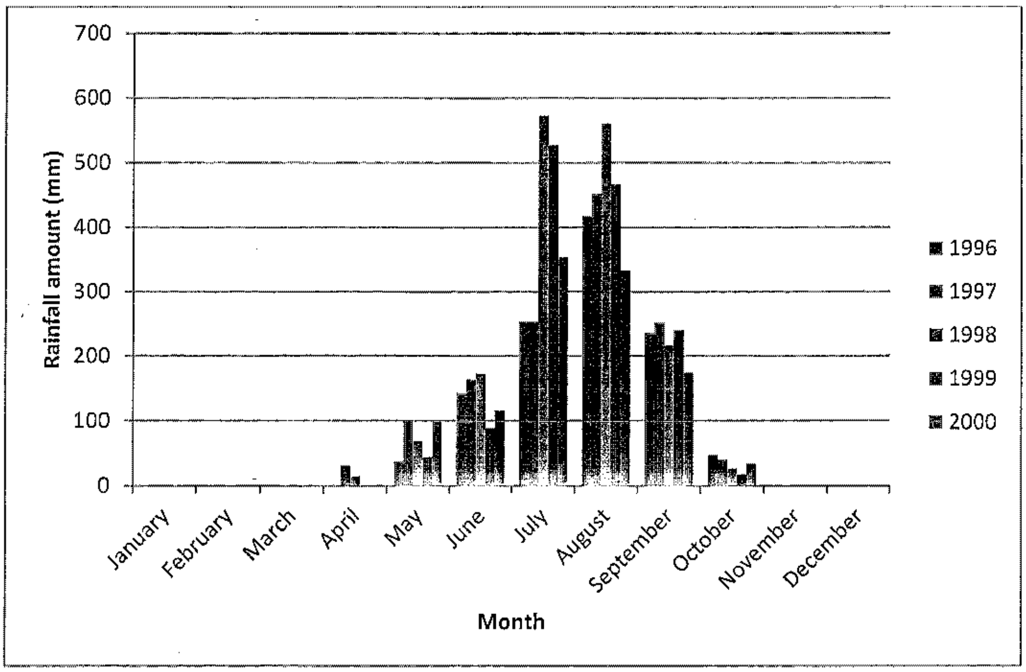


Fig 4d Comparison of monthly rainfall over Kano (1996 – 2000)

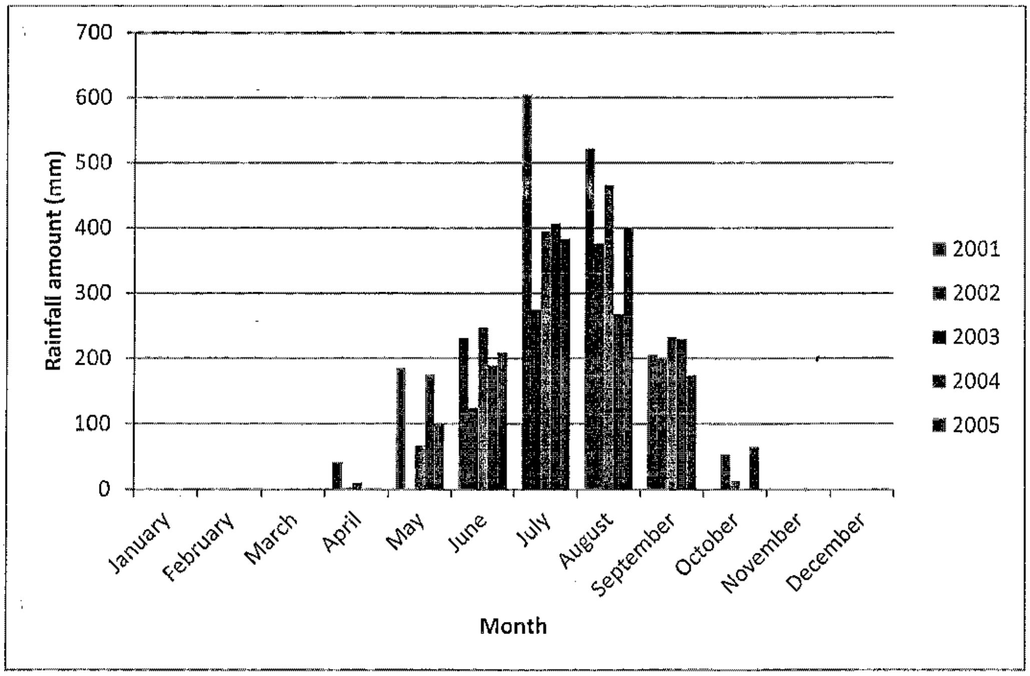


Fig 4e Comparison of monthly rainfall over Kano (2001 – 2005)

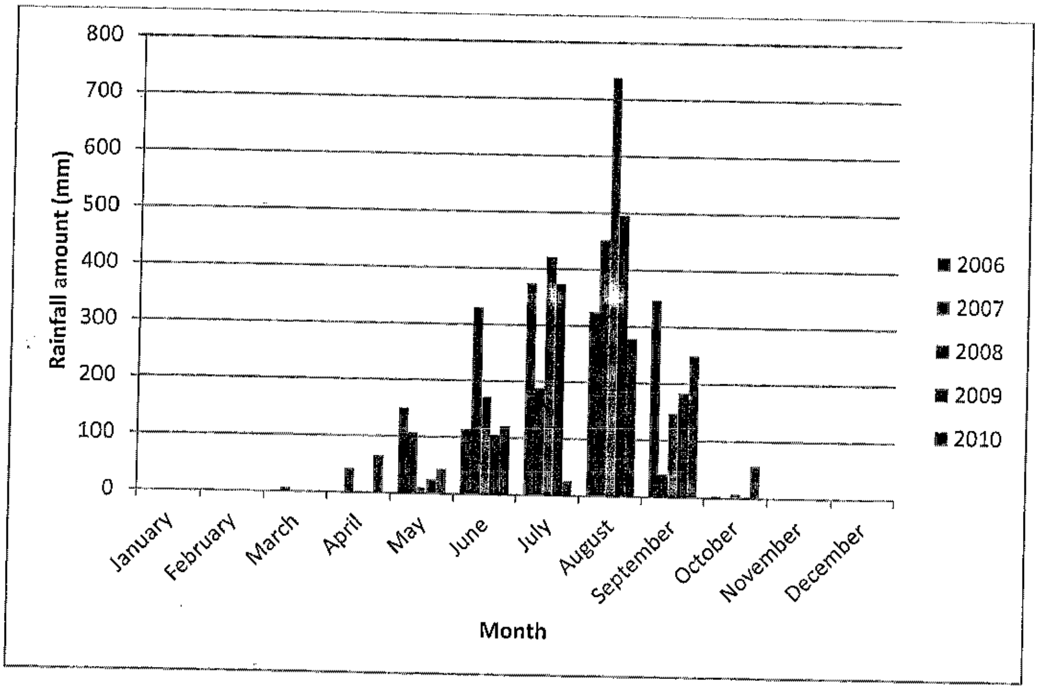


Fig 4f Comparison of monthly rainfall over Kano (2006 – 2010)

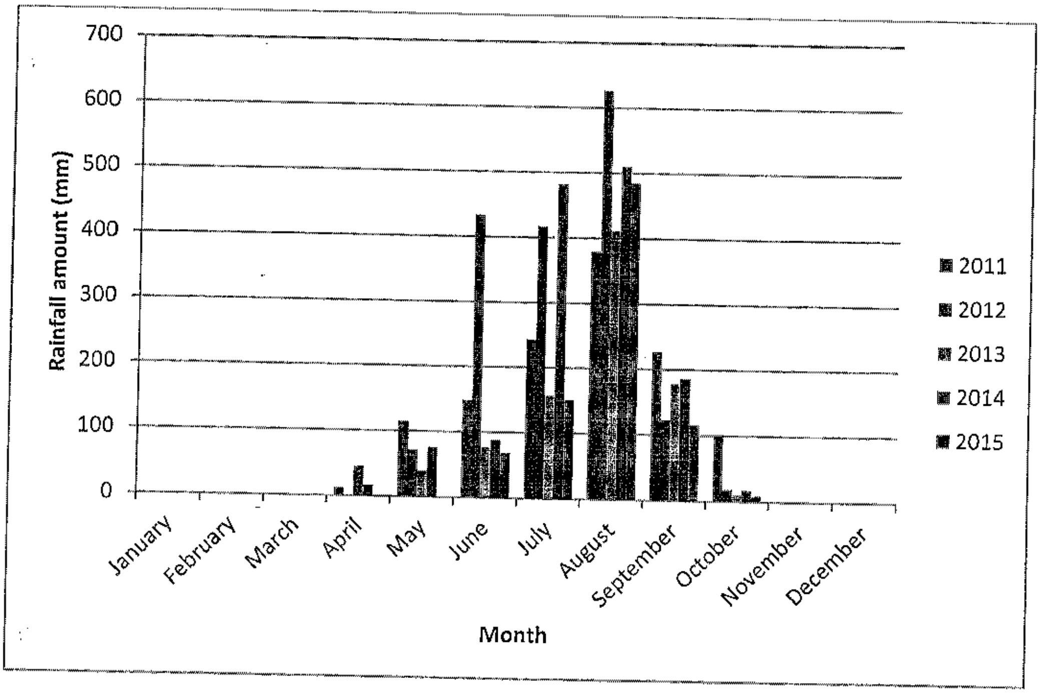


Fig 4g Comparison of monthly rainfall over Kano (2011 – 2015)

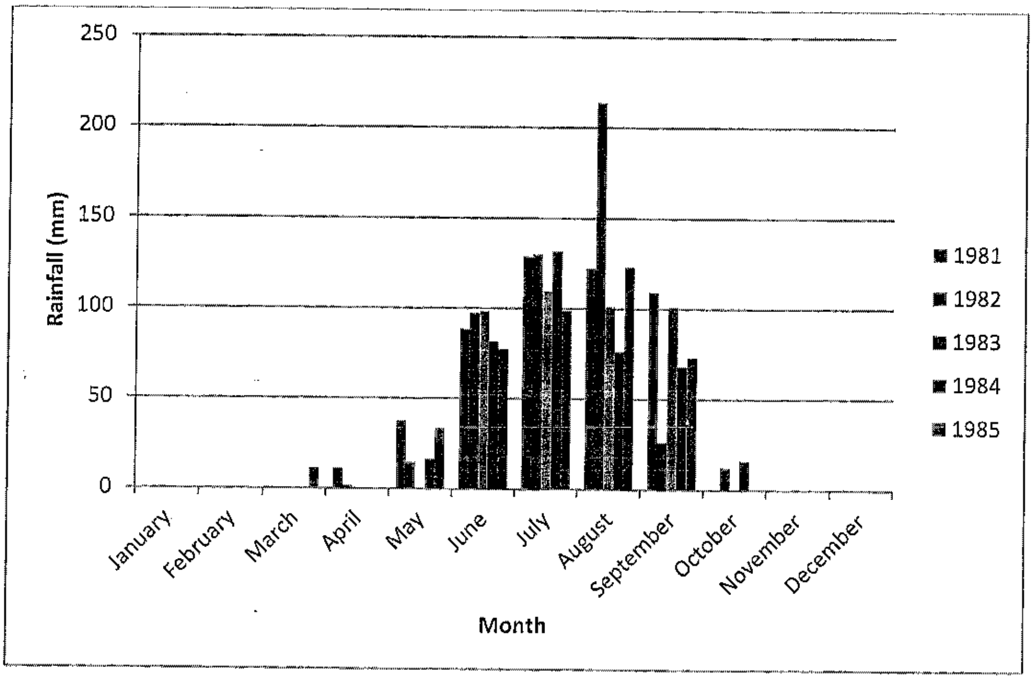


Fig 5a Comparison of monthly rainfall over Katsina (1981 – 1985)

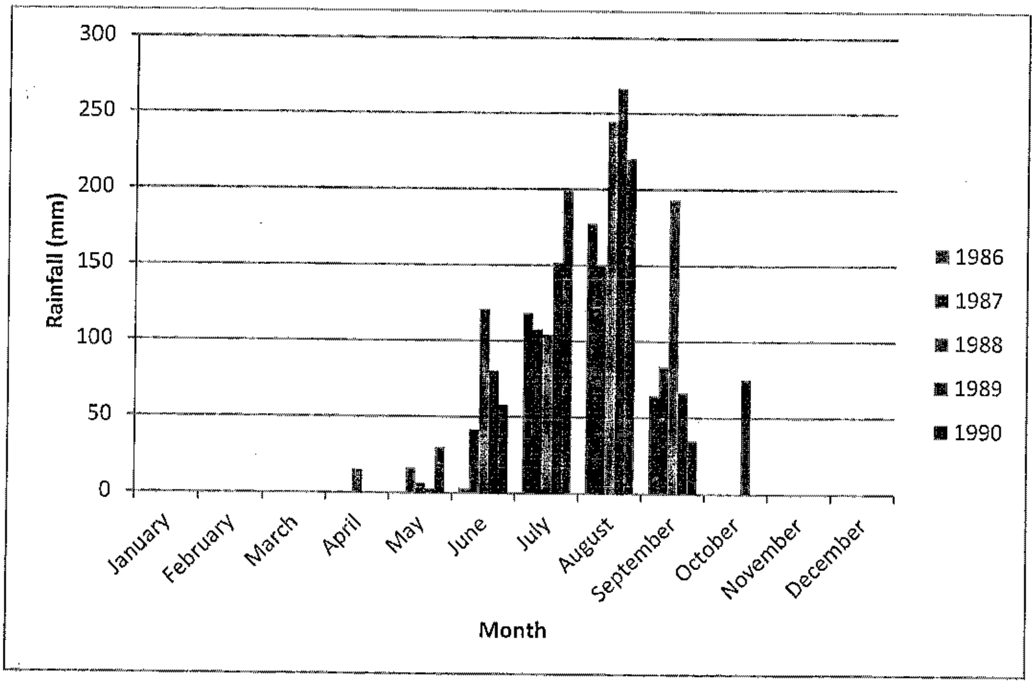


Fig 5b Comparison of monthly rainfall over Katsina (1986 – 1990)

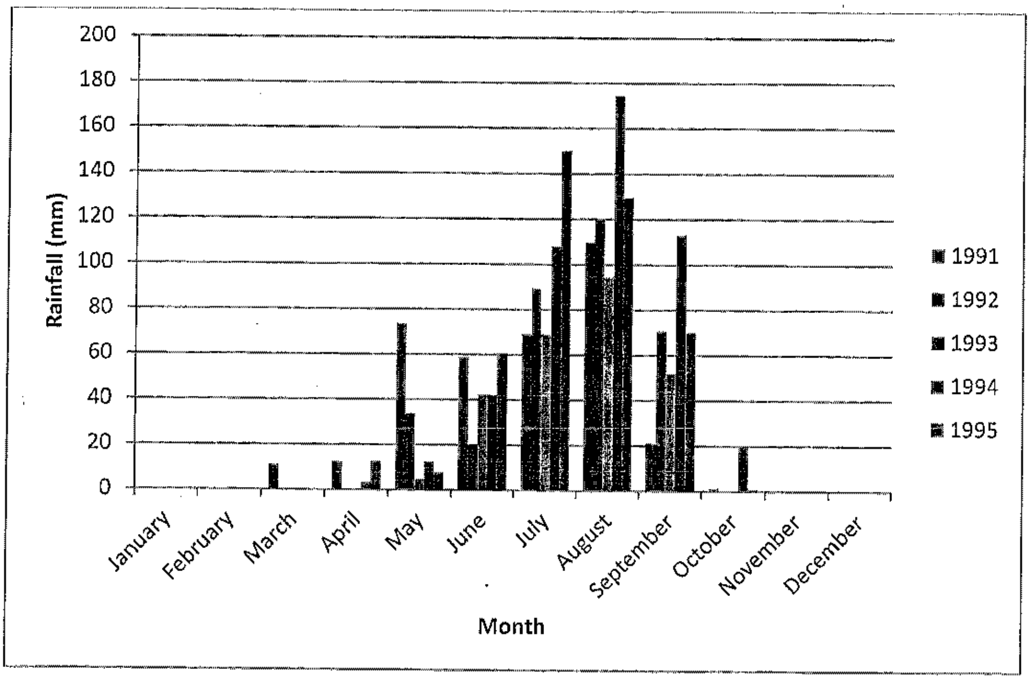


Fig 5c Comparison of monthly rainfall over Katsina (1991 – 1995)

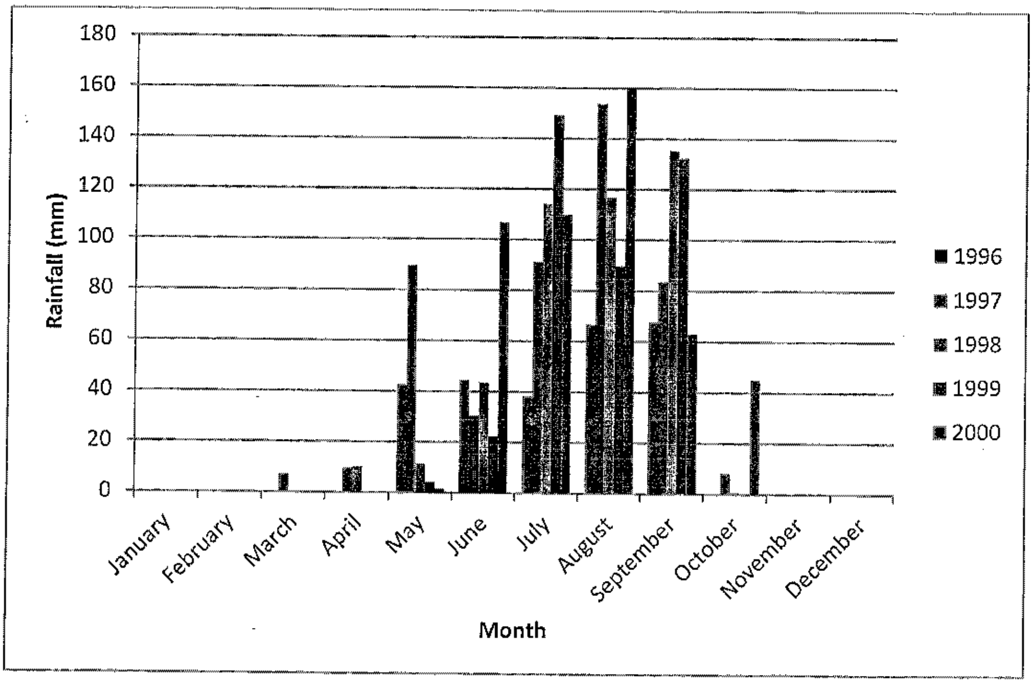


Fig 5d Comparison of monthly rainfall over Katsina (1996 – 2000)

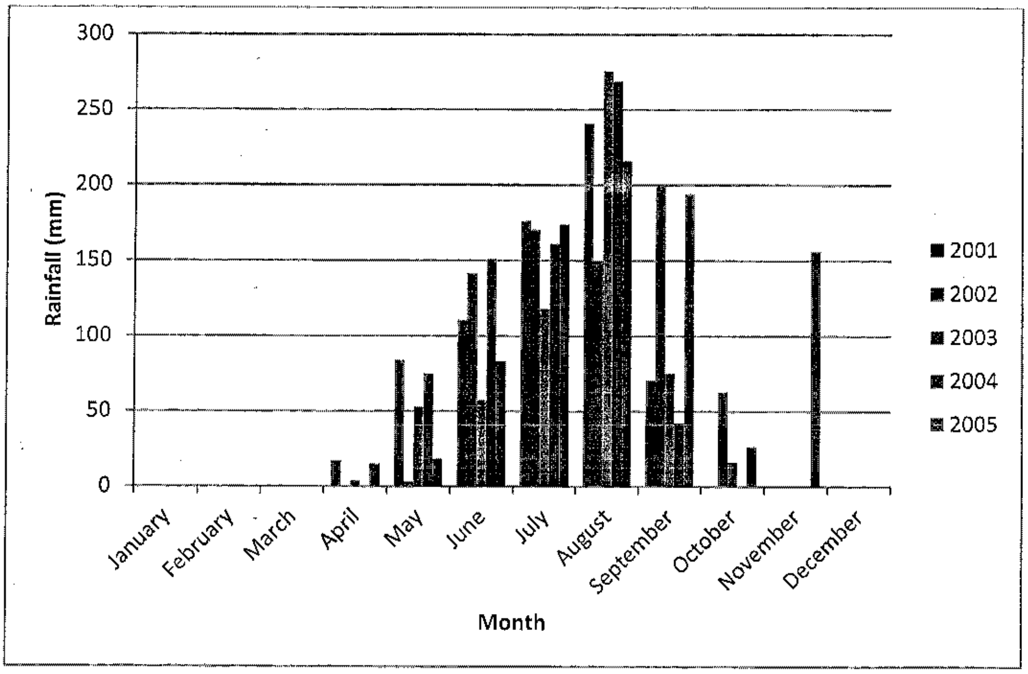


Fig 5e Comparison of monthly rainfall over Katsina (2001 – 2005)

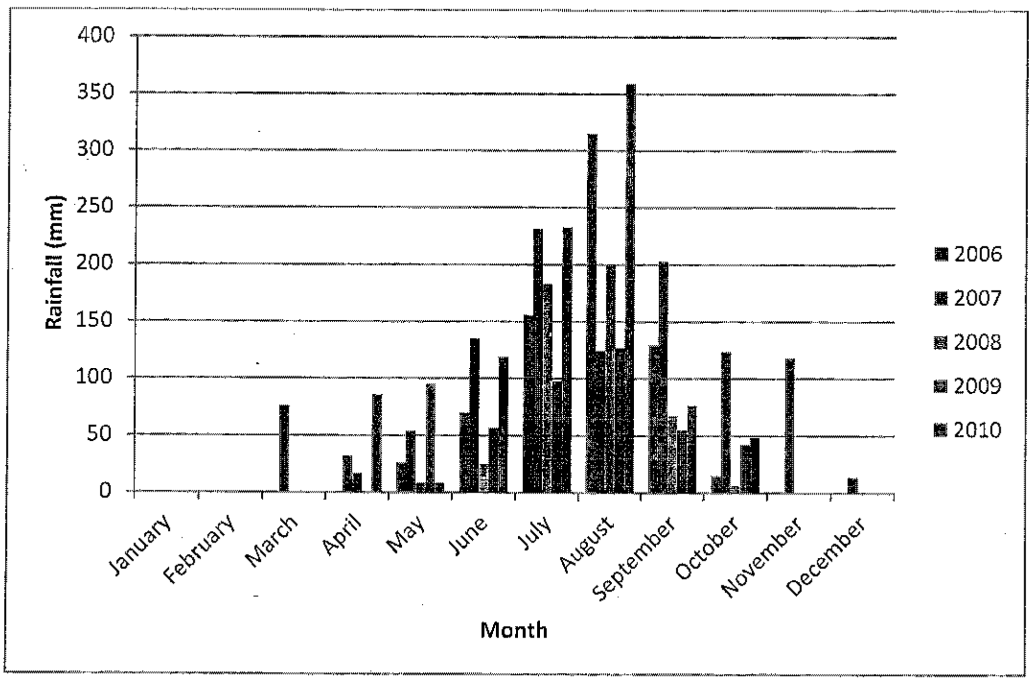


Fig 5f Comparison of monthly rainfall over Katsina (2006 – 2010)

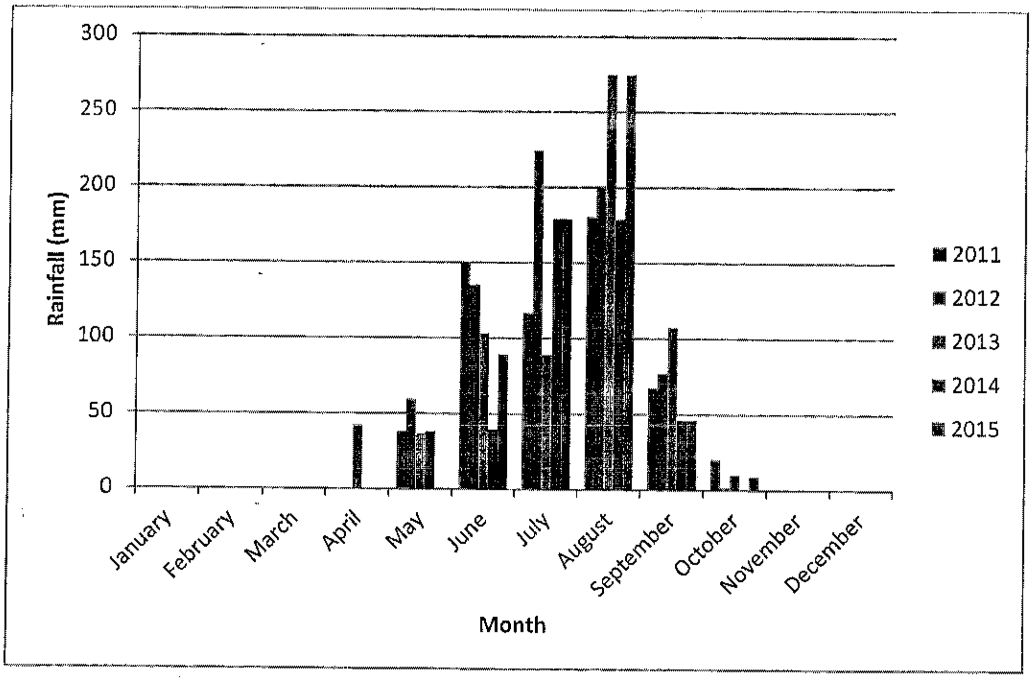


Fig 5g Comparison of monthly rainfall over Katsina (2011 – 2015)

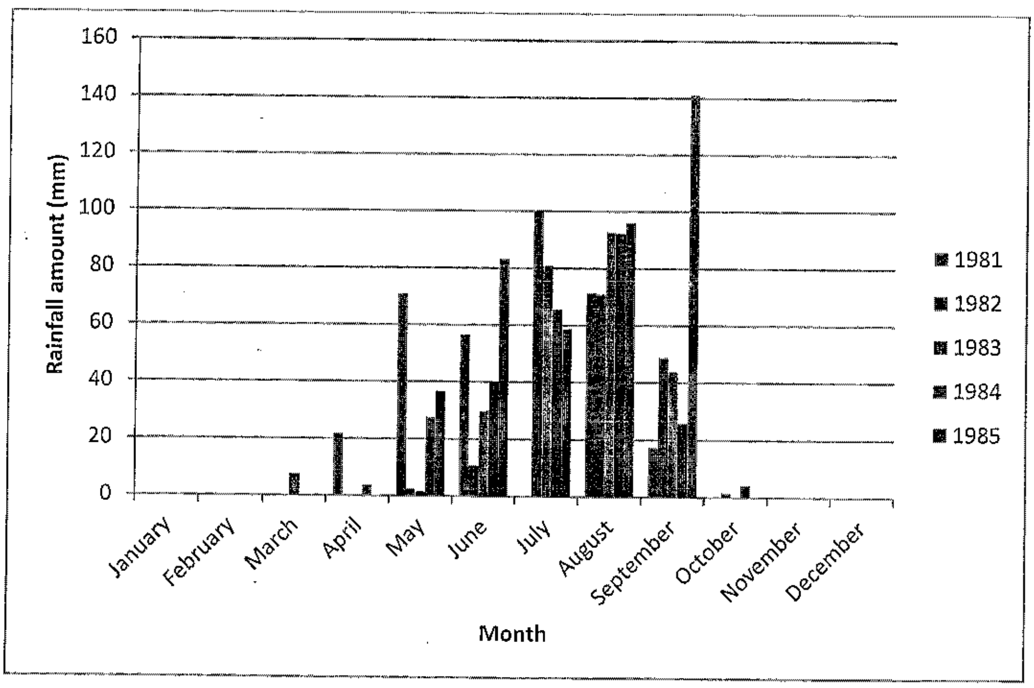


Fig 6a Comparison of monthly rainfall over Maiduguri (1981 – 1985)

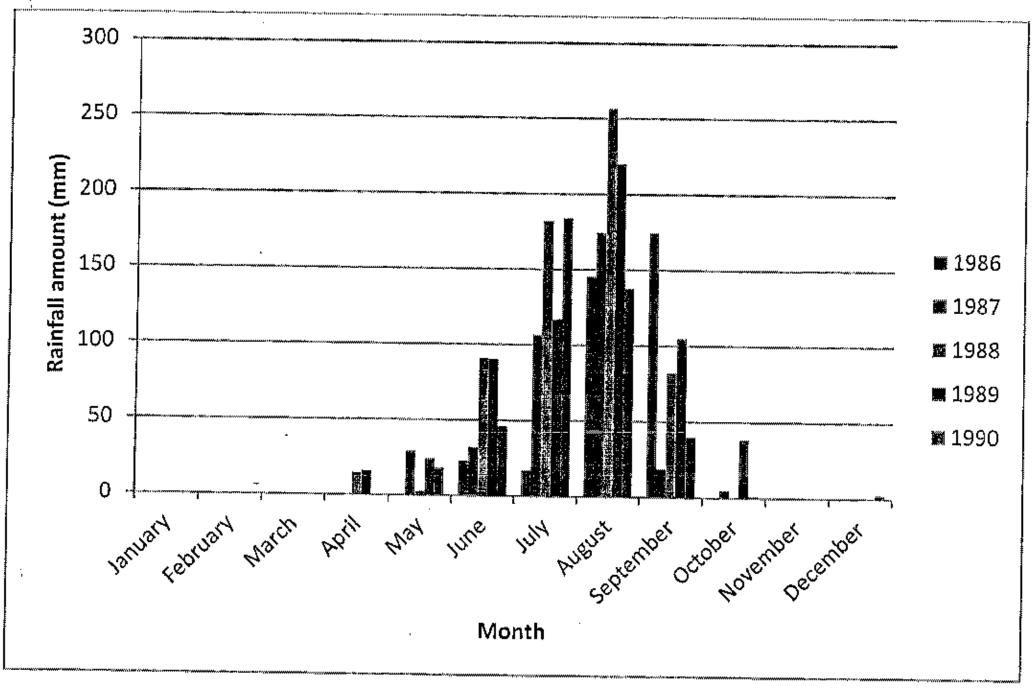


Fig 6b Comparison of monthly rainfall over Maiduguri (1986 – 1990)

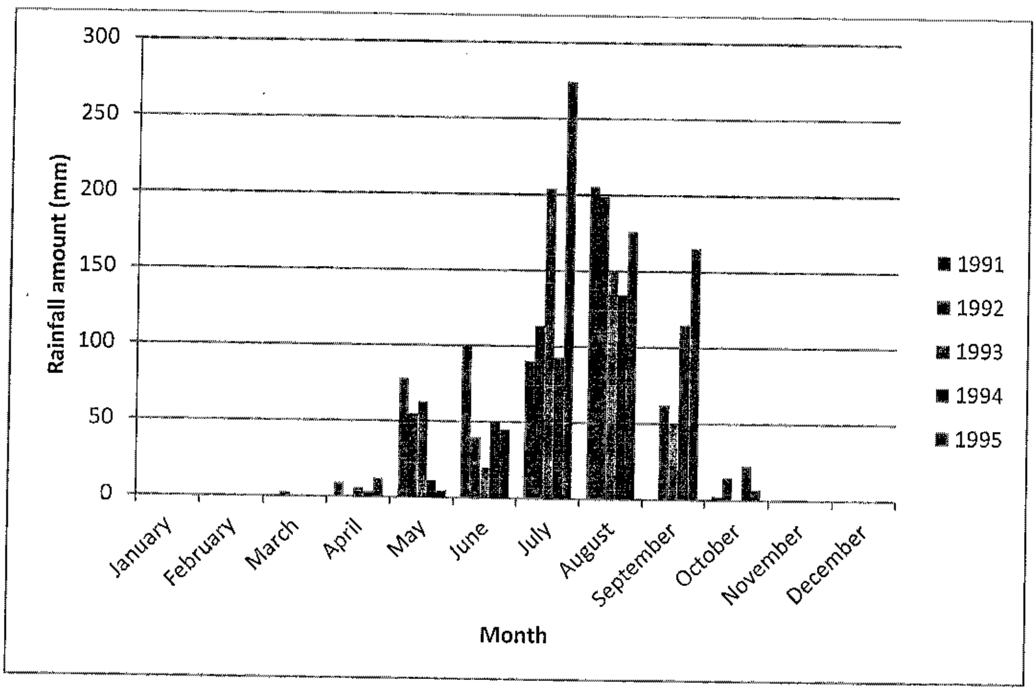


Fig 6c Comparison of monthly rainfall over Maiduguri (1991 – 1995)

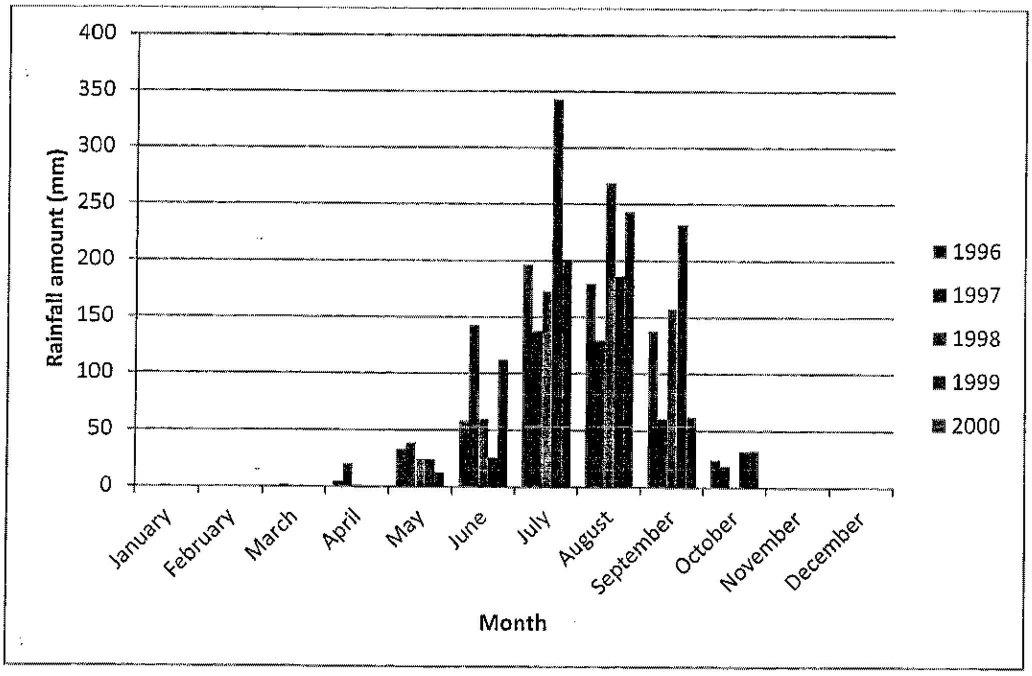


Fig 6d Comparison of monthly rainfall over Maiduguri (1996 – 2000)

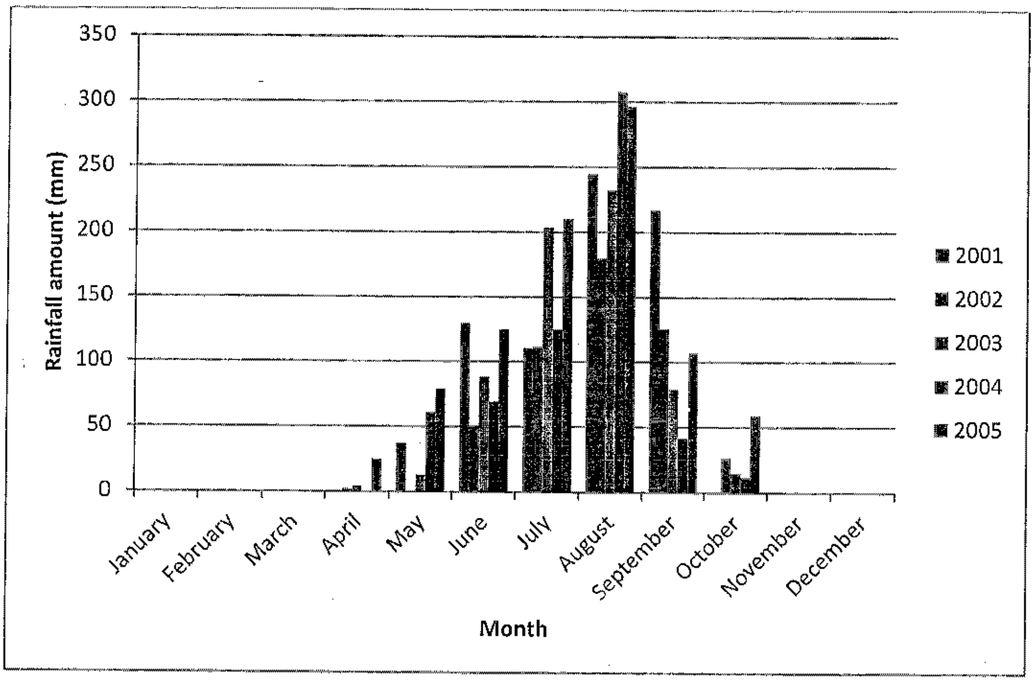
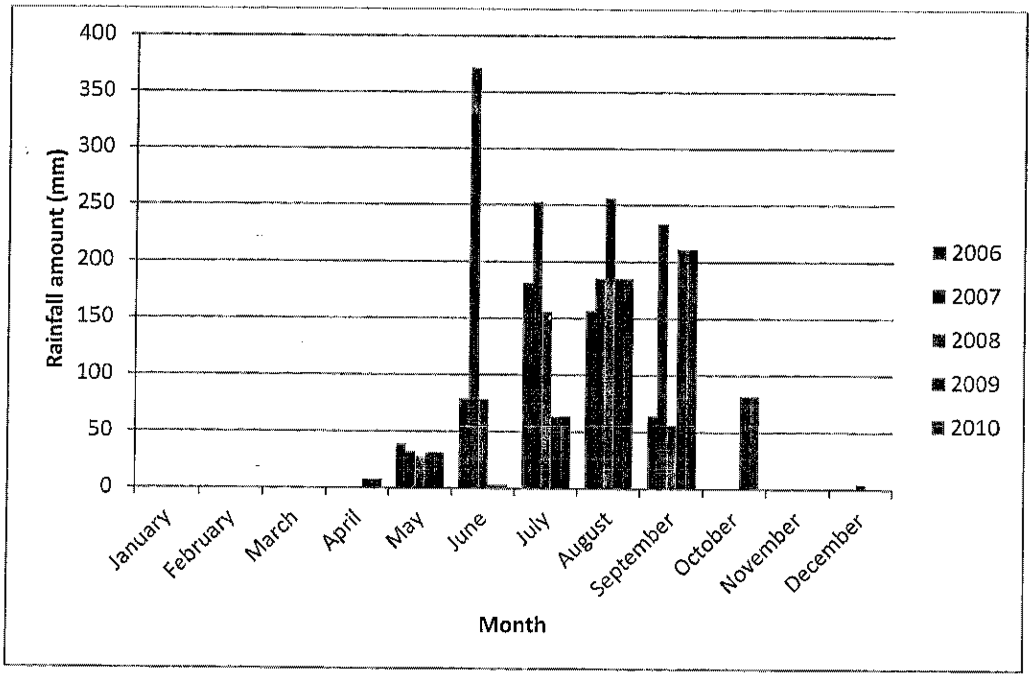


Fig 6e Comparison of monthly rainfall over Maiduguri (2001 – 2005)



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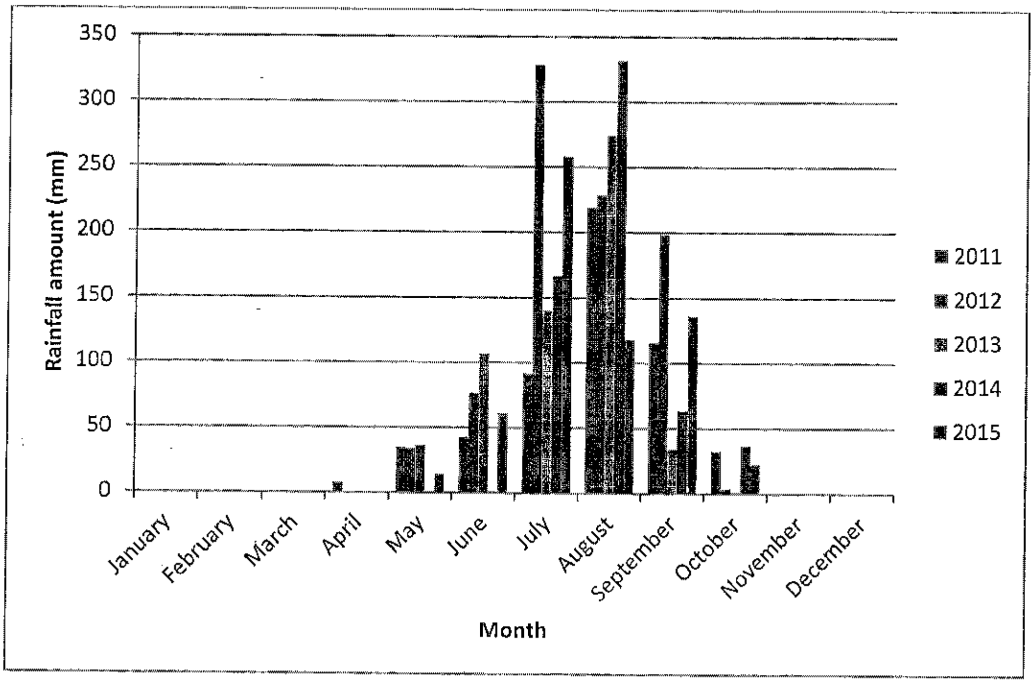


Fig 6g Comparison of monthly rainfall over Maiduguri (2011 – 2015)

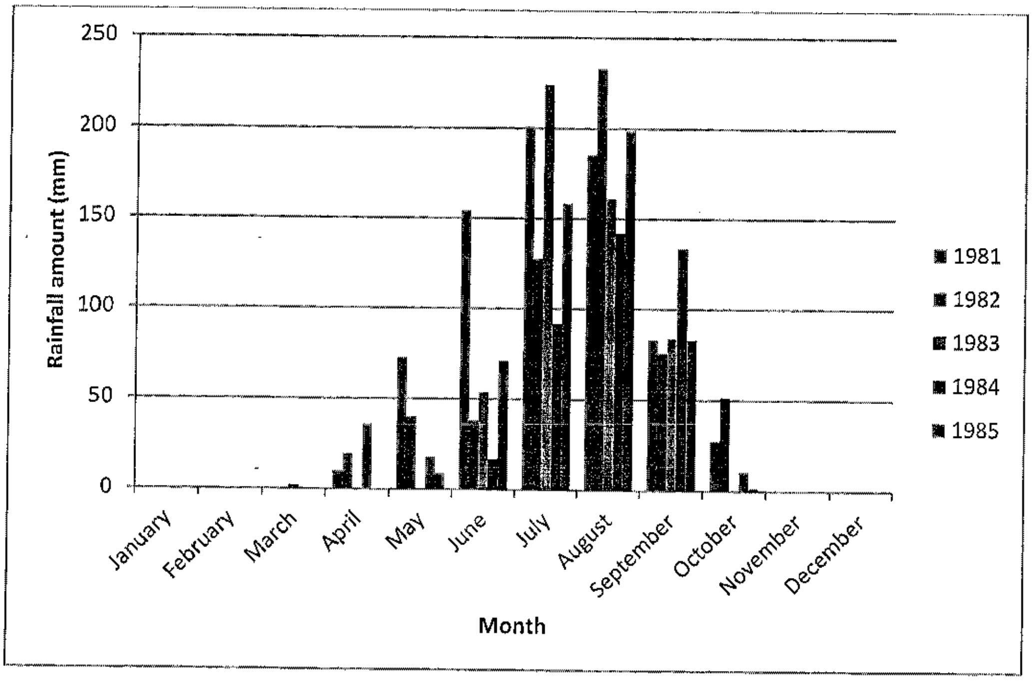


Fig 7a Comparison of monthly rainfall over Potiskum (1981 – 1985)

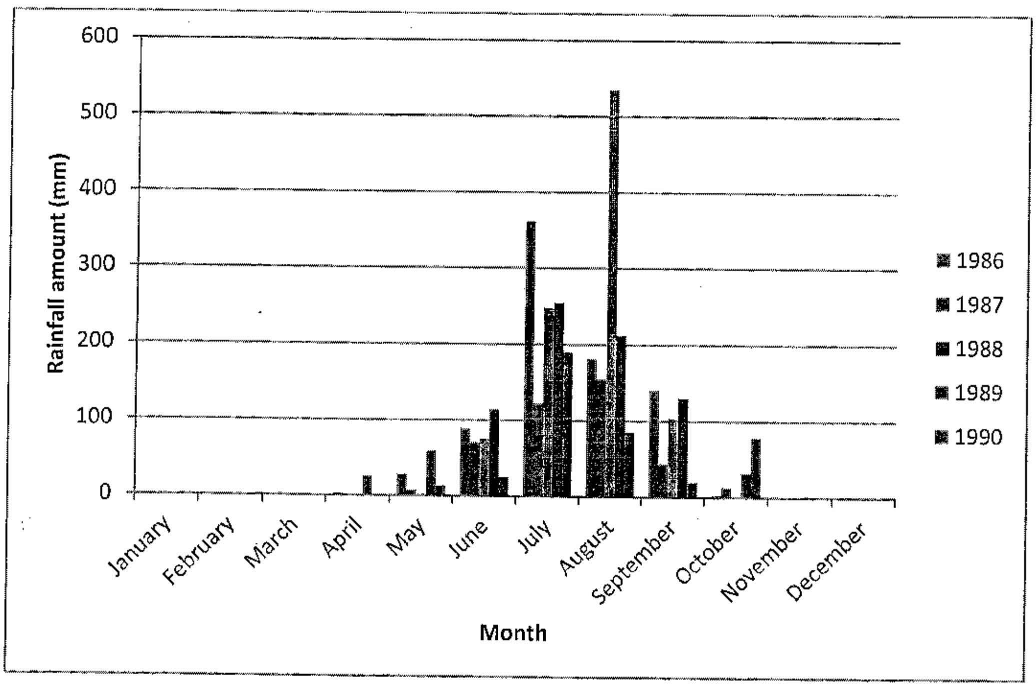


Fig 7b Comparison of monthly rainfall over Potiskum (1986 – 1990)

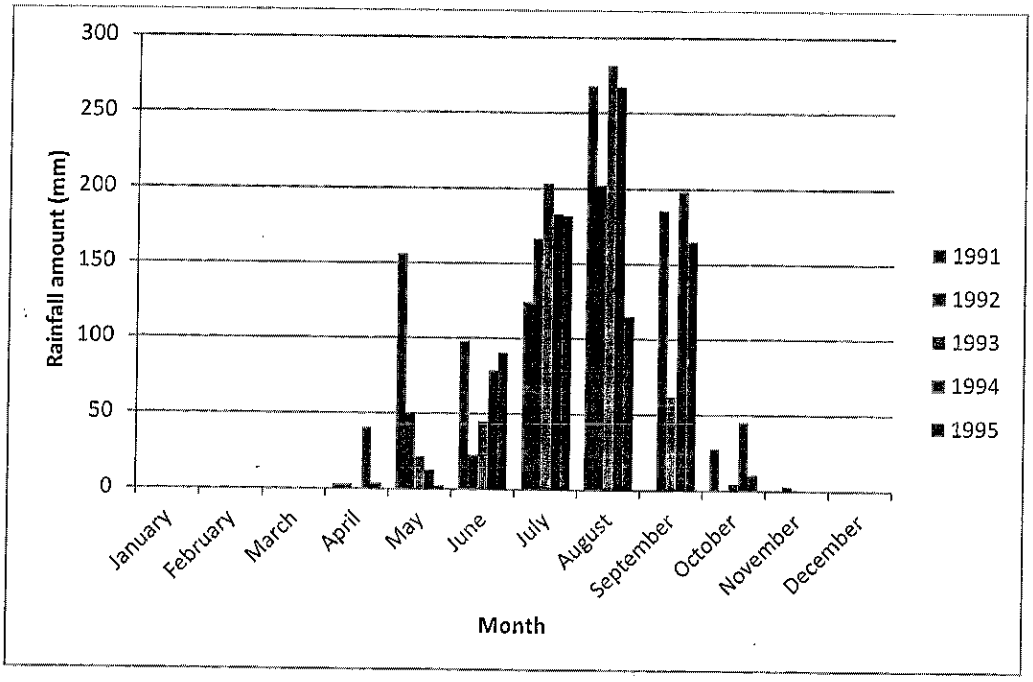


Fig 7c Comparison of monthly rainfall over Potiskum (1991 – 1995)

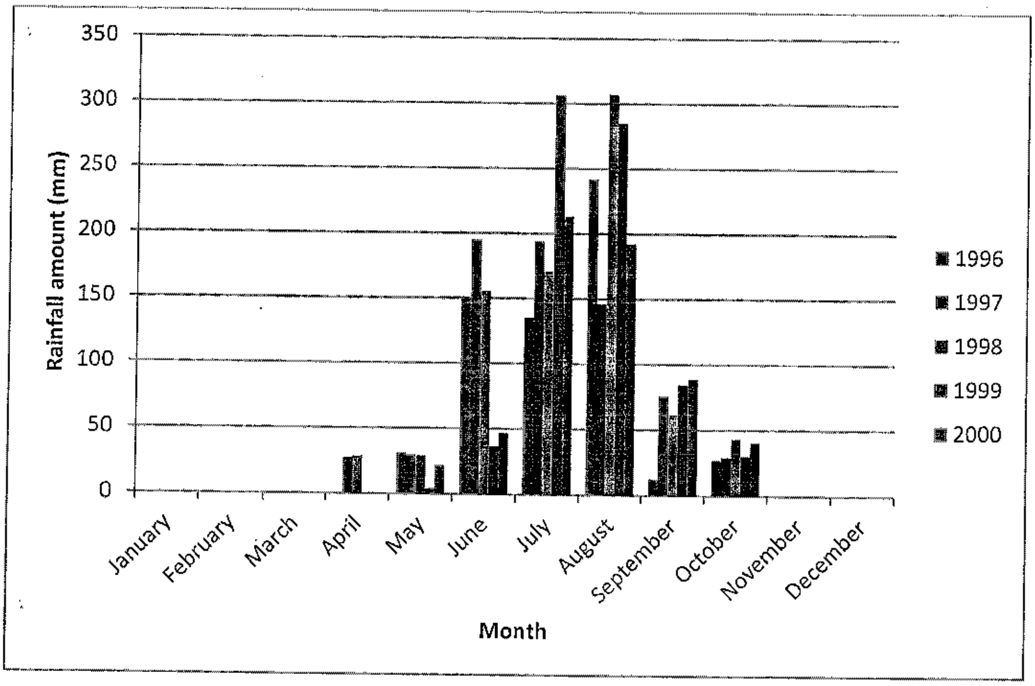
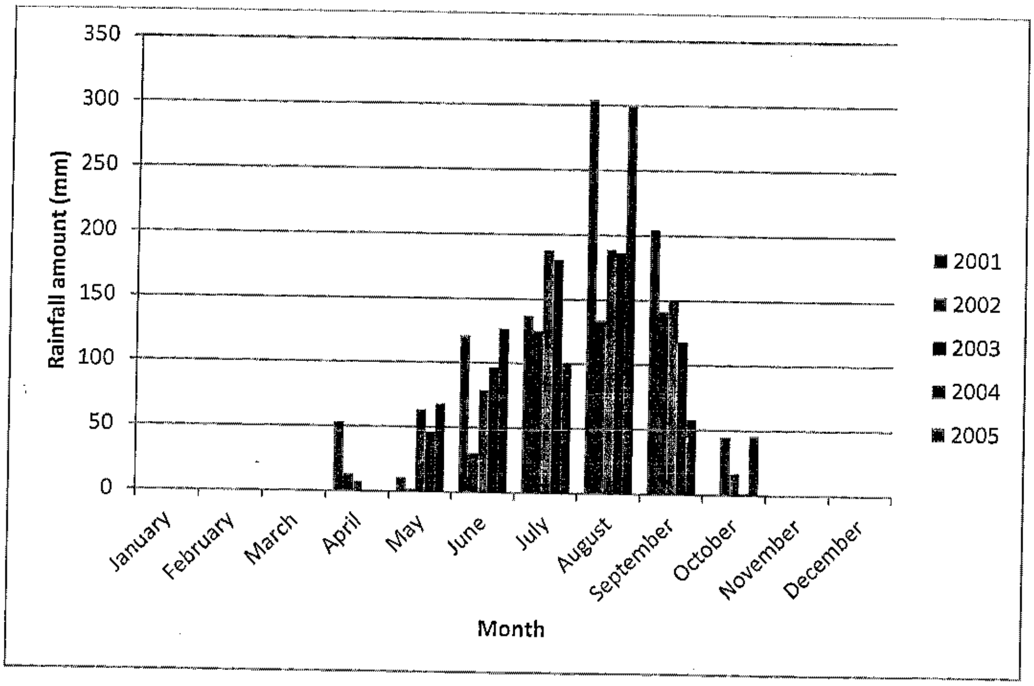


Fig 7d Comparison of monthly rainfall over Potiskum (1996 – 2000)



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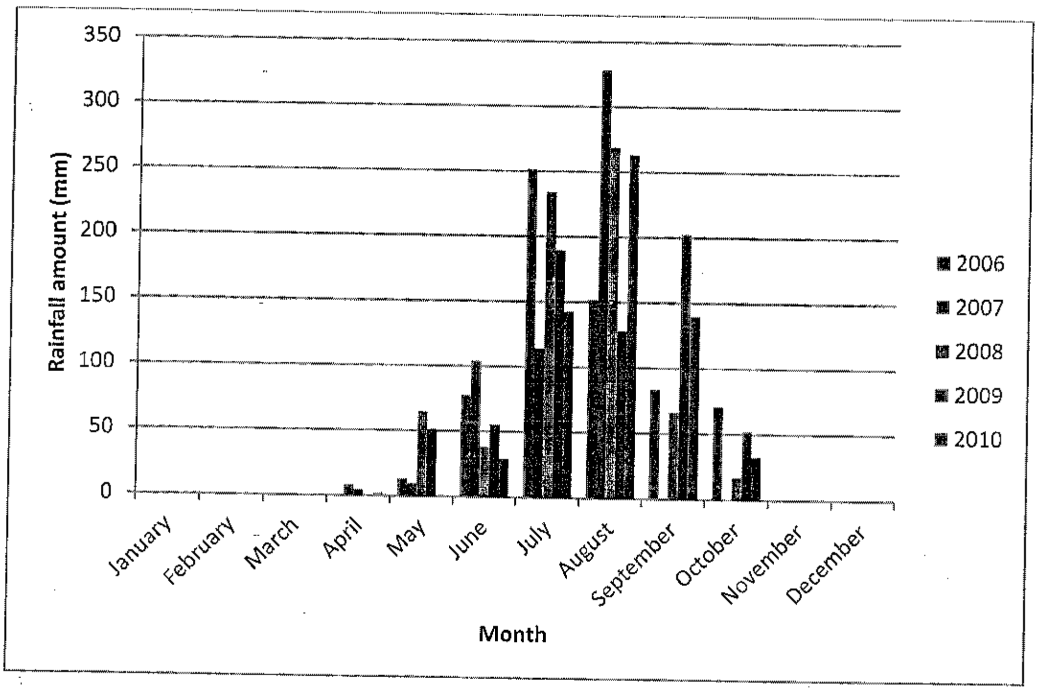

Fig 7f Comparison of monthly rainfall over Potiskum (2006 – 2010)

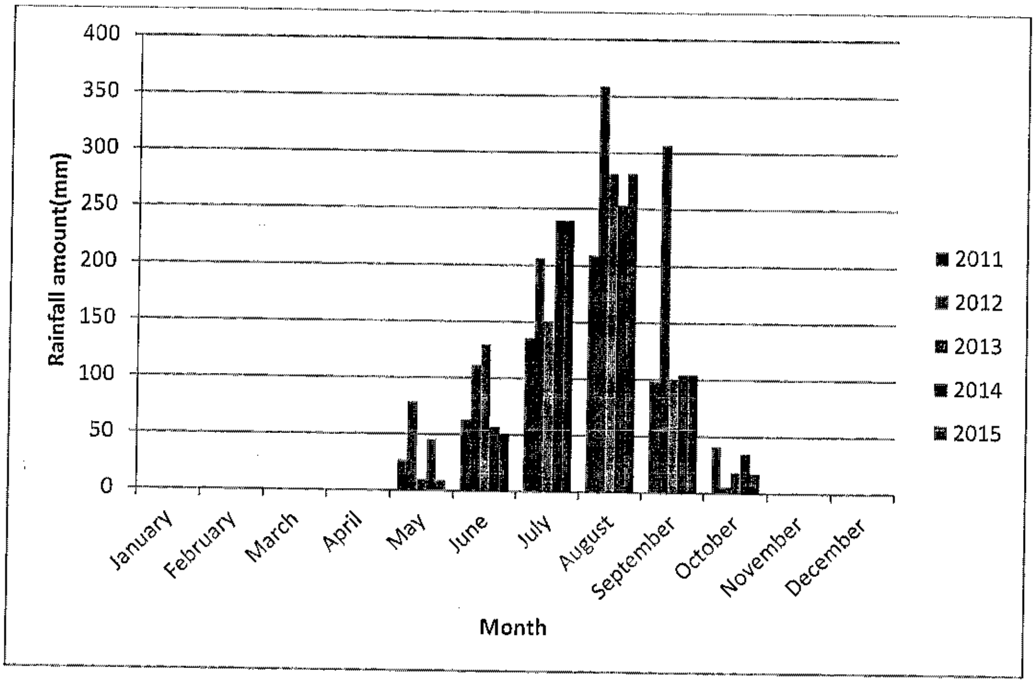

Fig 7g Comparison of monthly rainfall over Potiskum (2011 – 2015)

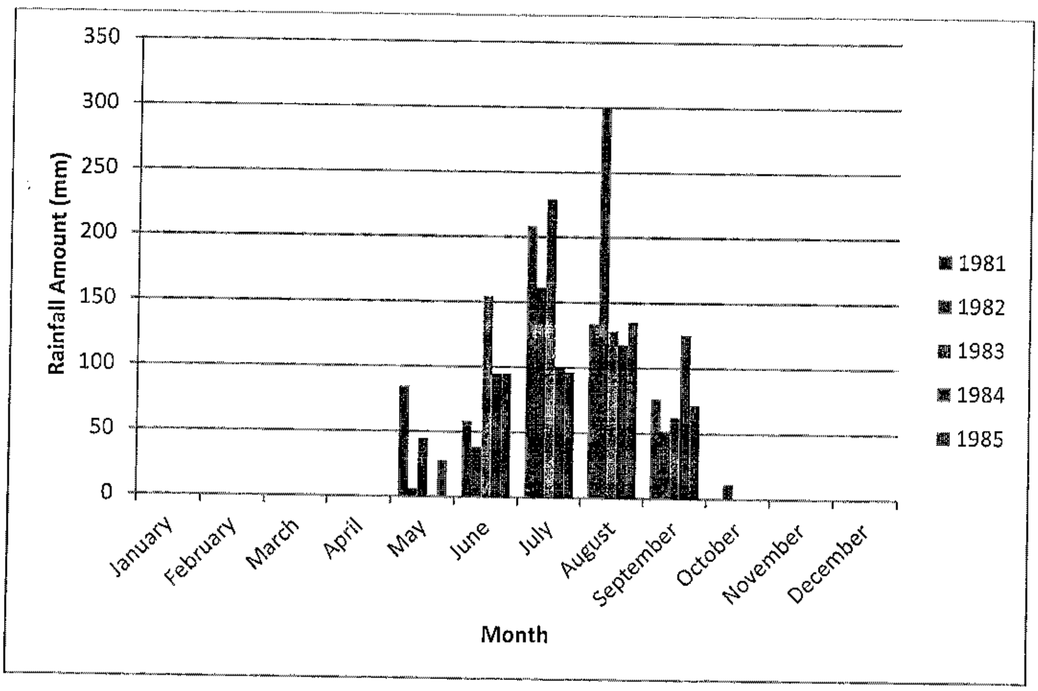

Fig 8a Comparison of monthly rainfall over Sokoto (1981 – 1985)

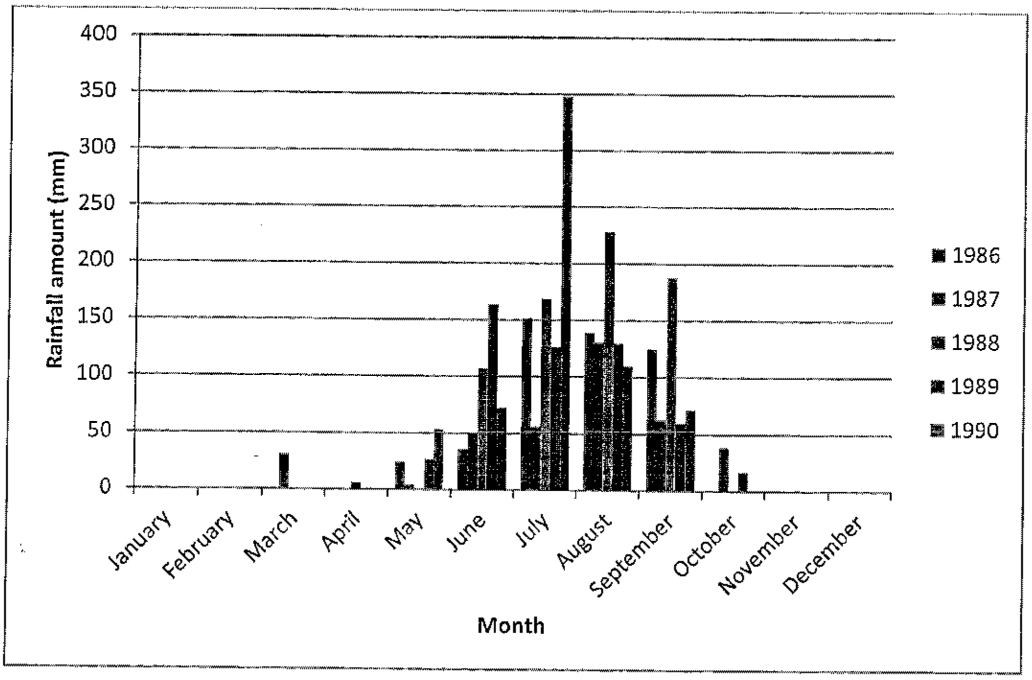

Fig 8b Comparison of monthly rainfall over Sokoto (1986 -1990)

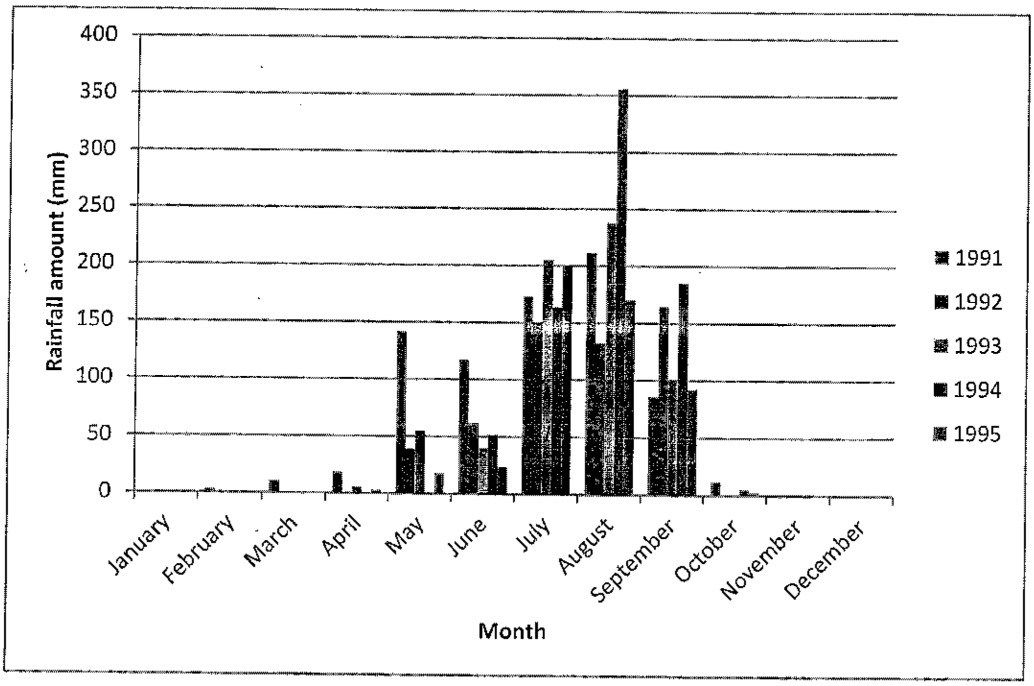

Fig 8c Comparison of monthly rainfall over Sokoto (1991 – 1995)

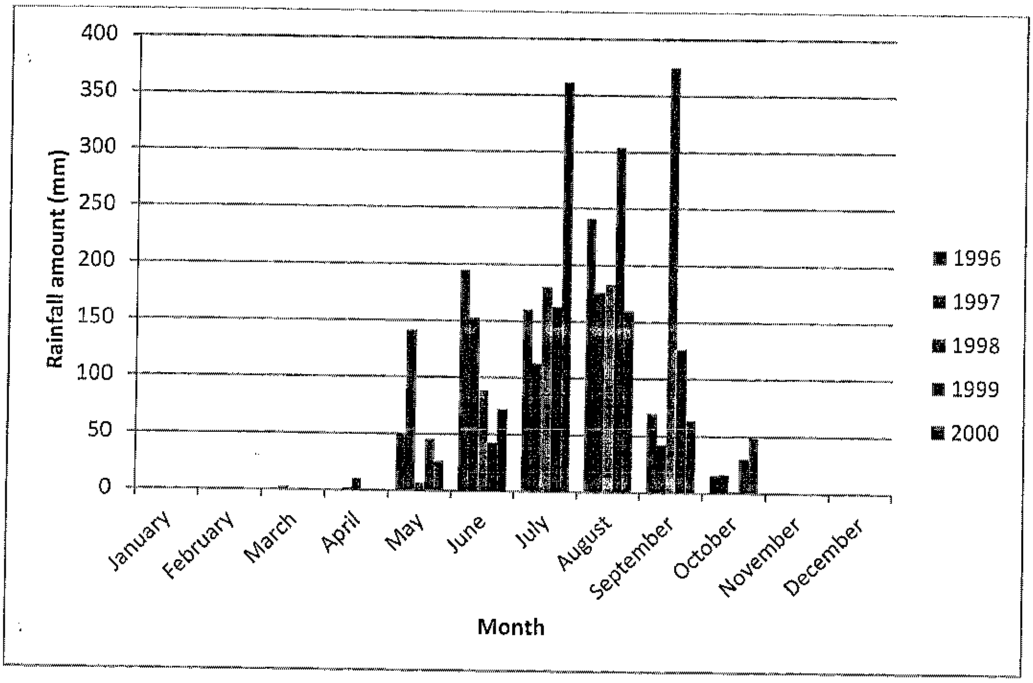

Fig 8d Comparison of monthly rainfall over Sokoto (1996 – 2000)

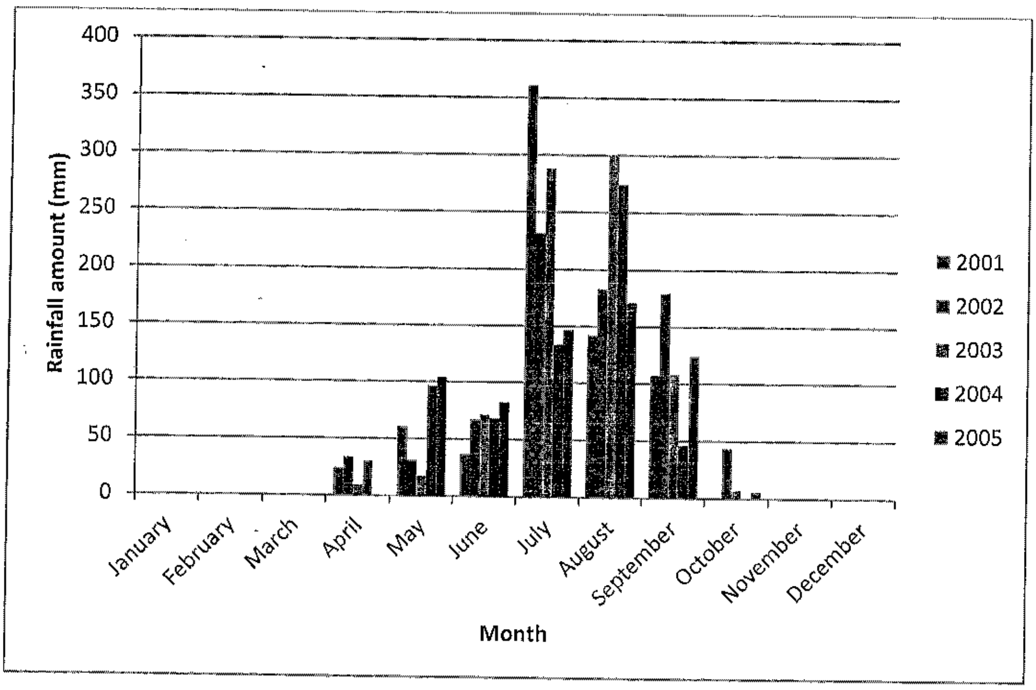

Fig 8e Comparison of monthly rainfall over Sokoto (2001 – 2005)

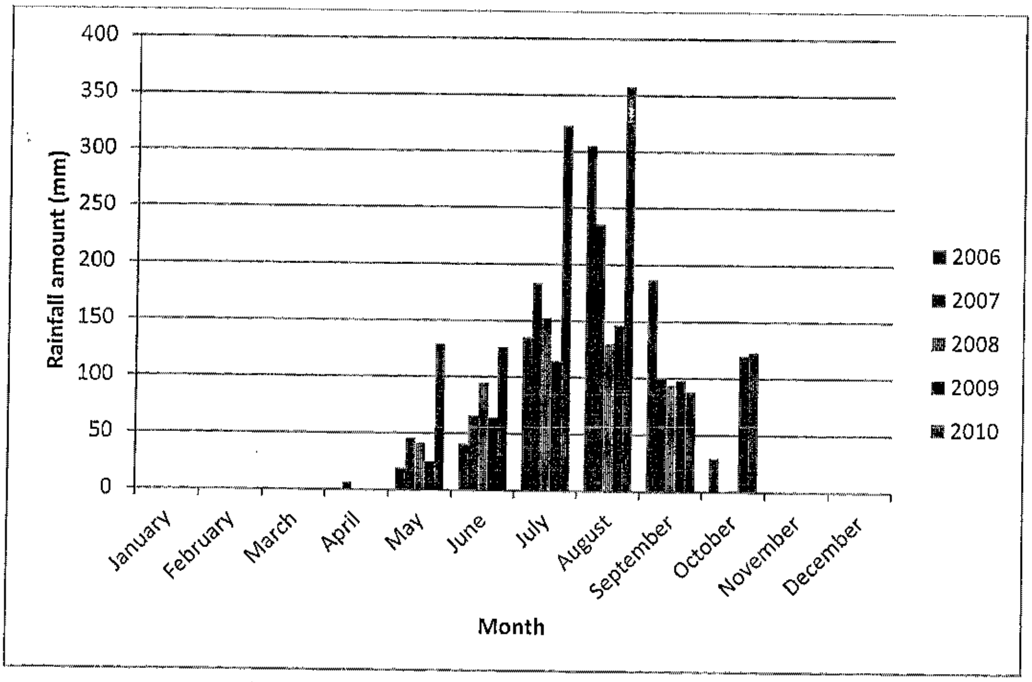

Fig 8f Comparison of monthly rainfall over Sokoto (2006 – 2010)

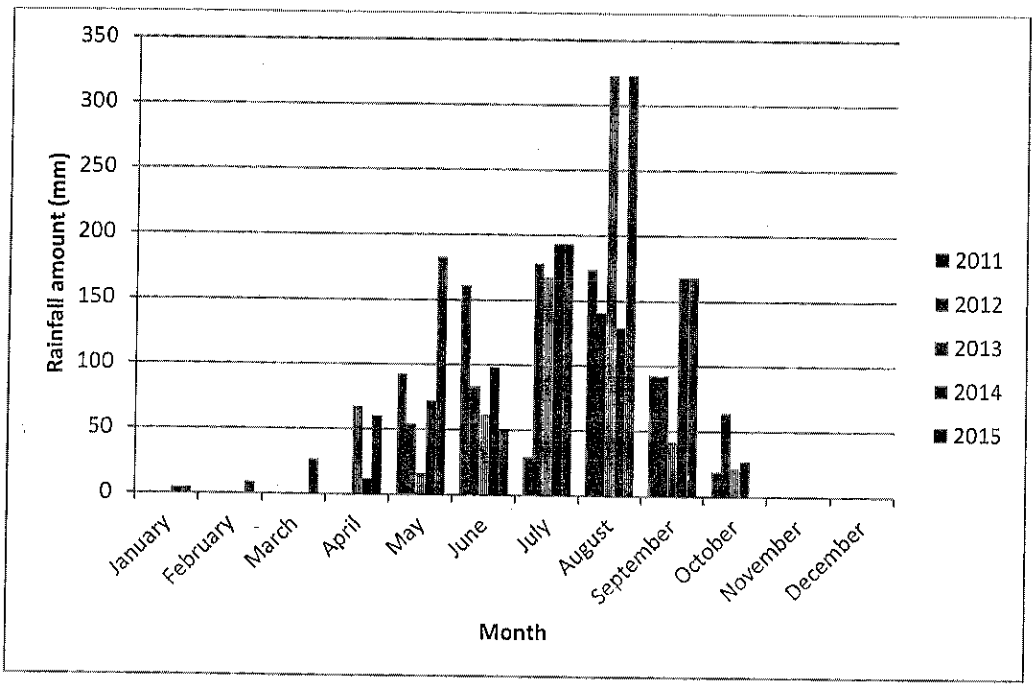

Fig 8g Comparison of monthly rainfall over Sokoto (2011 – 2015)

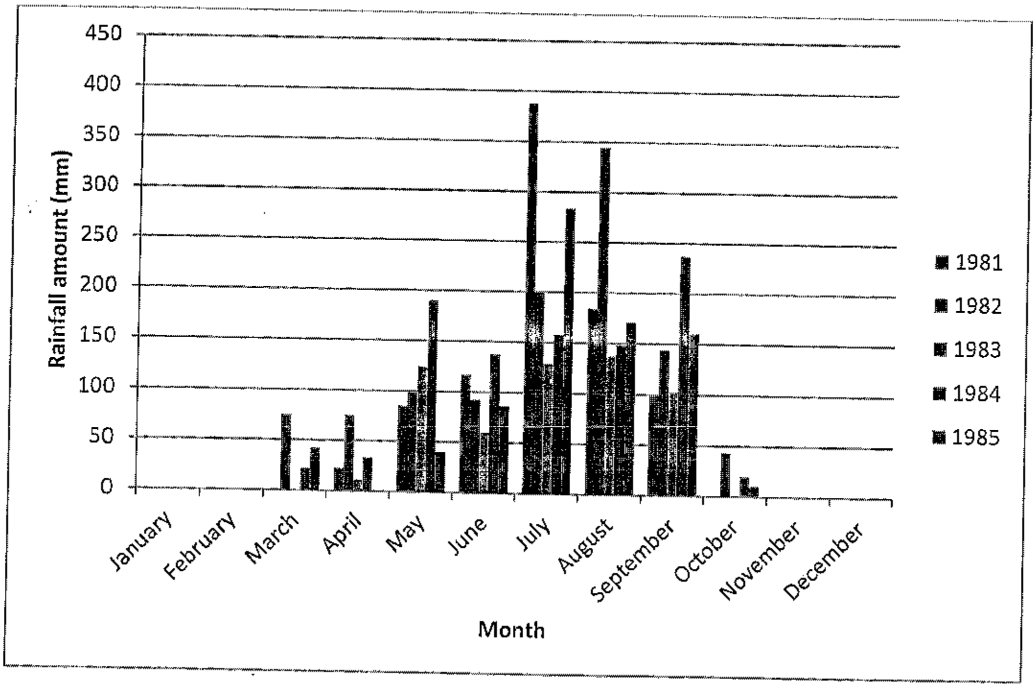

Fig 9a Comparison of monthly rainfall over Yelwa (1981 – 1985)

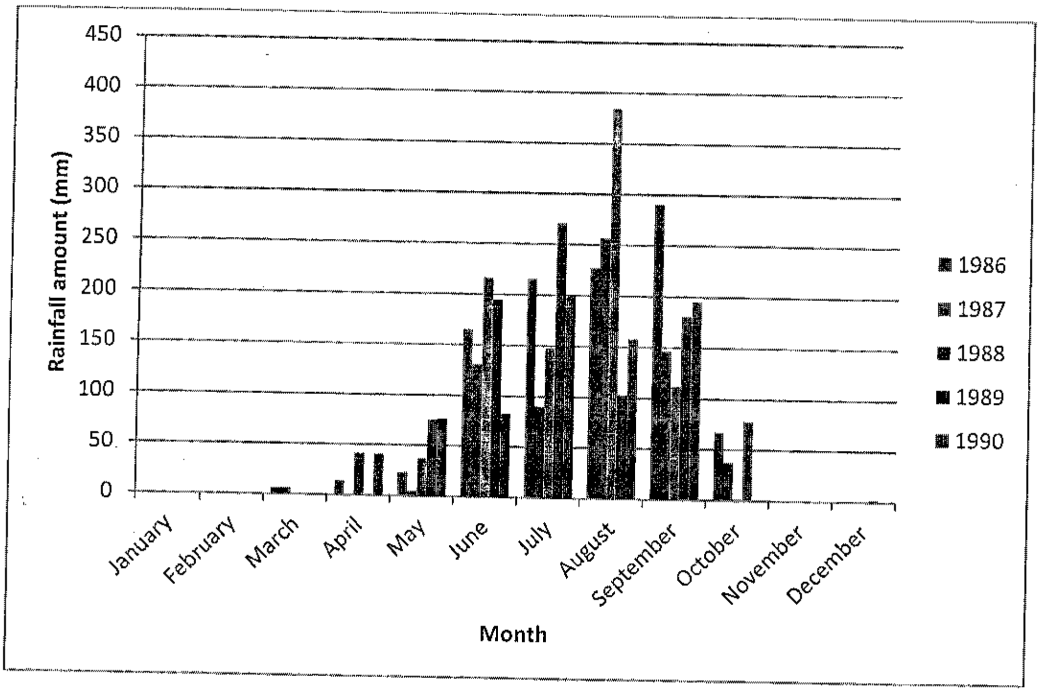

Fig 9b Comparison of monthly rainfall over Yelwa (1986 – 1990)

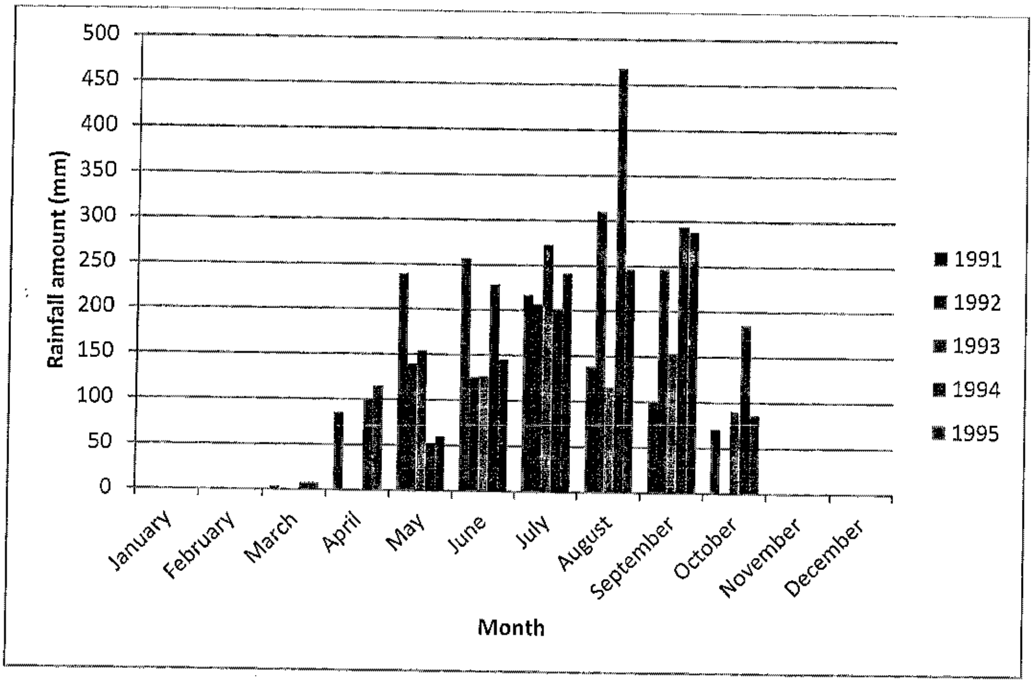

Fig 9c Comparison of monthly rainfall over Yelwa (1991 – 1995)

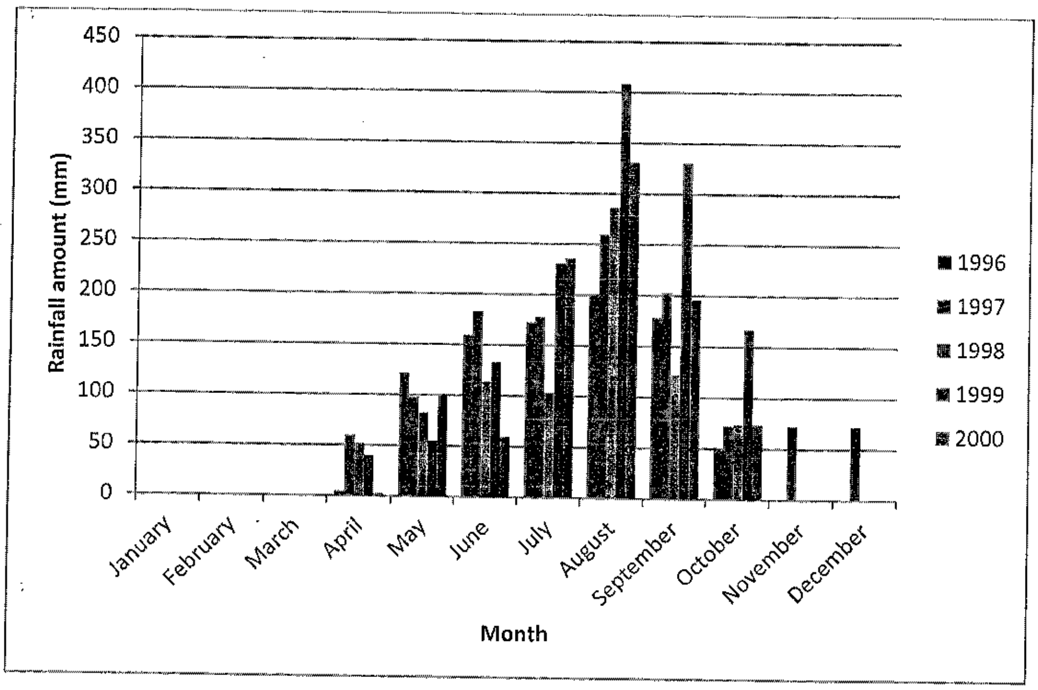

Fig 9d Comparison of monthly rainfall over Yelwa (1996 – 2000)

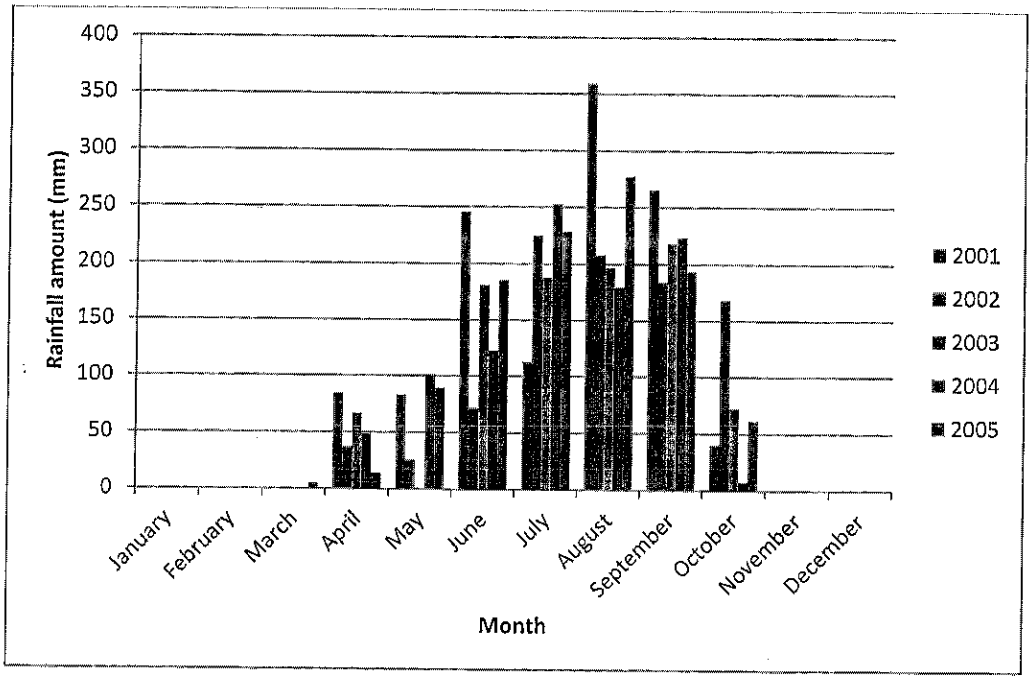

Fig 9e Comparison of monthly rainfall over Yelwa (2001 – 2005)

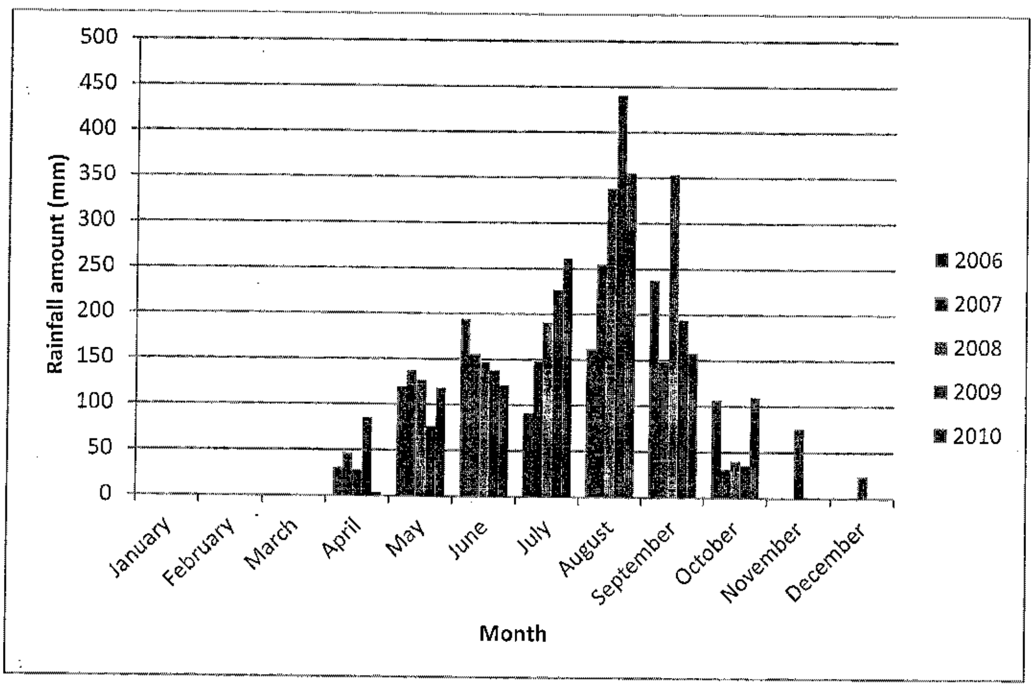

Fig 9f Comparison of monthly rainfall over Yelwa (2006 – 2010)

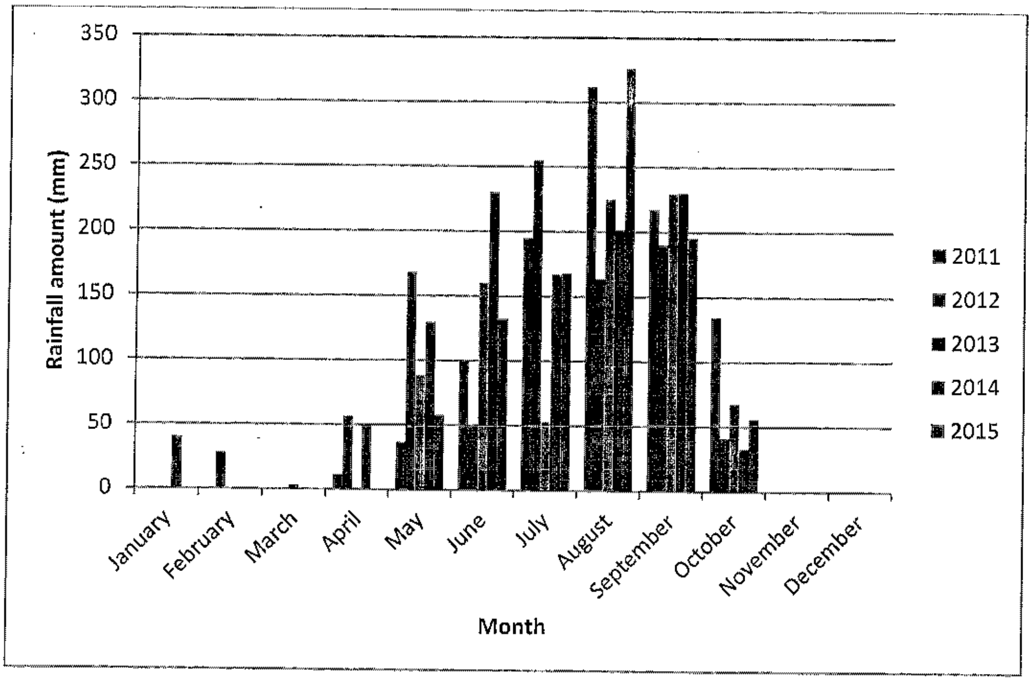

Fig 9g Comparison of monthly rainfall over Yelwa (2011 – 2015)

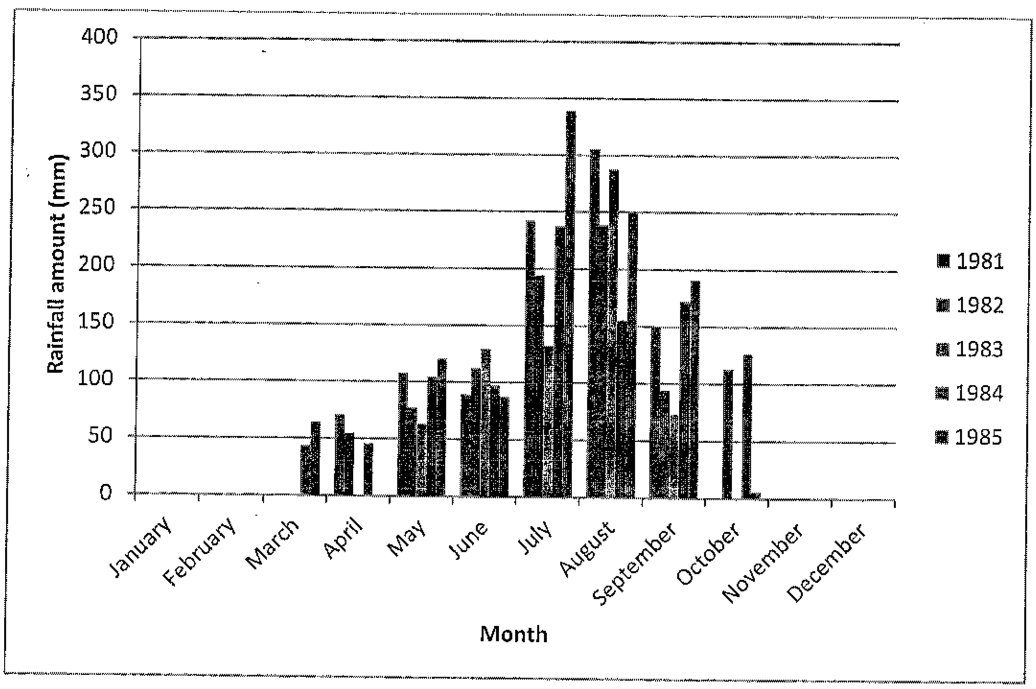

Fig 10a Comparison of monthly rainfall over Zaria (1981 – 1985)

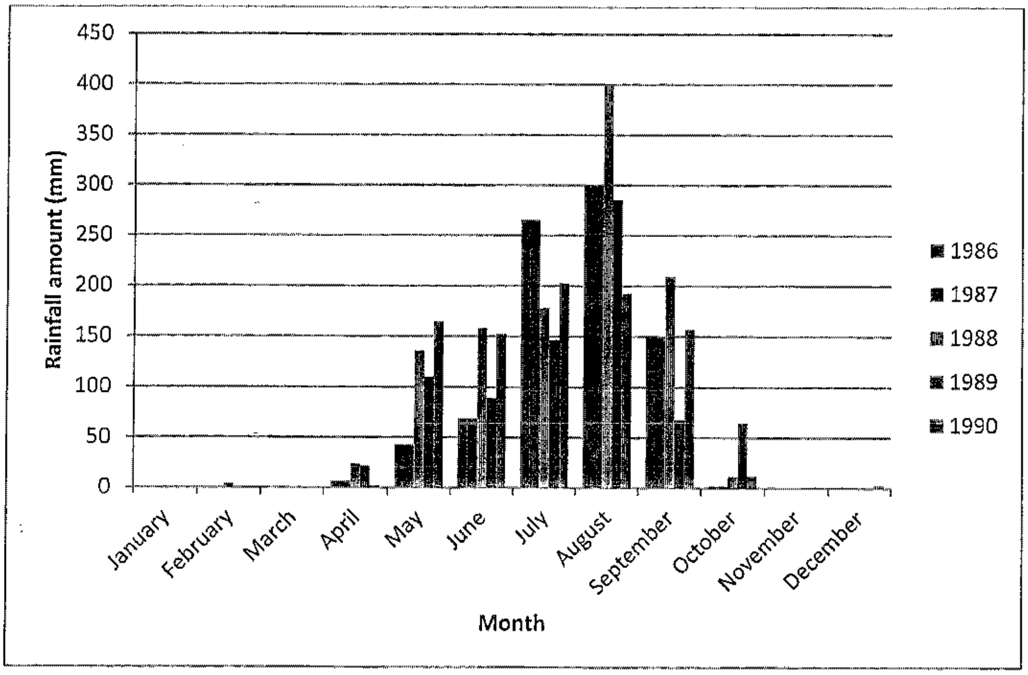

Fig 10b Comparison of monthly rainfall over Zaria (1986 – 1990)

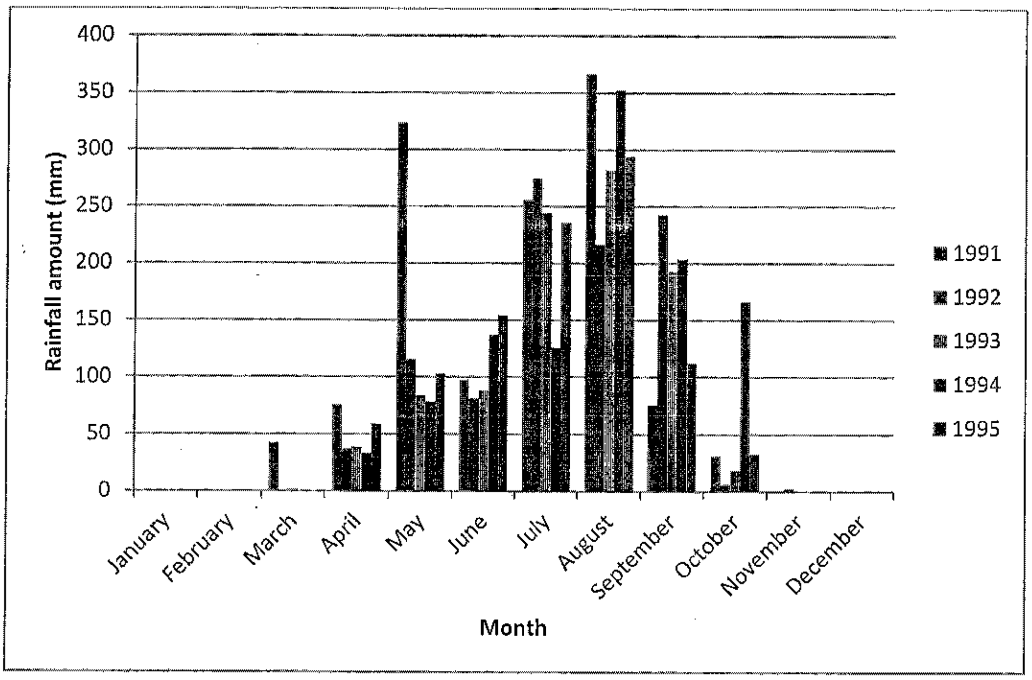

Fig 10c Comparison of monthly rainfall over Zaria (1991 – 1995)

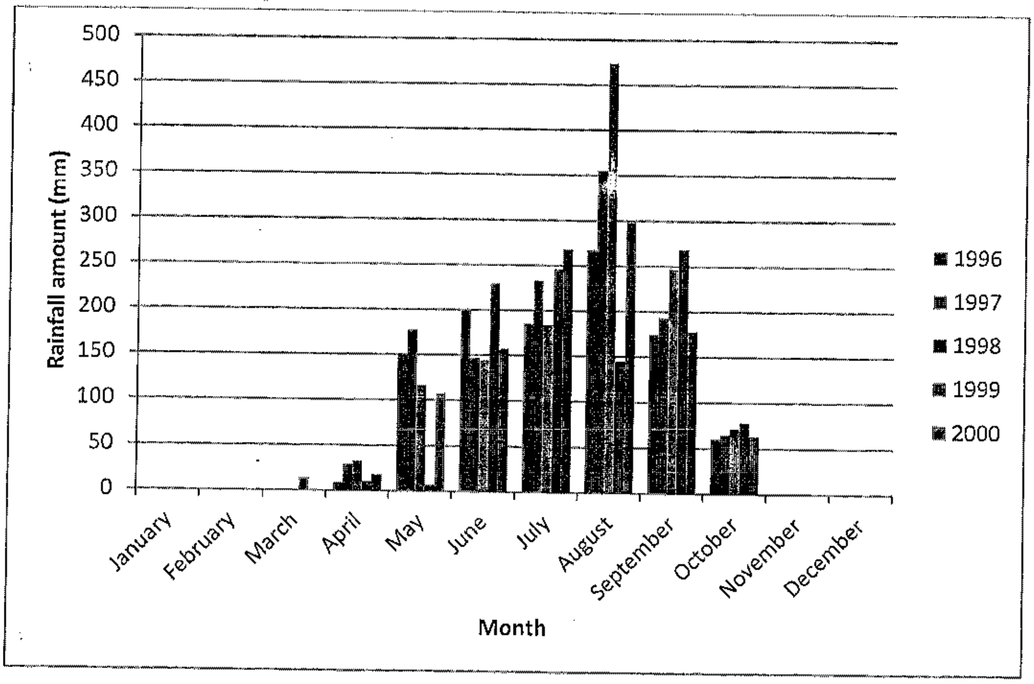

Fig 10d Comparison of monthly rainfall over Zaria (1996 -2000)

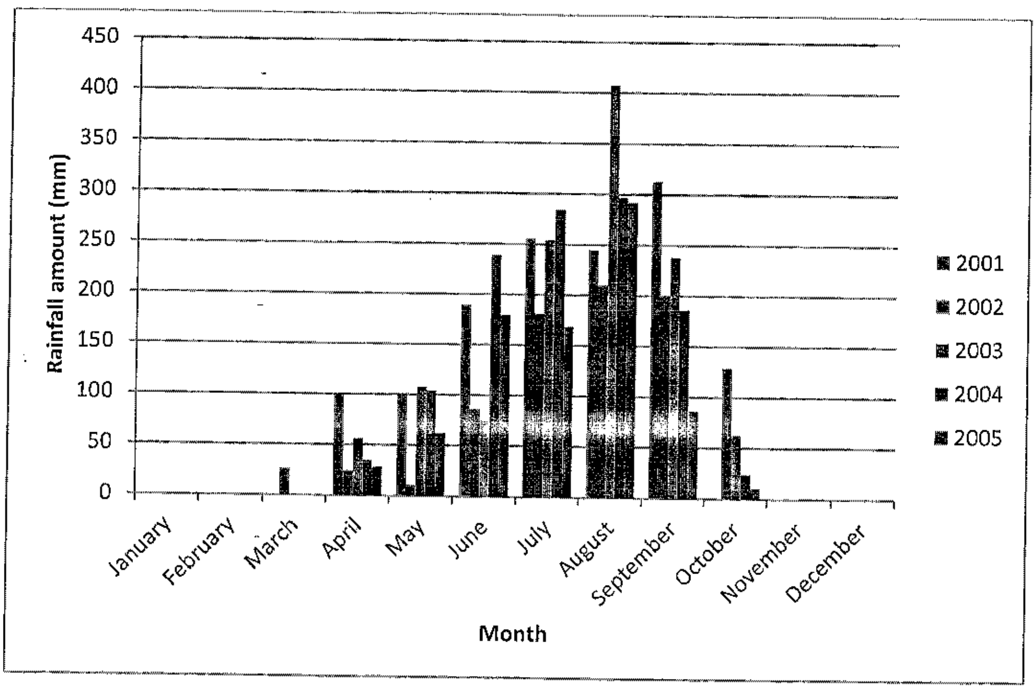

Fig 10e Comparison of monthly rainfall over Zaria (2001 – 2005)

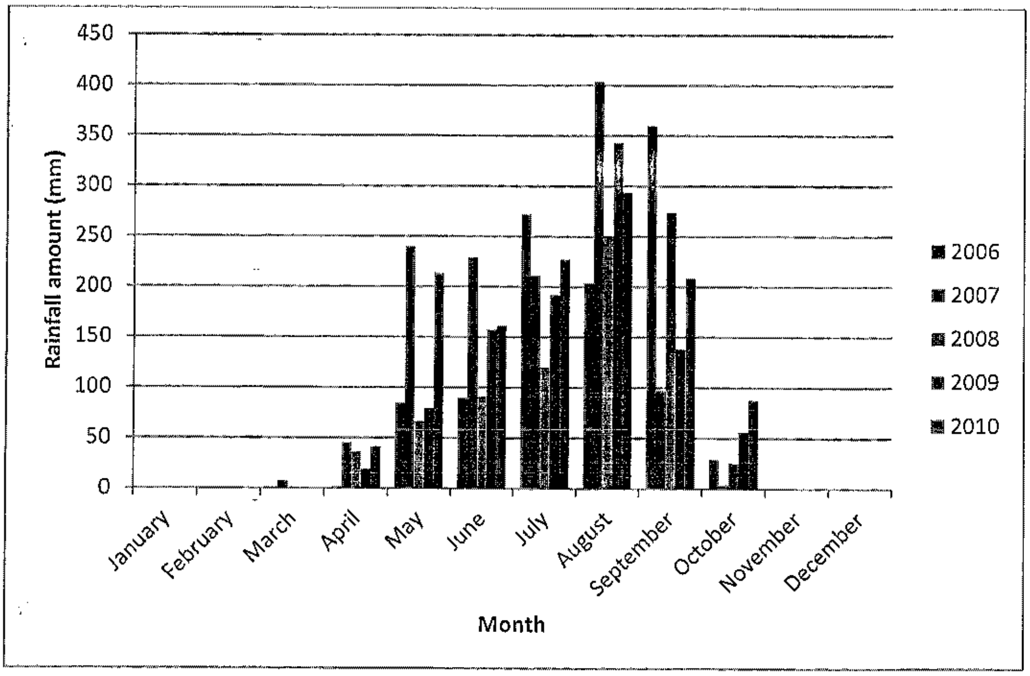

Fig 10f Comparison of monthly rainfall over Zaria (2006 – 2010)

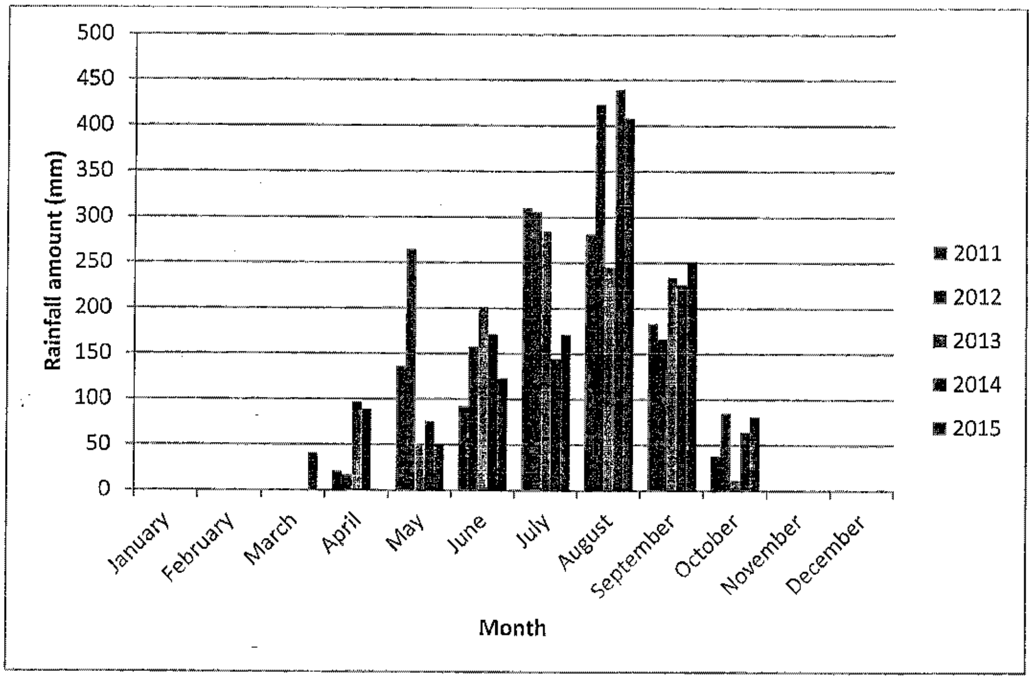

Fig 10g Comparison of monthly rainfall over Zaria (2011 – 2015)

4.2 Seasonal Rainfall Distribution

From figure 11-19, it was discovered that the study area has single maxima type of rainfall pattern, which peaks in August for all the stations studied.

The rainy (wet) season months of May through September accounted for 74.7%, 89.5%, 95.9%, 93.7, 96.1%, 95%, 95.5%, 88.9%, 91.5%, 93% of RF in Gasau, Kaduna, Kano, Katsina, Maiduguri, Potiskum, Sokoto, Yelwa and Zaria respectively during the study period (1981-2015), while the dry season months of October through April contributed just 25.34%, 10.5%, 4.1%, 6.3%, 3.9%, 5%, 4.5%, 11.1%, 8.5%, 7% in Gasau, Kaduna, Kano, Katsina, Maiduguri, Potiskum, Sokoto, Yelwa and Zaria respectively of the total RF during the study period.

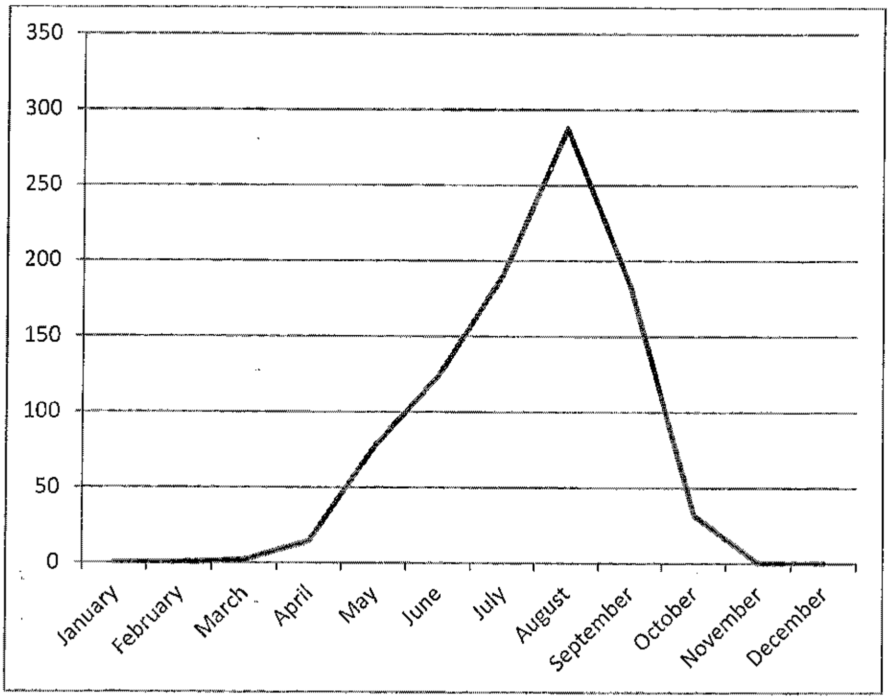

Fig 11 Mean Seasonal Rainfall Distribution Gasua

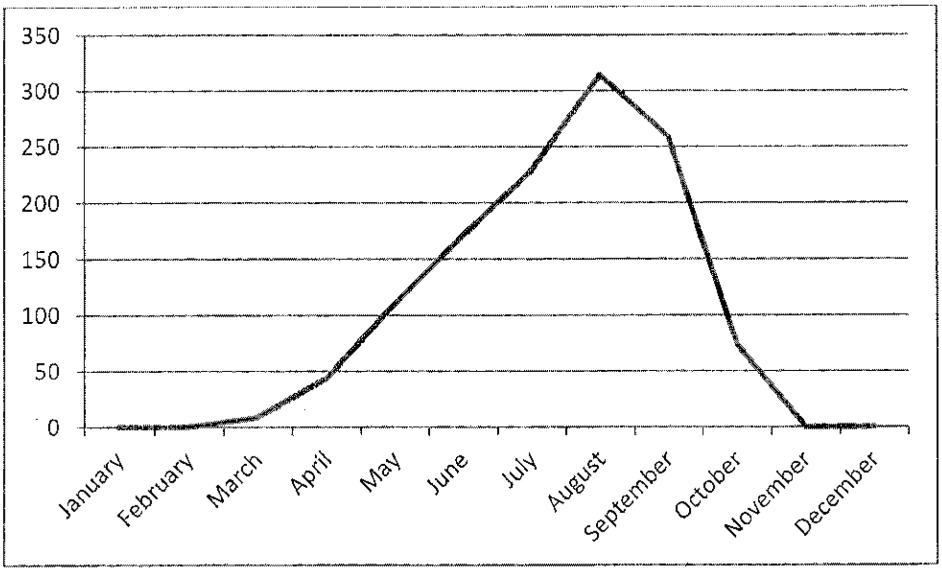

Fig 12 Mean Seasonal Rainfall Distribution Kaduna

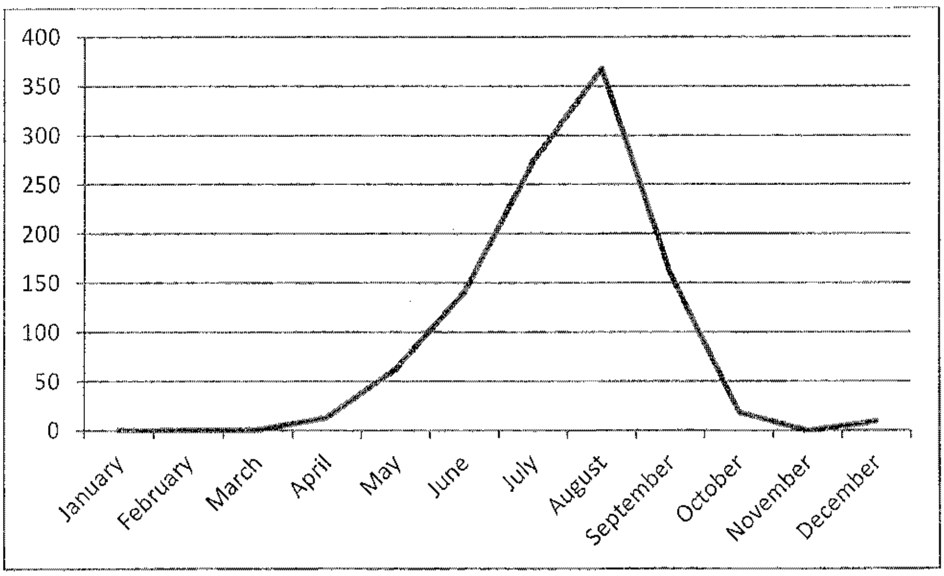

Fig 13 Mean Seasonal Rainfall Distribution Kano

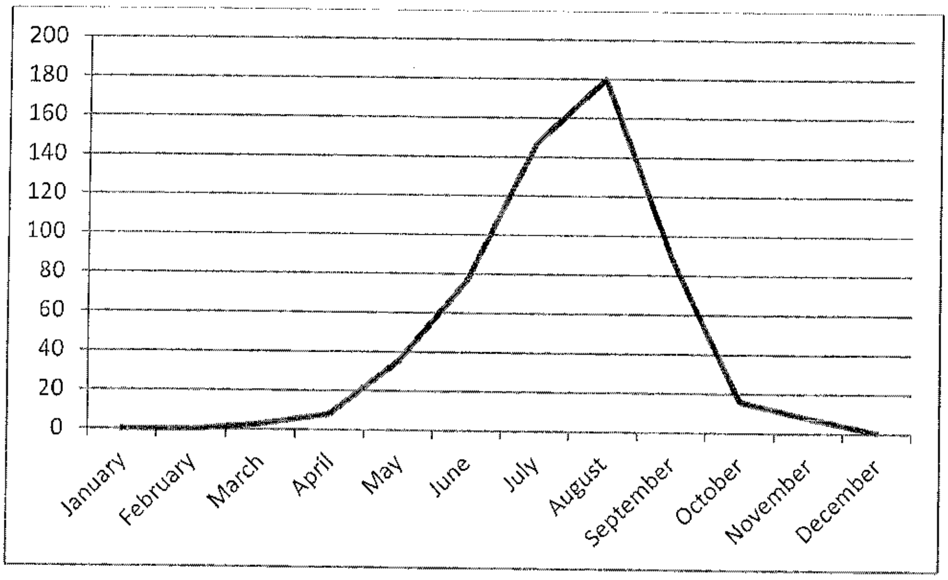

Fig 14 Mean Seasonal Rainfall Distribution Katsina

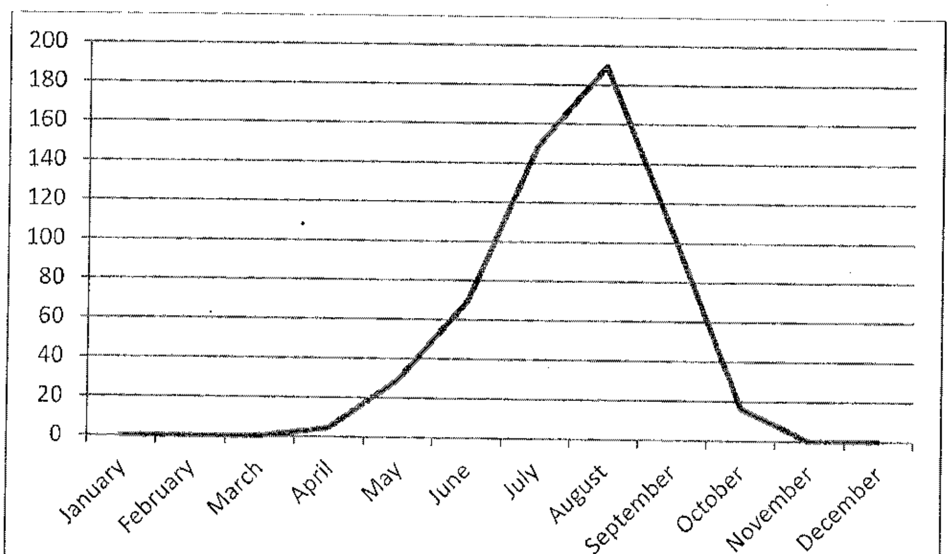

Fig 15 Mean Seasonal Rainfall Distribution Maiduguri

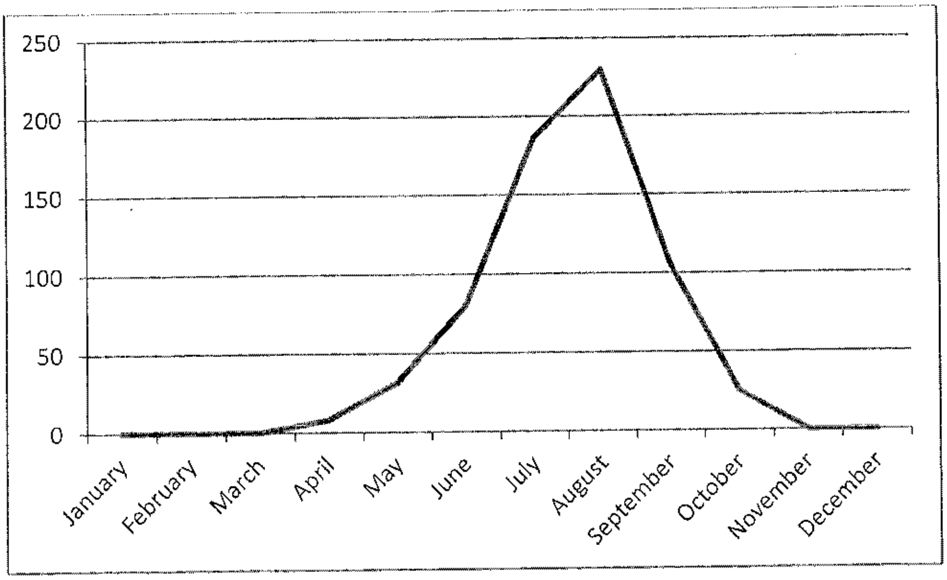

Fig 16 Mean Seasonal Rainfall Distribution Potiskum

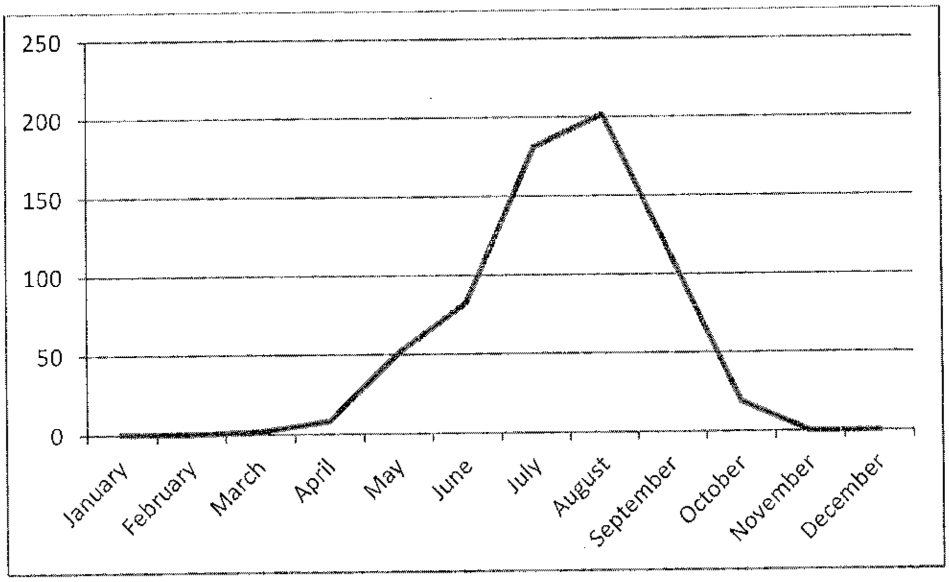

Fig 17 Mean Seasonal Rainfall Distribution Sokoto

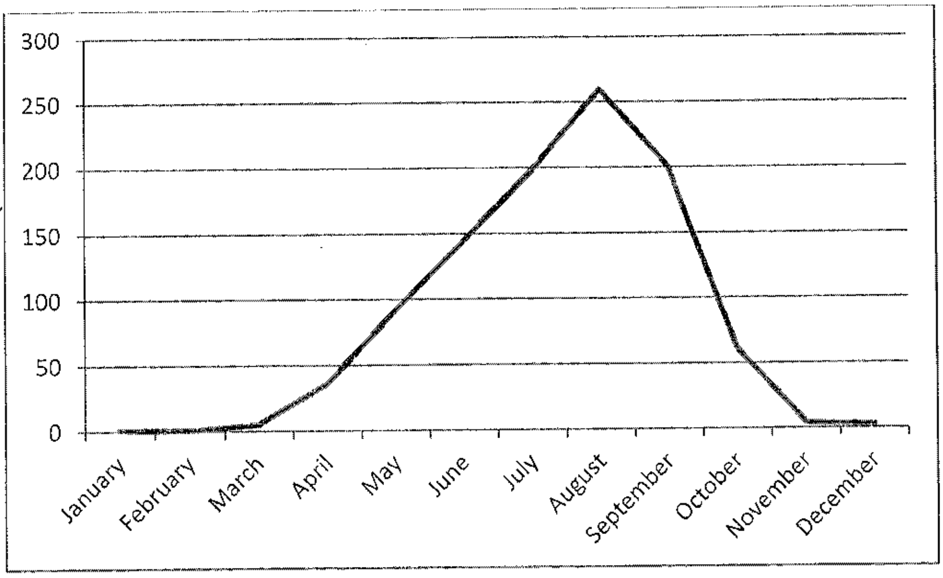

Fig 18 Mean Seasonal Rainfall Distribution Yelwa

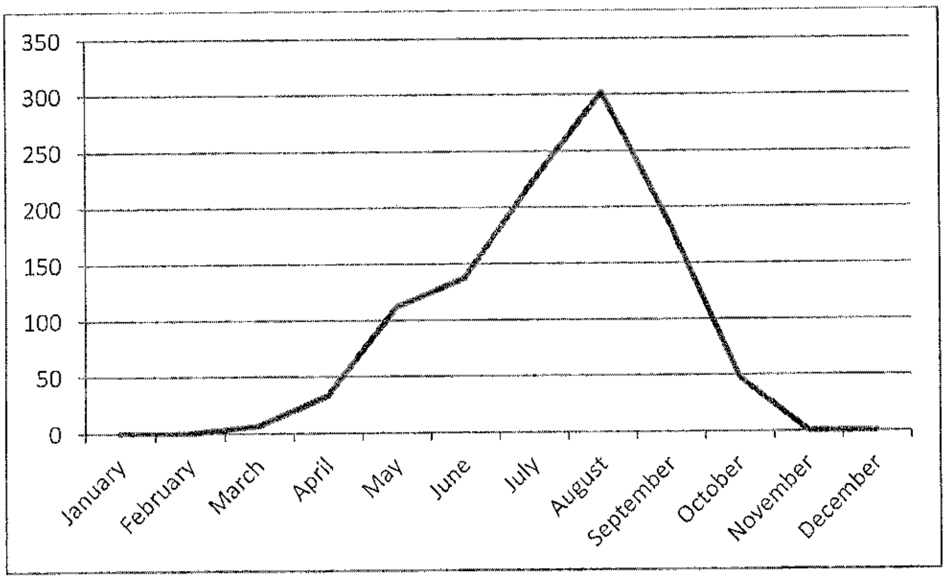

Fig 19 Mean Seasonal Rainfall Distribution Zaria

Table 1-9 shows the total, mean, standard deviation (σ), and coefficient of variation (CV) of the various periods of study in the study area.

The drier months has the highest CV, this implies that RF are very much unreliable during the dry season and more reliable during wet seasons.

The study shows that RF varies within months, years and seasons, the variation or fluctuation is natural.

Rainfall in Northern Nigeria shows little dissimilarities in climate pattern during the 35 years period of study. For instance the CV of the various time scale of study falls within certain % for both annual and seasonal distribution. The annual CV is lower than the seasonal CV. This implies that the annual RF is more reliable and predictable than the seasonal RF in the study area. The annual CV for the various study periods shows that, for Gasua, 1981-1992 recorded 11.33%, 1993-2004 had 11.79% and 2005-2015 recorded 11.15%, for Kaduna, 1981-1992 recorded 10.09%, 1993-2004 had 9.81%% and 2005-2015 recorded 10.27%, for Kano, 1981-1992 recorded 13.33%, 1993-2004 had 12.25% and 2005-2015 recorded 13.05%, for Katsina, 1981-1992 recorded 13.26%, 1993-2004 had 12.81% and 2005-2015 recorded 11.52%, for Maiduguri, 1981-1992 recorded 13.74%, 1993-2004 had 12.80% and 2005-2015 recorded 13.06%, for Potiskum, 1981-1992 recorded 13.54%, 1993-2004 had 12.22% and 2005-2015 recorded 12.84%, for Sokoto, 1981-1992 recorded 13.81%, 1993-2004 had 11.93% and 2005-2015 recorded 11.57%, for Yelwa, 1981-1992 recorded 10.69%, 1993-2004 had 10.10% and 2005-2015 recorded 9.84%, for Zaria, 1981-1992 recorded 10.62%, 1993-2004 had 10.07% and 2005-2015 recorded 10.29.

Note the seasonal variation is higher than the annual variation because the differences between the wet season and dry season are compared in seasonal CV, while the differences between years are considered in annual CV calculation.

Table 1 Descriptive Statistics for Gasau

Table 1a (1981-1992)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Total	0.0	9.2	55.8	149.7	922.0	1467.0	2312.2	2974.2	2219.4	140.7	0.0	0.0
Mean	0.0	0.8	4.7	12.5	76.8	122.3	192.7	247.9	185.0	11.7	0.0	0.0
Std	0.0	2.5	11.2	17.0	42.1	31.8	47.6	79.9	89.3	19.1	0.0	0.0
Cv	-	322.5	240.0	136.4	54.8	26.0	24.7	32.2	48.3	162.7	-	-

Table 1b (1993-2004)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Total	0	0	9.8	197.2	887.2	1720	2331	3978	2492	546	0	0
Mean	0	0	1.508	30.34	136.5	264.5	358.7	612	383.4	84	0	0
Std	0	0	3.111	55.12	228.4	439.9	595.4	1019	641.9	147	0	0
Cv	-	-	206.3	181.7	167.3	166.3	166	166.6	167.4	175	-	-

Table 1c (2005-2015)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Total	3.2	0	0	159.4	874	1142	2039	3107	1655	426	0	0
Mean	0.291	0	0	14.49	79.45	103.8	185.4	282.4	150.5	38.7	0	0
Std	0.965	0	0	15.96	30.9	35.63	62.65	71.14	49.81	33.2	0	0
Cv	331.7	-	-	110.1	38.88	34.32	33.79	25.19	33.1	85.7	-	-

Table 2 Descriptive Statistics for Kaduna

Table 2a (1981-1992)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Total	0	11.8	117.4	495.7	1354	1929	2565.3	3932	2693.3	654.5	1.3	0
Mean	0	0.983	9.783	41.31	112.8	160.7	213.78	327.7	224.44	54.54	0.1083	0
Std	0	3.406	20.86	32.28	48.34	51.52	70.46	87.7	53.865	45.68	0.3753	0
Cv	-	346.4	213.2	78.15	42.84	32.05	32.96	26.76	24	83.75	346.41	-

Table 2b (1993-2004)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Total	0	0	107.2	574.4	1208	2236	3120.1	3454	3511.1	915.5	0	0
Mean	0	0	8.933	47.87	100.7	186.3	260.01	287.8	292.59	76.29	0	0
Std	0	0	13.72	31.61	35.86	30.38	102.83	73.49	77.817	47.92	0	0
Cv	-	-	153.6	66.05	35.63	16.31	39.549	25.53	26.596	62.81	-	-

Table 2c (2005-2015)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Total	0	1.3	84.3	467.2	1309	1822	2314.9	3598	2866.1	1008	0	0
Mean	0	0.118	7.664	42.47	119	165.7	210.45	327.1	260.55	91.61	0	0
Std	0	0.392	16.55	29.59	48.68	64.45	62.883	130.4	122.31	54.85	0	0
Cv	-	331.7	216	69.67	40.91	38.9	29.881	39.86	46.942	59.87	-	-

Table 3 Descriptive Statistics for Kano

Table 3a (1981-1992)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
total	0	8.1	23.2	173.7	580.7	1062	2201.5	3013	1209	84.2	0.7	0
mean	0	0.675	1.933	14.48	48.39	88.53	183.46	251	100.8	7.017	0.0583	0
Std	0	2.338	6.181	20.58	38.52	47.07	54.472	136.8	46.26	13.5	0.2021	0
Cv	-	346.4	319.7	142.2	79.6	53.17	29.692	54.51	45.9	192.4	346.41	-

Table 3b (1993-2004)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
total	0	1.1	0	106.3	860.1	1971	4140.1	4724	2410	273.3	0	334.4
mean	0	0.092	0	8.858	71.68	164.3	345.01	393.7	200.8	22.78	0	27.87
Std	0	0.318	0	13.7	59.72	67.7	158.9	115.7	44.88	19.62	0	96.53
Cv	-	346.4	-	154.6	83.33	41.21	46.058	29.38	22.35	86.13	-	346.4

Table 3c (2005-2015)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
total	0	0	6	183.9	737.2	1867	3216.7	5100	1971	292.9	0	0
mean	0	0	0.545	16.72	67.02	169.7	292.43	463.7	179.2	26.63	0	0
Std	0	0	1.809	23.38	47.37	114.7	145.6	131.8	78.86	33.32	0	0
Cv	-	-	331.7	139.9	70.69	67.56	49.791	28.43	44	125.1	-	-

Table 4 Descriptive Statistics for Katsina

Table 4a (1981-1992)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
total	0	0	22.1	40.1	265.4	825.5	1636	1924	911.2	104.8	0	0
mean	0	0	1.8417	3.342	22.12	68.79	136.3	160.3	75.933	8.733	0	0
Std	0	0	4.2788	5.819	21.08	34.07	66.11	62.38	45.762	21.52	0	0
Cv	-	-	232.33	174.1	95.32	49.53	48.49	38.91	60.266	246.4	-	-

Table 4b (1993-2004)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
total	0	0	7.2	56.2	388.3	853.2	1645	1920	1103.8	154.6	0	0
mean	0	0	0.6	4.683	32.36	71.1	137.1	160	91.983	12.88	0	0
Std	0	0	2.0785	6.023	34.49	44.37	66.27	69.28	44.964	20.73	0	0
Cv	-	-	346.41	128.6	106.6	62.41	48.35	43.3	48.882	160.9	-	-

Table 4c (2005-2015)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
total	0	0	76.1	191	581.8	1005	1862	2450	1070	303.9	274.3	13.4
mean	0	0	6.9182	17.36	52.89	91.35	169.3	222.7	97.273	27.63	24.94	1.218
Std	0	0	22.945	27.02	71.8	41.15	50.74	74.93	55.912	35.53	56.12	4.04
Cv	-	-	331.66	155.6	135.8	45.05	29.98	33.64	57.48	128.6	225	331.7

Table 5 Descriptive Statistics for Maiduguri

Table 5a (1981-1992)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
total	0	0	10.1	65.7	346.7	642	1115	1761	758.4	67.3	0	2.5
mean	0	0	0.842	5.475	28.89	53.5	92.89	146.8	63.2	5.6083	0	0.208
Std	0	0	0.662	8.024	26.79	30.68	58.09	64.18	55.264	11.532	0	0.754
Cv	-	-	78.68	146.6	92.71	57.34	62.53	43.73	87.443	205.62	-	361.8

Table 5b (1993-2004)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
total	0	0	94.58	279.9	873	1674	3613	4646	2468	495.37	0	365.3
mean	0	0	7.882	23.32	72.75	139.5	301.1	387.2	205.67	41.28	0	30.44
Std	0	0	0.452	5.928	20.41	39.39	73.4	55.82	64.245	11.923	0	0
Cv	-	-	5.728	25.42	28.05	28.23	24.38	14.42	31.238	28.883	-	0

Table 5c (2005-2015)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
total	0	0	0	47.8	357.2	949.3	1909	2435	1429.5	318.4	0	3.9
mean	0	0	0	4.345	32.47	86.3	173.6	221.3	129.95	28.945	0	0.355
Std	0	0	0	7.685	19.11	103.5	84.25	63.65	72.566	32.403	0	1.176
Cv	-	-	-	176.8	58.84	119.9	48.54	28.76	55.839	111.94	-	331.7

Table 6 Descriptive Statistics for Potiskum

Table 6a (1981-1992)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
total	0	0	1.8	99.9	454.2	828.2	2270	2560	1082	243.2	3	0
mean	0	0	0.15	8.325	37.85	69.017	189.1	213.3	90.19	20.267	0.25	0
Std	0	0	0.52	12.091	43.96	40.965	75.04	111.4	52.98	24.462	0.866	0
Cv	-	-	346.4	145.23	116.2	59.355	39.67	52.23	58.74	120.7	346.4	-

Table 6b (1993-2004)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
total	0	0	0.3	174	274.5	1123	2219	2650	1362	293.7	0	0
mean	0	0	0.025	14.5	22.88	93.583	184.9	220.8	113.5	24.475	0	0
Std	0	0	0.087	18.46	18.61	52.499	47.28	68.89	59.31	17.268	0	0
Cv	-	-	346.4	127.31	81.35	56.098	25.57	31.2	52.24	70.555	-	-

Table 6c (2005-2015)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
total	0	0	0	13.7	376.2	844.5	2004	2823	1265	334.5	0	0
mean	0	0	0	1.2455	34.2	76.773	182.2	256.6	115	30.409	0	0
Std	0	0	0	2.5327	28.19	35.691	55.42	69.6	81	21.22	0	0
Cv	-	-	-	203.36	82.42	46.489	30.43	27.12	70.42	69.783	-	-

Table 7 Descriptive Statistics for Sokoto

Table 7a (1981-1992)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
total	0	2.8	41.2	24.1	413.5	987.4	1819	1761.7	979.8	78.3	0	0
mean	0	0.25	3.7455	2.191	37.591	89.76	165.4	160.15	89.073	7.118	0	0
Std	0	0.84	9.5432	5.619	43.108	43.74	78.51	59.678	40.964	12.12	0	0
Cv	-	332	254.79	256.5	114.68	48.73	47.48	37.263	45.989	170.3	-	-

Table 7b (1993-2004)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
total	0	0	2.8	116.2	585.4	971.9	2712	2860.2	1660.8	170.7	0	0
mean	0	0	0.2154	8.938	45.031	74.76	208.6	220.02	127.75	13.13	0	0
Std	0	0	0.7766	12.17	38.538	48.06	81.03	70.84	87.876	17.1	0	0
Cv	-	-	360.56	136.2	85.581	64.28	38.84	32.198	68.785	130.2	-	-

Table 7c (2005-2015)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Total	8.4	8.9	26.3	147.2	782.6	929.2	1817	2435.4	1253.8	412.1	0	0
Mean	0.764	0.81	2.3909	13.38	71.145	84.47	165.2	221.4	113.98	37.46	0	0
Std	1.7	2.68	7.9297	25.28	52.011	35	70.25	89.338	43.506	45.48	0	0
Cv	222.6	332	331.66	188.9	73.105	41.43	42.52	40.351	38.169	121.4	-	-

Table 8 Descriptive Statistics for Yelwa

Table 8a (1981-1992)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
total	0	0	155.3	322.9	1133	1663	2504	2563.6	2013.4	327.7	0	1.9
mean	0	0	12.942	26.908	94.38	138.6	208.7	213.63	167.78	27.308	0	0.158
Std	0	0	23.178	29.265	69.63	59.44	79.03	91.414	63.748	30.555	0	0.548
Cv	-	-	179.09	108.76	73.77	42.89	37.87	42.79	37.994	111.89	-	346.4

Table 8b (1993-2004)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
total	0	0	15.7	609.5	933.8	1769	2415	3457	2656.2	1087.1	72.4	72.4
mean	0	0	1.3083	50.792	77.82	147.4	201.2	288.08	221.35	90.592	6.033	6.033
Std	0	0	2.9651	37.169	41.84	55.96	53.06	137.66	62.01	55.106	20.9	20.9
Cv	-	-	226.63	73.179	53.76	37.97	26.37	47.784	28.014	60.829	346.4	346.4

Table 8c (2005-2015)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
total	40	28	9	326.8	1148	1614	1982	3054.9	2347.3	717.3	75.3	23.8
mean	3.64	2.55	0.8182	29.709	104.4	146.7	180.2	277.72	213.39	65.209	6.845	2.164
Std	12.1	8.44	1.7034	27.201	38.24	48.41	65.1	86.655	54.456	35.831	22.7	7.176
Cv	332	332	208.2	91.556	36.64	33	36.12	31.202	25.52	54.947	331.7	331.7

Table 9 Descriptive Statistics for Zaria

Table 9a (1981-1992)

Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
total	0	3.7	150.7	336.7	1454.9	1314	2715	3353	1681	407.5	2.4	2.7
mean	0	0.308	12.56	28.06	121.24	109.5	226.3	279.4	140.1	33.96	0.2	0.225
Std	0	1.068	23.14	28.08	71.292	30.53	58.3	72.74	57.93	44.34	0.693	0.779
Cv	-	346.4	184.3	100.1	58.802	27.89	25.77	26.04	41.36	130.6	346.4	346.4

Table 9b (1993-2004)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
total	0	0	41.5	445.3	1145.3	1844	2696	3627	2504	770.4	0.2	0
mean	0	0	3.458	37.11	95.442	153.7	224.7	302.3	208.7	64.2	0.017	0
Std	0	0	8.233	25.03	48.426	53.92	45.96	87.47	51.59	46.31	0.058	0
Cv	-	-	238.1	67.45	50.739	35.09	20.46	28.94	24.72	72.14	346.4	-

Table 9c (2005-2015)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
total	0	0	48.4	393.9	1320.3	1653	2408	3584	2224	491.7	0	0
mean	0	0	4.4	35.81	120.03	150.3	218.9	325.8	202.2	44.7	0	0
Std	0	0	12.19	31.61	80.962	46.59	66.33	81.64	80.26	31.38	0	0
Cv	-	-	2.77	0.883	0.6745	0.31	0.303	0.251	0.397	0.702	-	-

4.3 Annual Rainfall Distribution

The result of this study shows that annual rainfall within the study period in Gasau ranged between 615.9 mm in 2007 and 1503.7 mm in 1994 when the number of rain days was 46 and 72 days (Fig. 20). The trend of number of rain days in Figure 20 show that the least number of rain days is 42 days with annual amount of rainfall of 846.7 mm in the year 1983 while the highest number of rain days occurred in the years 1994 and 2010 with 72 days which recorded 1503.7 mm and 1024.3 mm annual rainfall respectively.

In Kaduna, the annual rainfall within the study period ranged between 793.4 mm in 2008 and 1658.9 mm in 2014 when the number of rain days was 73 and 91 days (Fig. 21). The trend of number of rain days in Figure 21 show that the least number of rain days is 69 days with annual amount of rainfall of 884.4 mm in the year 1983 while the highest number of rain days occurred in the year 1994 with 97 days which recorded 1066.9 mm annual rainfall. While in Kano, the annual rainfall within the study period ranged between 473.7 mm in 1984 and 1789.4 mm in 2001 when the number of rain days was 39 and 58 days (Fig. 22). The trend of number of rain days in Figure 22 show that the least number of rain days is 33 days with annual amount of rainfall of

499.7 mm in the year 1983 while the highest number of rain days occurred in the year 1997 with 66 days which recorded 1293.9 mm annual rainfall.

In Katsina, the annual rainfall within the study period ranged between 262 mm in 1993 and 1110.2 mm in 2007 when the number of rain days was 29 and 82 days (Fig. 23). The trend of number of rain days in Figure 23 show that the least number of rain days is 29 days with annual amount of rainfall of 262 mm in the year 1993 while the highest number of rain days occurred in the year 2007 with 82 days which recorded 1110.2 mm annual rainfall. For Maiduguri, the annual rainfall within the study period ranged between 234.4 mm in 1982 and 1073.9 mm in 2007 when the number of rain days was 23 and 42 days (Fig. 24). The trend of number of rain days in Figure 24 show that the least number of rain days is 23 days with annual amount of rainfall of 234.4 mm in the year 1982 while the highest number of rain days occurred in the year 1999 with 54 days which recorded 842.6 mm annual rainfall.

For Potiskum, the annual rainfall within the study period ranged between 410.5 mm in 1990 and 1067.9 mm in 2010 when the number of rain days was 30 and 54 days (Fig. 25). The trend of number of rain days in Figure 25 show that the least number of rain days is 27 days with annual amount of rainfall of 524.7 mm in the year 1981 while the highest number of rain days occurred in the year 1998 with 55 days which recorded 796.6 mm annual rainfall. In Sokoto, the annual rainfall within the study period ranged between 327.9 mm in 1987 and 1146.7 mm in 2010 when the number of rain days was 30 and 56 days (Fig. 26). The trend of number of rain days in Figure 26 show that the least number of rain days is 29 days with annual amount of rainfall of 439 mm in the year 1984 while the highest number of rain days occurred in the year 2015 with 63 days which recorded 1017.2 mm annual rainfall.

The annual rainfall for Yelwa within the study period ranged between 563.5 mm in 1983 and 1196 mm in 1999 when the number of rain days was 42 and 83 days (Fig. 27). The trend of number of rain days in Figure 27 show that the least number of rain days is 42 days with annual amount of rainfall of 563.5 mm in the year 1983 while the highest number of rain days occurred in the year 2008 with 90 days which recorded 1322.1 mm annual rainfall. In Zaria, the annual rainfall within the study period ranged between 685.6 mm in 1983 and 1419.2 mm in 2012 when the number of rain days was 61 and 75 days (Fig. 28). The trend of number of rain days in Figure 28 show that the

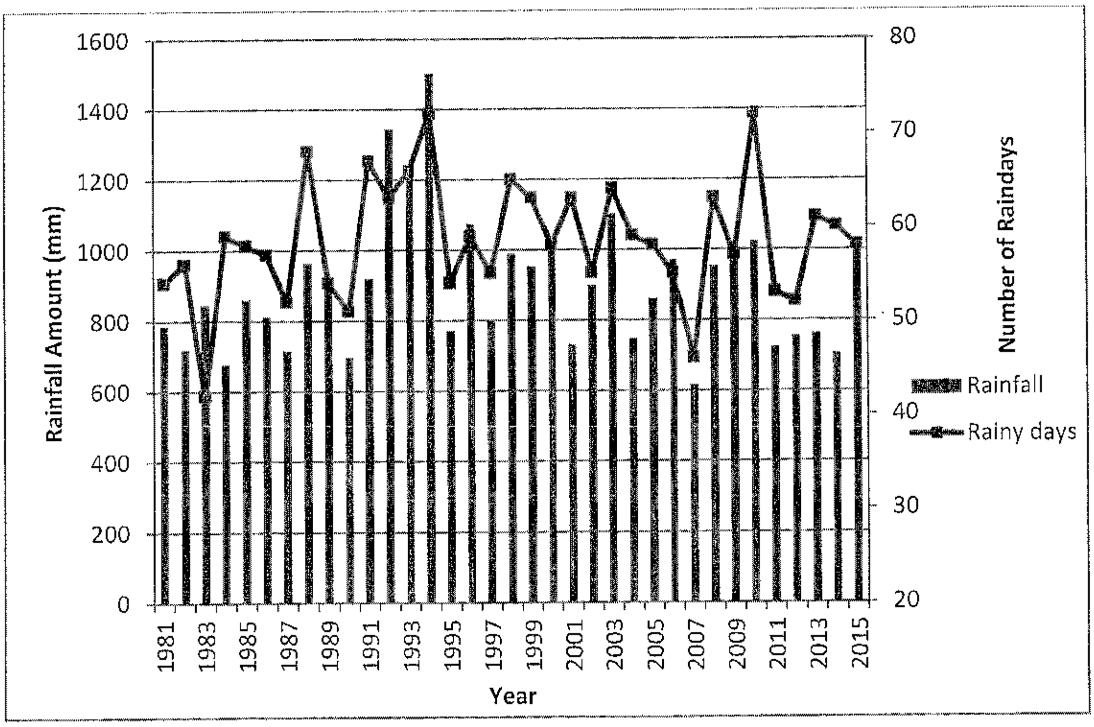

Fig 20 Annual values of rainfall and number of raindays in Gasua (1981 – 2015)

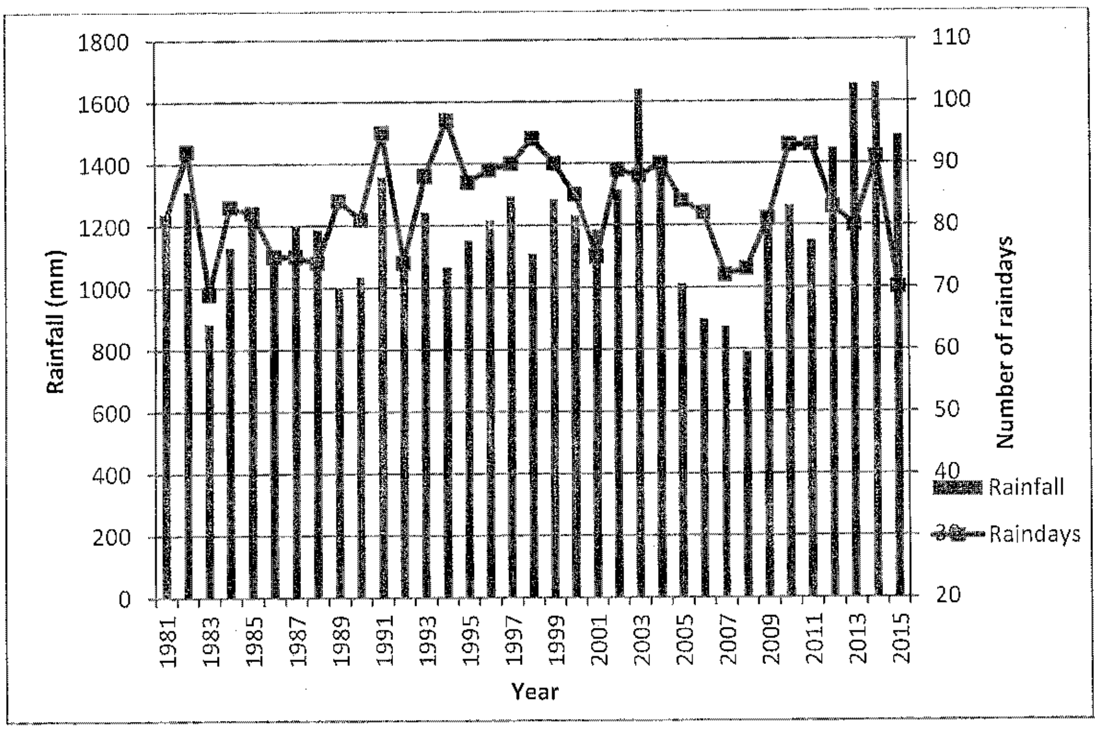

Fig 21 Annual values of rainfall and number of raindays in Kaduna (1981 – 2015)

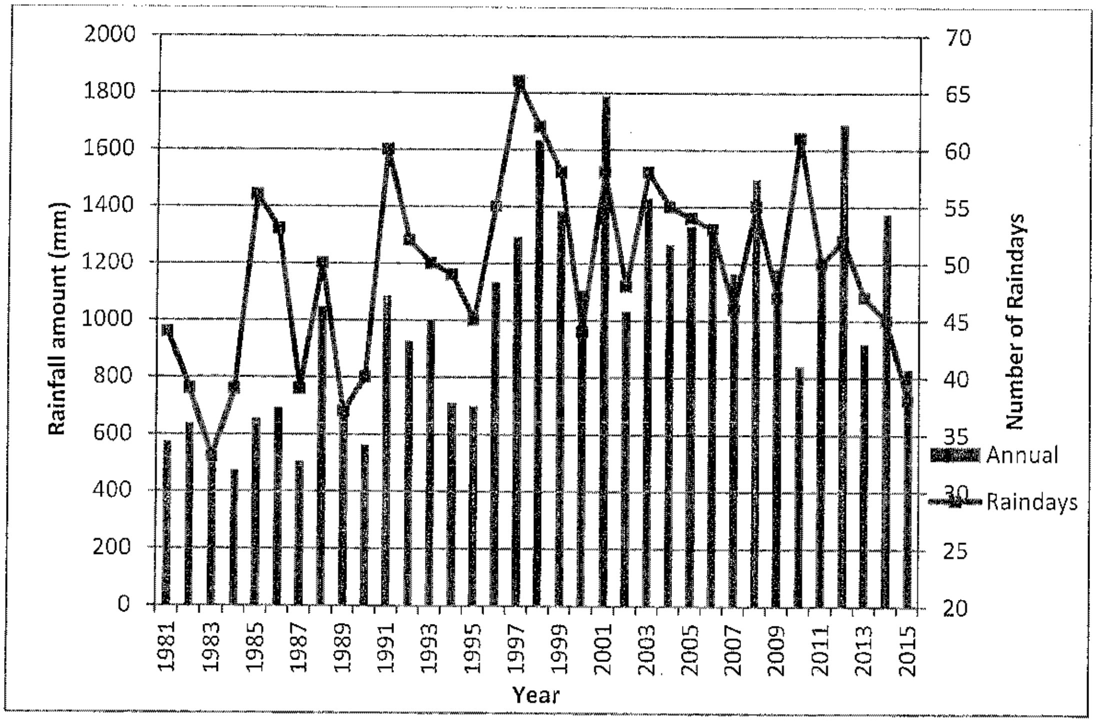

Fig 22 Annual values of rainfall and number of raindays in Kano (1981 – 2015)

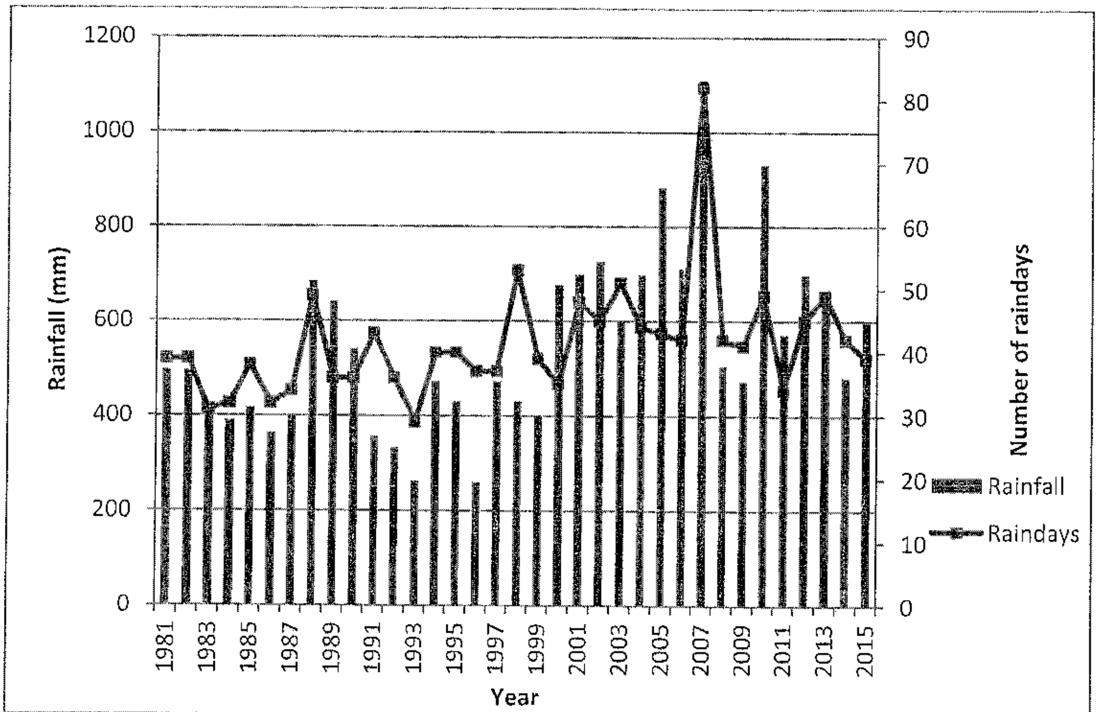

Fig 23 Annual values of rainfall and number of raindays in Katsina (1981 – 2015)

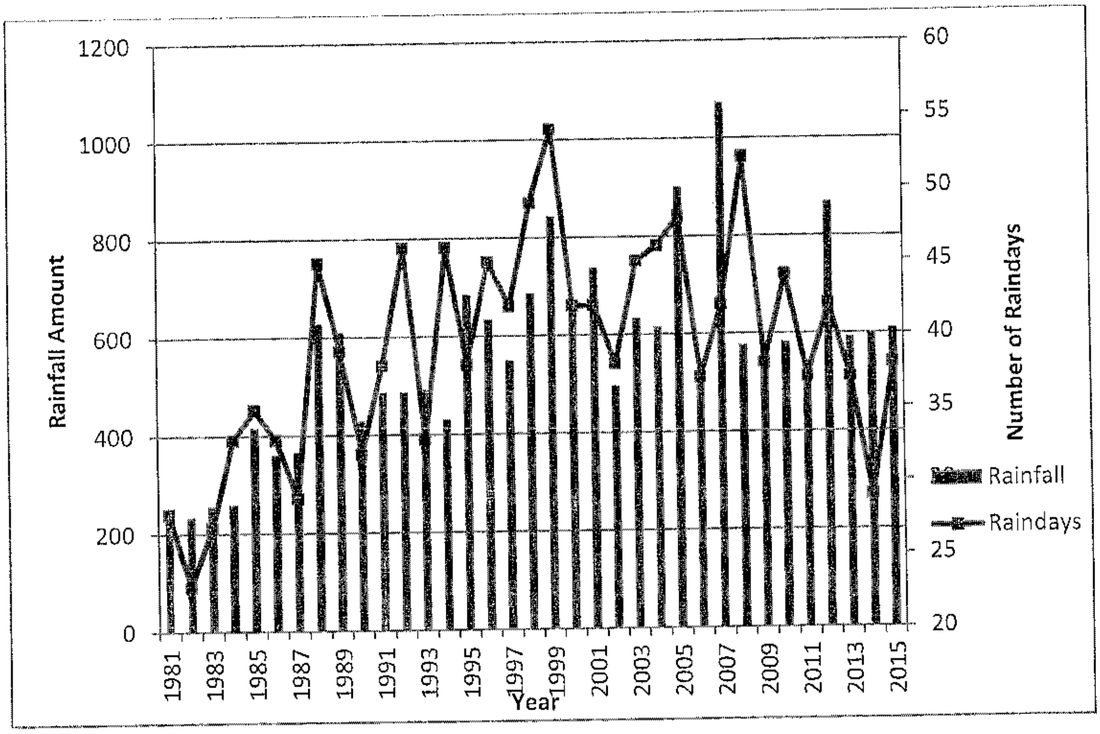

Fig 24 Annual values of rainfall and number of raindays in Maiduguri (1981 – 2015)

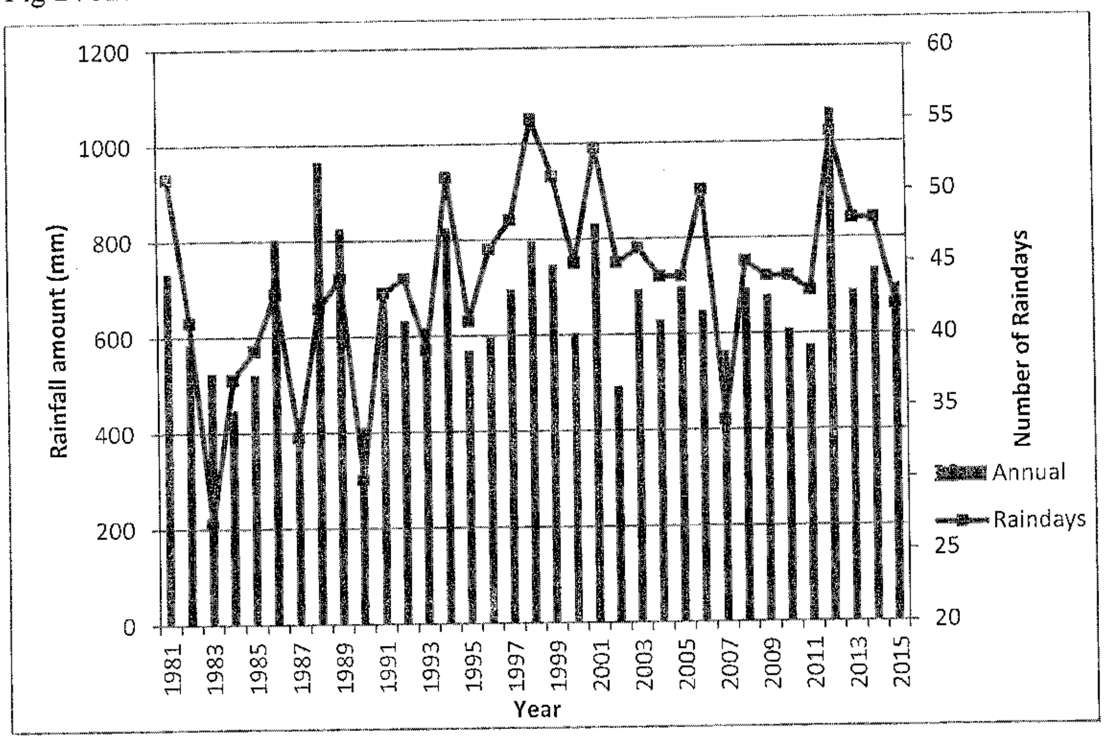

Fig 25 Annual values of rainfall and number of raindays in Potiskum (1981 – 2015)

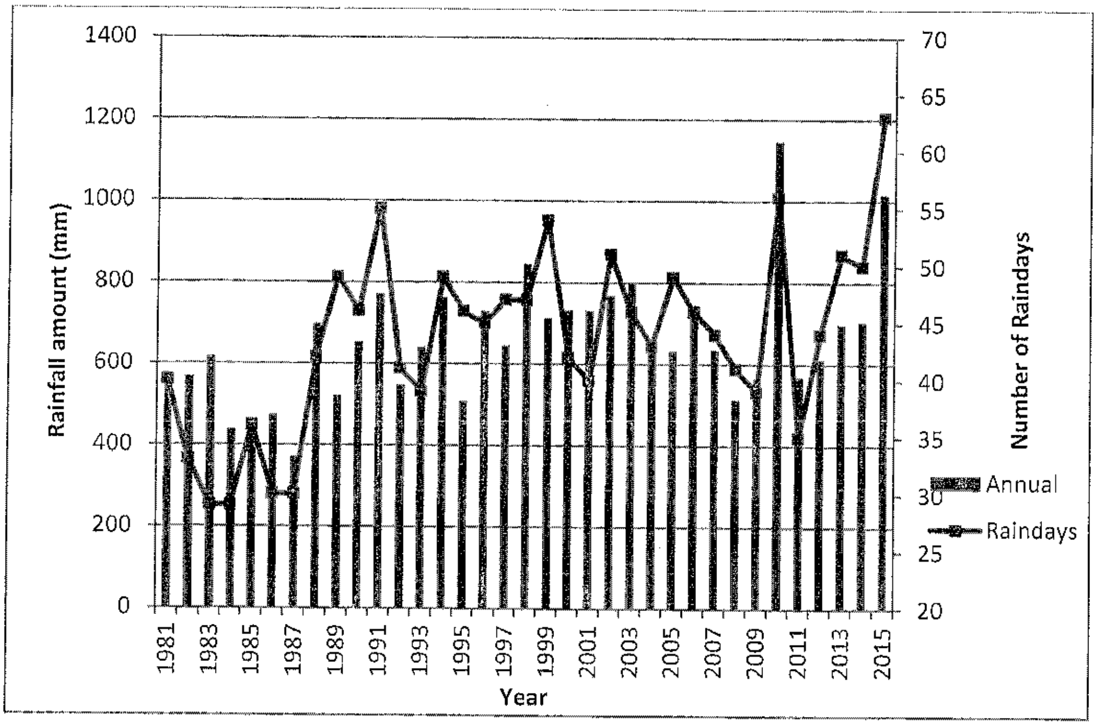

Fig 26 Annual values of rainfall and number of raindays in Sokoto (1981 – 2015)

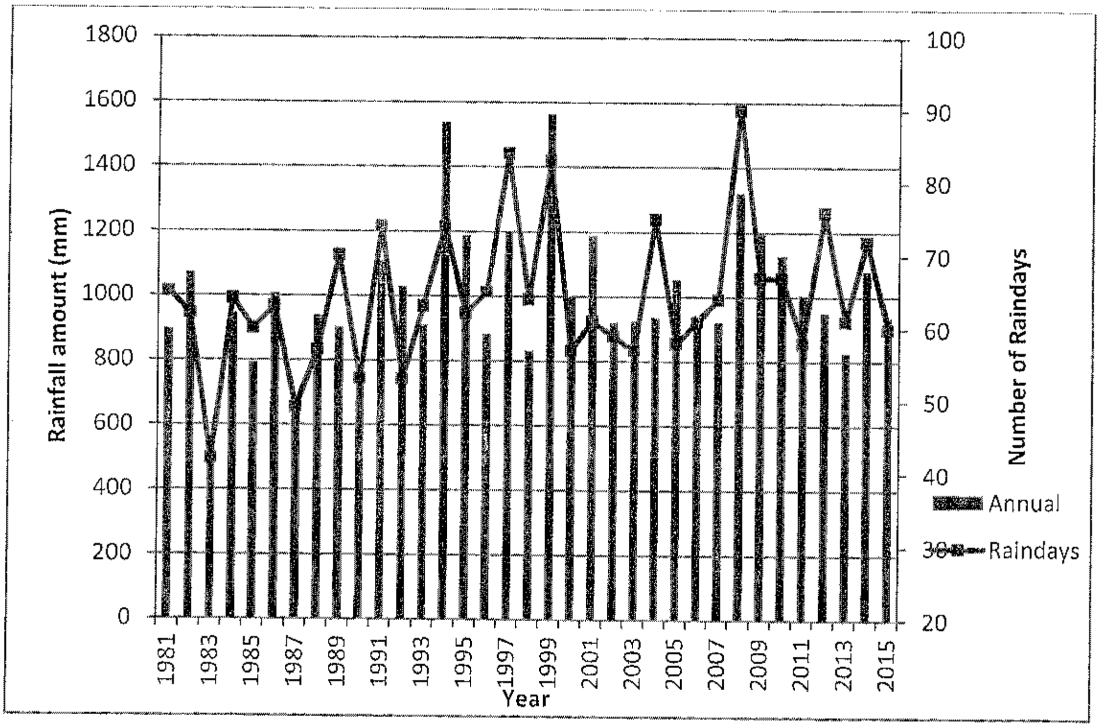

Fig 27 Annual values of rainfall and number of raindays in Yelwa (1981 – 2015)

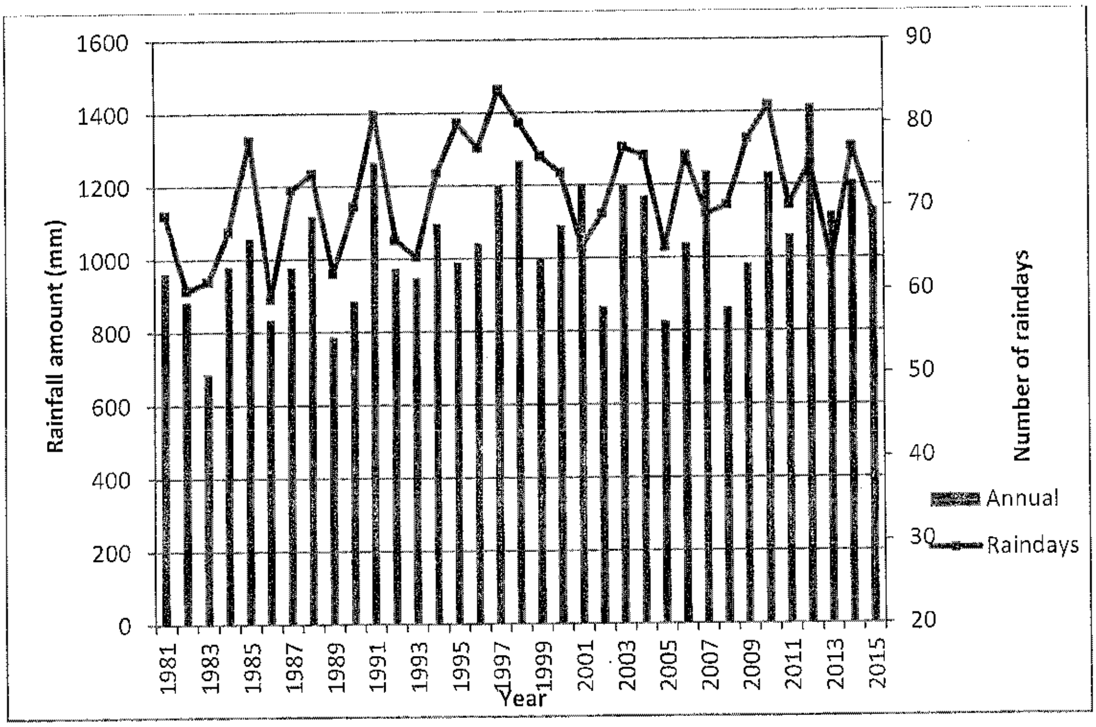

Fig 28 Annual values of rainfall and number of raindays in Zaria (1981 – 2015)

4.4 Onset, Cessation and Length of growing season

Table 10: Summary of Onset, Cessation dates and Length of Growing season

Station	Onset Date	Cessation Date	Length of Growing Season (Days)
Gasau	May-25	Sep-17	115 +1 = **116**
Kaduna	May-15	Sep-27	135 +1 = **136**
Kano	May-30	Sep-12	105 +1 = **106**
Katsina	May-30	Oct-02	125 +1 = **126**
Maiduguri	Jun-04	Sep-17	105 +1 = **106**
Potiskum	Jun-04	Sep-22	110 +1 = **111**
Sokoto	May-30	Sep-17	110 +1 = **111**
Yelwa	May-15	Sep-27	135 +1 = **136**
Zaria	May-10	Sep-22	135 +1 = **136**
Northern Nigeria	May-30	Sep-22	115 +1 = **116**

Figures 29–37 respectively show the rainfall onset and retreat periods and the length of the growing season in Gasau, Kaduna, Kano, Katsina, Maiduguri, Potiskum,

Sokoto, Yelwa, Zaria and Northern Nigeria using the relative definition method (percentage mean cumulative method). The period of the year when 7–8% mean cumulative rainfall of the 5-day periods is attained (corresponding to the time of rainfall onset) in Gasau is around the middle of the third dekad of May (with percentage cumulative rainfall of 7.07%). The corresponding periods for Kaduna, Kano, Katsina, Maiduguri, Potiskum, Sokoto, Yelwa, Zaria and Northern Nigeria are respectively around the middle of the second dekad of May, end of the third dekad of May, end of the third dekad of May, middle of the first dekad of June, middle of the first dekad of June, end of the third dekad of May, middle of the second dekad of May, end of the first dekad of May and end of the third dekad of May, with cumulative percentage rainfall values of 7.76%, 6.47%, 7.72%, 7.91%, 7.24%, 8.72%, 8.22%, 7.38% and 7.24% respectively. The periods of the year when over 90% of the mean cumulative rainfall for the 5-day periods is attained (corresponding to the time of rainfall retreat) are respectively around the end of the second dekad of September, end of the third dekad of September, beginning of the second dekad of September, early October, end of the second dekad of September, beginning of the third dekad of September, end of the second dekad of September, late September, beginning of the third dekad of September, beginning of the third dekad of September for Gasau, Kaduna, Kano, Katsina, Maiduguri, Potiskum, Sokoto, Yelwa, Zaria and Northern Nigeria.

Their respective cumulative percentage rainfall values are 90.41%, 92.18%, 90.75%, 96.53%, 92.42%, 93.84%, 93.48%, 91.69%, 92.78% and 90.50%.

The mean length of the growing season for Gasau is approximately 4 months, and for Kaduna, Kano, Katsina, Maiduguri, Potiskum, Sokoto, Yelwa, Zaria and Northern Nigeria this is approximately 5 months, 4 months, 4 months, 4 months, 4 months, 4 months, 5 months, 5 months and 4 months respectively.

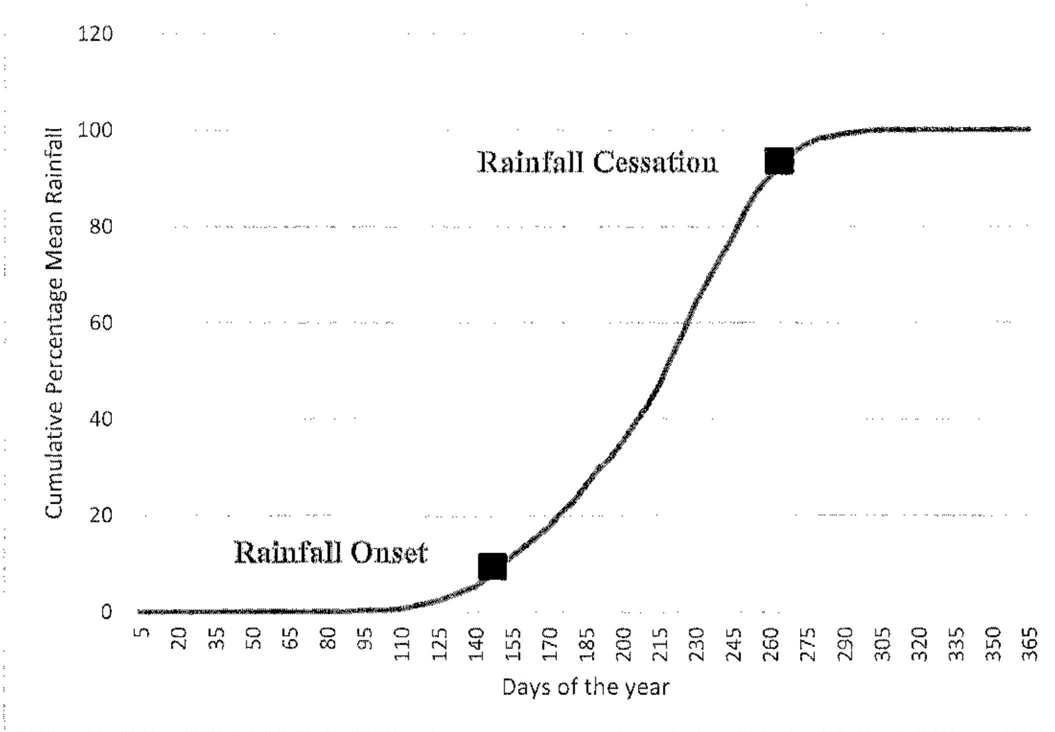

Figure 29 Rainfall onset, rainfall retreat, and length of the growing season in Gasua

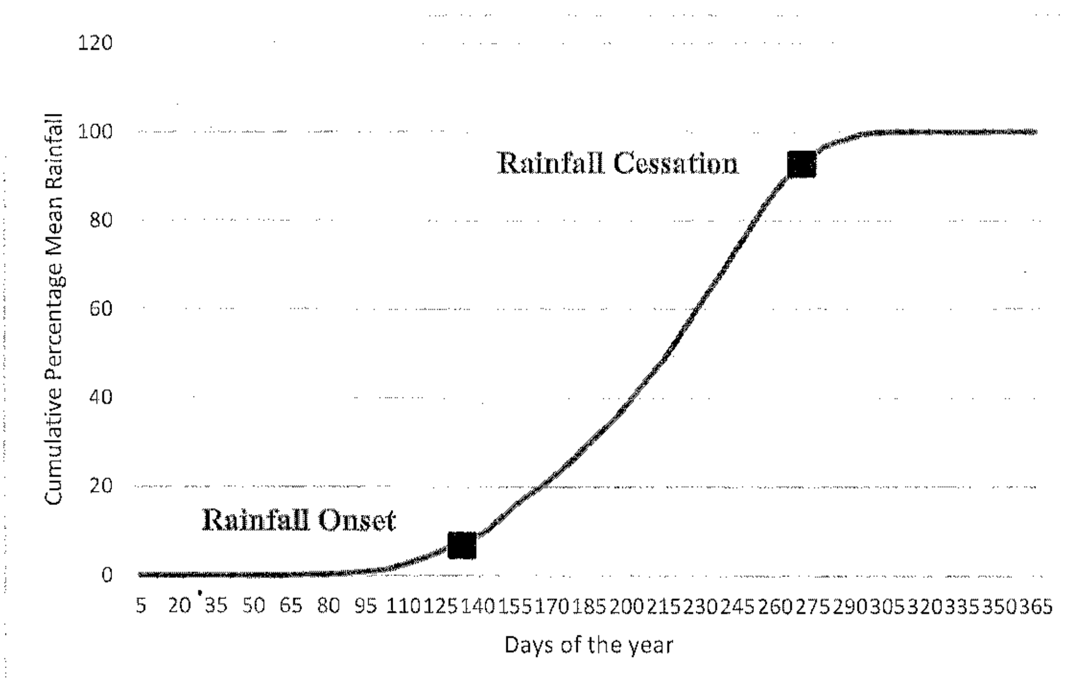

Figure 30 Rainfall onset, rainfall retreat, and length of the growing season in Kaduna

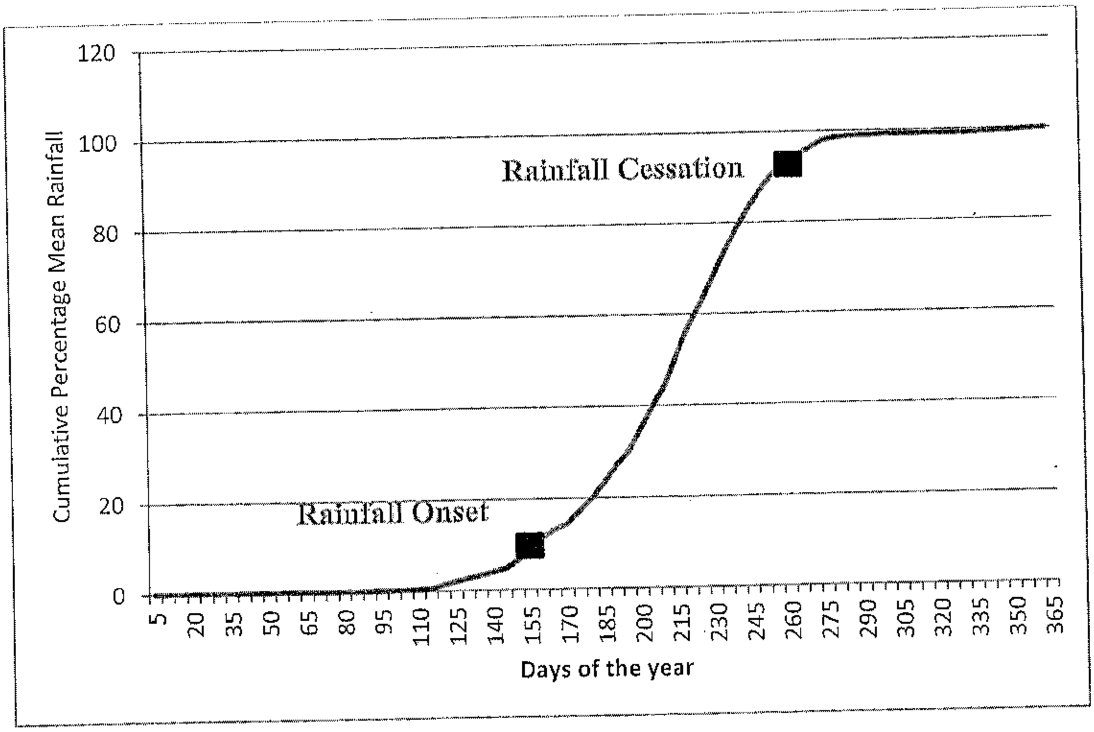

Figure 31 Rainfall onset, rainfall retreat, and length of the growing season in Kano

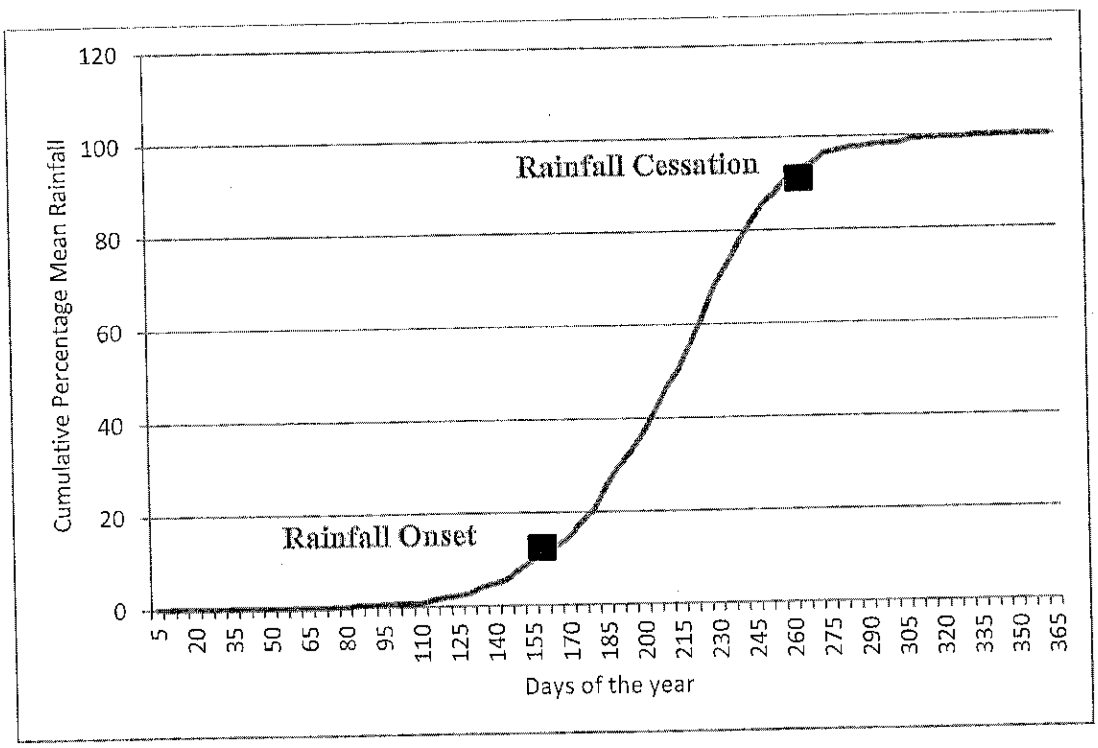

Figure 32 Rainfall onset, rainfall retreat, and length of the growing season in Katsina

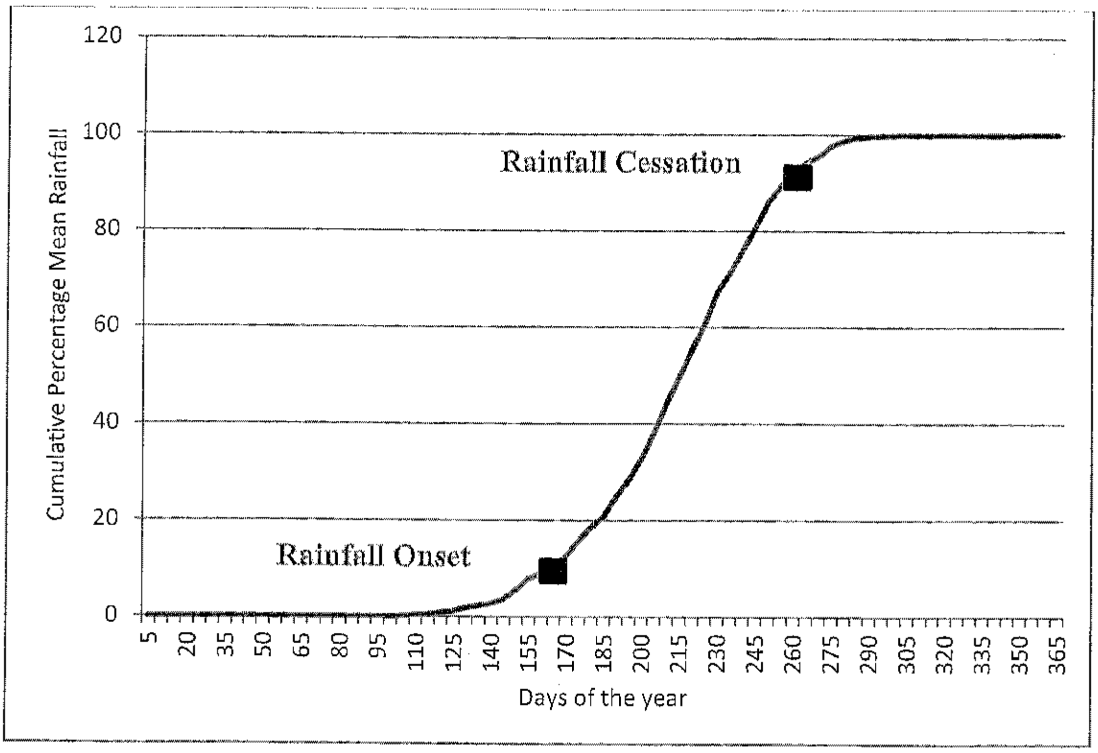

Figure 33 Rainfall onset, rainfall retreat, and length of the growing season in Maiduguri

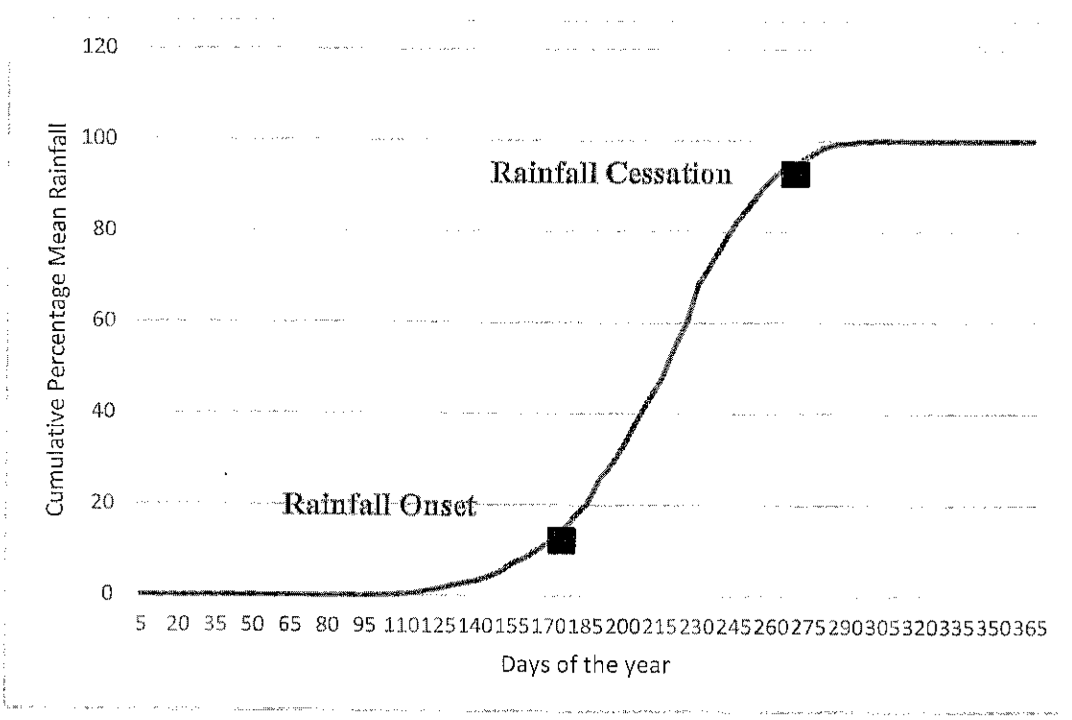

Figure 34 Rainfall onset, rainfall retreat, and length of the growing season in Potiskum

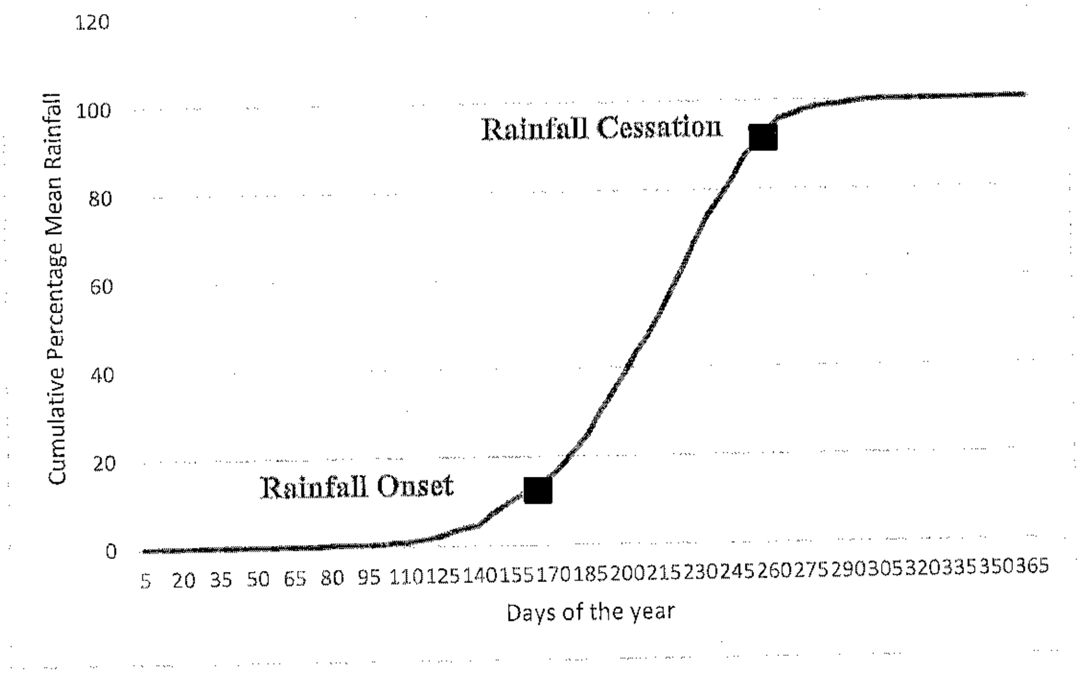

Figure 35 Rainfall onset, rainfall retreat, and length of the growing season in Sokoto

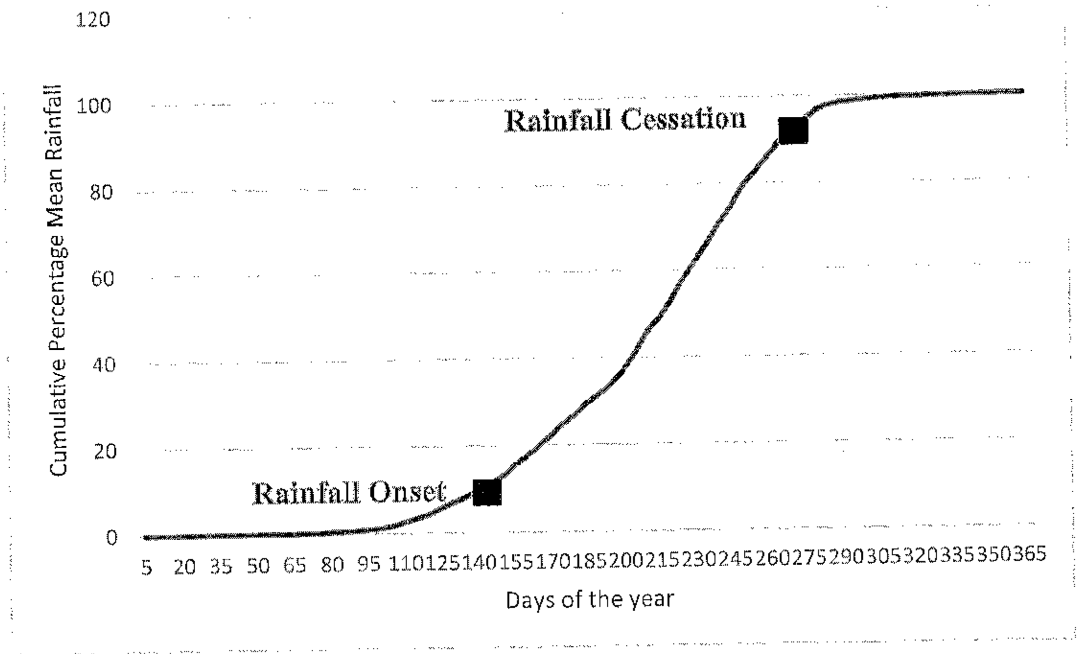

Figure 36 Rainfall onset, rainfall retreat, and length of the growing season in Yelwa

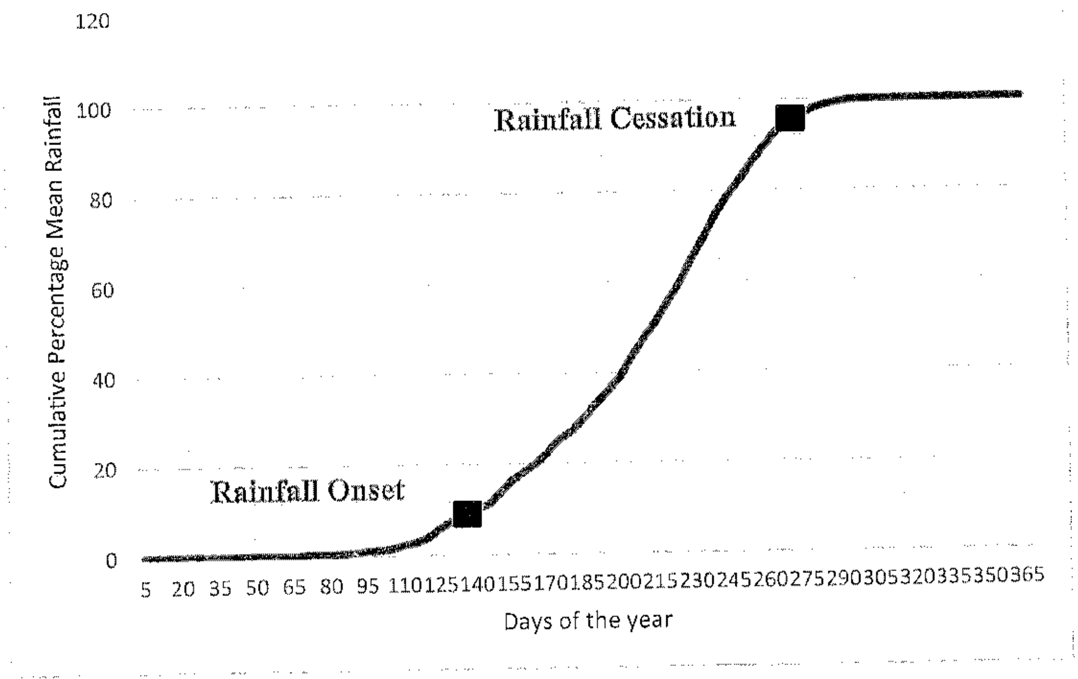

Figure 37 Rainfall onset, rainfall retreat, and length of the growing season in Zaria

4.5 Discussion

The most important characteristics of rainfall to farmers are the amount and distribution of rainfall during the length of growing season, reliability of rainfall after planting and rainfall variability. The amount and distribution of rainfall during the length of growing season or wet season is most important to farmers because most small-scale farmers that constitute the bulk of farming population practice rain-fed farming because they cannot afford huge financial investments that irrigation system requires.

Apart from other rainfall characteristics, the total amount of rain during this period is important in determining the type of crops that are cultivated in the study area. This is because the amount and distribution of rainfall in turn determines the availability of water for crop production (Tesfaye et al. 2004, Omotosho et al. 2013). Inadequate rainfall during the length of growing season may hamper the cultivation of crops.

The number of rain days serves as a marker that can be used to verify the distribution of rainfall. During the length of growing season of crops, farmers expect a balance between the distribution of rain days and moderation in rainfall amounts per rain day throughout the season. A fall in the number of rain days associated with an increase rainfall per rain day signifies an increase in the intensity of rainfall. The increase in rainfall intensity could have a number of negative effects on agriculture both in the short and long-term. It increases the rate of erosion and loss of particulate nutrients from arable soils, thereby reducing soil fertility and productivity (Fraser et al. 1999). An increase in the intensity of rainfall may be a potential serious risk of an increased flood frequency and severity for most regions of the world (Gordon et al. 1992, Fowler et al. 1995). High daily rainfall may be potentially destructive to agriculture in sensitive areas that are prone to flood. This situation could compound the problem of food shortages and lead to unprecedented food price increases.

Generally, the study shows that increase in the number of rain days does not depict high amount of rainfall.

The onset of rainy season is a very important event to farmers in Sub-Sahara Africa. The onset of rains marks the beginning of three main activities – planting, weeding and harvesting (Omotosho, 1990) which determine the socio-economic life and survival of the farming household. The importance of farming in the lives of these households also means that other activities are based on the accomplishment of these three activities (Omotosho et al. 2000). Planting that depends and is influenced directly by the onset of the rainy season, is the first activity on which the other two activities are based. Significant shifts in the onset of rains will therefore affect both agriculture and many other non-agricultural activities of small-scale farmers. Several researchers have reported how variability of the onset and cessation of the rainy season in tropical region pose a serious challenge in the process of determining when the rainy season/ planting season begins (Oladipo et al. 1993, Omotosho et al. 2000). Despite the fact that farmers contend that the onset of rains is becoming more uncertain with a tendency towards delayed onset, the data used for this study shows that there is no serious delay or shift in the onset of rains in the study area.

Judging by the relative definition method of determining the length of the growing season, the growing seasons in Gusau, Kaduna, Kano, Katsina, Maiduguri, Potiskum, Sokoto, Yelwa, Zaria and Northern Nigeria extend over 4 months (third dekad of May to the end of the second dekad of September), 5 months (the middle of the second dekad of May to the end of the third dekad of September), 4 months (end of the third dekad of May to the beginning of the second dekad of September), 4 months (end of the third dekad of May to early October), 4 months middle of the first dekad of June to the end of the second dekad of September), 4 months (middle of the first dekad of June to the beginning of the third dekad of September) , 4 months (end of the third dekad of May to the end of the second dekad of September), 5 months (middle of the second dekad of May to late September), 5 months (end of the first dekad of May to the beginning of the third dekad of September) and 4 months (end of the third dekad of May to the beginning of the third dekad of September) respectively.

CHAPTER FIVE

5.0 CONCLUSION

This study examined the relative efficiency of the use of rainfall amount in the determination of rainfall onset and retreat dates in Nigeria. The method employed in the determination of the rainfall onset and retreat dates is percentage cumulative mean rainfall value. The results obtained showed that with respect to the mean rainfall onset and retreat dates the method is quite efficient.

All the results obtained (rainfall onset and retreat periods and the length of the growing season) compare well with other studies carried out in the region with only little disparities in onset dates.

It is known that the frequency of rainfall during the course of the year within the tropics appears to be mostly governed by the movement of the ITD and the critical depth of the warm, moist mT air required for a location to experience rainfall regularly (>1500 m; see Ojo (1977)). This implies that, as the ITD advances northward, any newly invaded place that is less than 4° of latitude south of the ITD may, at best, experience isolated showers of uncertain amount and intensity (Flohn, 1960; Adedokun, 1981). A similar but converse situation prevails during the retreat period. The disparities in the dates of the start of the growing season as comparing with other studies are more than those of the cessation because the ITD advances into the continent gradually but it retreats rapidly (Ayoade, 1974; Adefolalu, 1983). The implication of this gradual advance and rapid retreat of the ITD is that isolated showers of uncertain amount and intensity would prevail over Nigeria over a relatively longer period of time at the beginning than towards the end of the growing season (Odekunle, 2004).

It is known that rainfall onset in Nigeria is usually foreshadowed by a succession of isolated showers of uncertain amount and intensity with intervening dry periods of varying duration (Walter, 1967). Thus, at the beginning or end of the year, one or two large isolated showers (as early as the first week in January or as late as December) may constitute the specified proportion of the total rainfall amount required for rainfall to be assumed to have commenced or retreated. This situation would definitely generate misleading onset/retreat dates. Whereas, rainfall frequency, in terms of rainy days, appears to yield more realistic onset and retreat dates mainly because the most prominent characteristic of the true rainfall onset and retreat period is rainfall frequency (Walter, 1967; Ilesanmi, 1972a; Ojo, 1977; Adedokun, 1981; Hastenrath, 1985). Thus, rainfall commences in earnest at the beginning of the season when rainfall becomes frequent and retreats at the end of the season when rainfall is infrequent.

Fluctuations in the amount of annual rainfall and number of rain days which could be linked to climate change were observed based on this study. It was also observed that rainfall duration and number of rain days are still very favourable for the agricultural activities the study area is known for.

5.1 Recommendations

Studies of this type are invaluable to farmers and are prerequisites to analyze both the annual dates of onset and cessations of the rains and crops to be planted. This study like that of Omonijo, (2014) suggests that the emergent risks that could arise from climate variability make it imperative to develop an integrated long-term climate policy that is adaptive to the evolving climate challenges. The policy should essentially facilitate the establishment of a dense network of weather stations for monitoring climatic parameters.

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