STATISTICAL ANALYSIS OF RAINFALL CHARACTERISTICS IN AKURE, ONDO STATE.

BY

OYELAMI AZIZAT ROMOKE

(WMA/11/0051)

DEPARTMENT OF WATER RESOURCES MANAGEMENT AND AGRO-METEOROLOGY,

FEDERAL UNIVERSITY OYE-EKITI, EKITI STATE, NIGERIA.

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CERTIFICATION

This is to certify that this project was carried out by OYELAMI, AZIZAT ROMOKE with matriculation number WMA/11/0051, a student in the Department of Water Resources Management and Agricultural Meteorology, Faculty of Agriculture, Federal University Oye-Ekiti, Ekiti State, Nigeria.

______________	10/10/2016
Mrs. T. E Babalola	Date
Project Supervisor	
______________	21/10/2016
Prof. Agbenin	Date
Head of Department	

DEDICATION

This project is dedicated to Almighty Allah for always guiding me through the right path and for bestowing me with the wisdom, knowledge and understanding to carry out this project.

ACKNOWLEDGEMENT

I express my profound appreciation with sincerity and honesty to Almighty Allah, the Most Merciful who graciously blessed me with wisdom, knowledge and understanding towards the success of this project. Also for making my life a reality and for his love, divine wisdom, sustaining grace, protection, blessings, provision, kindness and support through my journey in life and my stay in the university.

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I acknowledge the constructive criticism of my supervisor Mrs. Babalola for her encouragement, support, patience and unquantifiable help during the process of this project and writing this report. May you not lack anything good and may God perfect and bless everything that concerns you (Amen). I sincerely appreciate the help of my lecturer Prof. Oguntunde, thanks a lot and God bless you. And to all the lecturers in the department for the quality knowledge imparted, you have all been a source of inspiration to me.

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ABSTRACT

This study examines the trends, onset, cessation and growing season of rainfall over Akure using data obtained from the archive of Nigerian Meteorological Agency (NIMET) Oshodi, Lagos, over the period of 1970–2005. Standardized Precipitation Index (SPI) was estimated from the available Rainfall records, Decadal analysis of Akure indicated 1991 – 2000 as a wet decade, while 1981 – 1990 was a dry decade. The onset and cessation dates were determined. The estimated parameters were subjected to time series analysis. Evaluation of trends was done using the Mann-Kendall test. Trend lines for each of the parameter were produced. The length of growing season in the study area ranges between 196 to 287 Julian days, the mean cessation date of the is about 310 Julian day and on the average, the rainy season starts from the 62 Julian day. The Mann-kendall statistic was used to investigate the significance of these trends. The results show that the rainy season has progressively been starting late. The results also indicated that the hydrological growing season is decreasing. The results of this study have great implications for both surface and underground water resource management, agriculture and sustainable food security not only for the Akure region but the state a at large. Increased irrigation agriculture is eminent in this environment

Key words: Cessation, Growing season, Onset, Trends, SPI

CHAPTER ONE

1.0 INTRODUCTION

Rainwater falls to the ground and is absorbed into the soil reaching locations in the bedrock known as aquifers. Aquifers hold huge volume of water in the water table. Many man-made wells feed directly from the water table, providing water for domestic use for man.

Rain, has a dramatic effect on agriculture. All plants need at least some water to survive; therefore rain (being the most effective means of watering) is important to agriculture. In the field of agriculture, rainfall is the most important climatic factor in Nigeria (Adebayo, 1997) because its onset ushers in planting season, its duration and distribution ensures crop sustainability and favorable yield, while its cessation marks harvesting and storing season. Whenever there is late onset, hunger, temporal unemployment and poverty looms. Dry spells and droughts which are related to rainfall and occur annually in Nigeria (Audu et al. 2012, Sawa, 2011) are injurious to crops leading to crop failure. The early and late cessations also destroy the late crops (Audu et al. 2012, Bello , 1998). Rainfall is one of the indices of agro – meteorological moisture (Audu, 2012).

Living organisms (both plants and animals including man) cannot survive without optimum water supply. Although, it has been argued that rainfall (water) and temperature are the most important climatic determinants of crop survival and production especially in Nigeria. However, generally; temperature has remained favorable to crop production especially during the growing season, but rainfall is not only disappointing, but also erratic, highly unreliable and unpredictable. The era in which rainfall was highly relied upon by farmers for sufficient crop production is gone. Meanwhile, Nigeria which still practices rain – fed agriculture rely on the "mercy of nature" to produce adequate food and the needed raw materials for the few agro allied industries. (Adebayo, 1997).

Apart from the socio - economic problems facing Nigerian farmers, climatic variability constitutes a major limiting factor in crop production due to the practice of rain - fed agriculture (Audu, 2012). Aside the beneficial effects of rainfall, it can also be destructive in nature; natural disasters like floods and landslides are caused by rainfall (Ratnayake and Herath, 2005). A regular rain pattern is usually vital to healthy plants, too much or too little rainfall can be harmful, even devastating to crops. Drought can kill crops and increase erosion, while overly wet weather can cause harmful fungus growth. Plant need varying amounts of rainfall to survive. Heavy rainfall events can lead to flooding which can in turn wipe out entire crops over wide areas, and can also cause soil erosion, water logging and reduced plant growth.

Generally, the study of the weather and climatic elements of a region is vital for sustainable development of agriculture and planning. Particularly, rainfall and temperature temporal analyses for trends, fluctuations and periodicities are deemed necessary as such can indirectly furnish the "health" status of an environment. A declining and/or rising trend etc may be quite instructive for different segments of the human and natural systems. Impending long or short term weather – related natural disasters for instance may be predicted and better mitigated or adaptive actions initiated through the analysis of the fluctuations and return periods of the series. Extreme weather events that can lead to drought and prolonged heat spell; flooding etc can be accessed through the statistical analysis of a region's temporal rainfall regime (Afangideh et al., 2010).

Over the years, there has been considerable increase in rainfall records which are very important in planning and design of the water projects and Agro Meteorological studies. The study of weather and climatic element; rainfall of Akure is vital for sustainable development of agriculture and planning in Ondo state.

Previous studies have analyzed rainfall trends over entire or part of Nigeria. For example, Adefolalu (1986) examines trends in rainfall pattern using 70-year period (1911–1980) rainfall data from 28 meteorological stations. Bello (1998) extended the work and compared the seasonality of rainfall distribution in Nigeria for two climate periods, 1930–1961 and 1962–1993. Ati et al. (2009) reported significant increase in rainfall over nine stations in northern Nigeria between 1953 and 2002. The results showed a general decline of dry season's contribution to annual rainfall i.e. dry period is getting drier. More recently, Oguntunde et al. (2011) analyzed rainfall trends over Nigeria using 1901–2002 rainfall data from Global Gridded Climatology of Climate Research Unit Time series (CRU TS.2.1). They concluded that annual rainfall has been reduced significantly over 20% of the landscape and the amount of annual rainfall reduced by 50–350 mm in 64% portion of Nigeria. It is important to state that rainfall of Nigeria and West Africa in generally is influenced by the dynamics of continental air mass and maritime air mass which meet along a slanting surface called Inter-Tropical Discontinuity (ITD) (Odekunle, 2004). Varying degrees of convective activity and precipitation takes place at the south of ITD while little or no cloud development or precipitation occur in the northern part of ITD (Ilesanmi, 1972).

1.1 STATEMENT OF PROBLEM

Extreme and unusual weather events, resulting in loss of life and property and disruption of socio-economic activities, are part of daily experiences all over the world. The increasing frequency and intensity of these events constitute a major challenge to socio-economic development, particularly in developing countries. Timely continuous analysis of weather and climate information is therefore vital tools for planning in key sectors of the economy that are sensitive to weather.

1.2 OBJECTIVES OF THE STUDY

The specific objectives are to:

I. To analyze trends and variability of rainfall.

II. To determine the variability Onset, Cessation and length of growing season in the study area.

III. To suggest measures of complementing rainfall for adequate crop production and ensuring food security.

1.3 JUSTIFICATION.

Many organizations have devoted more effort to collecting climatic data than to their subsequent analysis. This is similar to other areas where monitoring data are collected routinely. Sometimes the excuse for the lack of analysis is that the quality of the data is suspect. This is not a good reason, because one way to improve data quality is to analyze the existing data to demonstrate their importance and shortcomings. For a country like Nigeria whose welfare depend very much on rain-fed agriculture, a quantitative knowledge of water requirement of the region, availability of water for plant growth and supplemental irrigation etc. on a monthly of seasonal basis is an essential requirement for agricultural development. Analyses of historical rainfall data have been found to assist in understanding the pattern of rainfall distribution and occurrence, which aid in forecasting of rainfall pattern in the area and to provide information for early warning system in the region.

CHAPTER TWO

2. LITERATURE REVIEW

2.1 WEATHER AND CLIMATE

Weather and climate over the earth are not constant with time; they change on different time series ranging from the geological to the diurnal through annual seasonal and intra-seasonal time scales. Such variability is an inherent characteristic of the climate. The study of climate fluctuations involves the description and investigation of causes and effect of this fluctuation in the past and their statistical interpretation. Much of the work done is about variability of the two important meteorological parameters: rainfall and temperature.

2.1.2 RAINFALL

Information of the amount, intensity and distribution of monthly or annual rainfall for the most important places in the world is generally available. Long-term records of daily rainfall have been compiled for years; norms and standard deviations have been worked out; floods and droughts have been defined and climatic zones of potential evapotranspiration, transpiration have been mapped from rainfall patterns and crop studies. Investigations using electronic computers are continuously in progress and efforts are made to predict future trends in order to improve planning.

Most water resources planning programme and agricultural activities particularly (crop production) are dependent on the availability or non-availability of rainfall. The absence or presence of rain at certain times determines the degree of success or failure of these processes.

Major farm operations or farm management strategies depend on the current weather, and even the weather of the next few hours (Sivakumar et al. 1993). Analyses of historical rainfall data have been found to assist in understanding the pattern of rainfall distribution and occurrence. Such analyses have been carried out on yearly monthly, decadal, weekly and daily basis in several studies (Ajayi and Olufayo, 2002). (Sivakumar et al 1993) however noted that for agricultural purposes, the daily analysis produces the optimal result. Analyses of daily rainfall analysis have equally being approached from various perspectives, which include temporal distribution and pattern, total amount, intensity and spatial coherence. These analyses are applied in communication study, civil and water works and also in agricultural planning but the dependence of the dry and wet day sequence poses a greater challenge to agricultural production.

2.2 INSTRUMENTS FORMEASURING RAINFALL

Instruments for measuring precipitation are called rain gauges. Rain gauges are classified into recording and non-recording types. The latter include cylindrical and ordinary rain gauges, and measurement of rainfall with these types is performed manually by the observer. Some recording types such as siphon rain gauges have a built-in recorder, and the observer must physically visit the observation site to obtain data. Other types such as tipping bucket rain gauges have a recorder attached to them, and remote readings can be taken by setting a recorder at a site distant from the gauge itself to enable automatic observation.

2.2.1. CYLINDRICAL RAIN GAUGES

These instruments work according to a simple principle of measurement, and also have a straightforward structure. They offer the advantage of having a low rate of problem occurrence. It consists of a cylindrical vessel with a uniform diameter from top to bottom and an orifice at the top. It does not have a funnel. Rainwater enters through the orifice and accumulates in the cylindrical vessel, which is weighed at regular intervals with a precipitation scale. As the amount of precipitation is determined by subtracting the vessel weight from the total weight, the dry vessel is weighed before observation. The precipitation scale is graduated in millimeters based on the size of the rain gauge orifice.

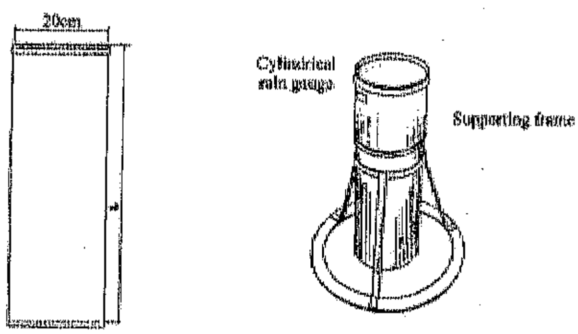


Figure 2.1 Cylindrical rain gauge and its supporting frame

2.2.2 ORDINARY RAIN GAUGES

Ordinary rain gauges are the type used at non-automated observatories. With such devices, the observer takes measurements using a rain-measuring glass at regular intervals. This type of rain gauge consists of a receptacle, a shell, a storage bottle, a storage vessel and a rain-measuring glass, which is a measuring cylinder graduated in precipitation amounts based on the diameter of the receptacle's orifice. The shell acts as a container for the storage bottle and the storage vessel. The storage vessel is a cylindrical metallic container that houses the storage bottle. The measuring cylinder is transparent, and is graduated in units of precipitation. Rainwater entering through the receptacle accumulates in the storage bottle, and the precipitation amount is measured with the measuring glass. Rainwater that overflows from the storage bottle enters the storage vessel. The amount of overflow is also measured with the measuring glass, and is added to the amount of precipitation in the storage bottle.

2.3 RAINFALL CHARACTERISTICS IN NIGERIA

Rainfall in Nigeria is characterized by high degree of variability and it is the element of climate most influential to determining the variety and abundance of flora and fauna, land use, economic development and practically all aspect of human activity

2.3.1 LENGTH OF GROWING SEASON

The Length of growing season in any given region refers to the number of days when plant growth takes place. The growing season often determine which crop to grow in a particular area, as some crop require long growing seasons while others mature rapidly. Growing season length is dependent on various factors. Depending on the region and climate, the growing season is influenced by rainfall, air temperature, daylight hours e.t.c. changes in length of growing season can be have both positive and negative effects.

2.3.2 RAINFALL ONSET DAYS

The onset dates are the most critical. Reliable prediction of onset time will greatly assist on-time preparation of farmlands, mobilization 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(Omotosho, 2004).

Prediction methods have been proposed, some based on rainfall data alone (Ilesanmi, 1972; Obasi and Adefolalu, 1977; Stern et al., 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 et al., 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 favorable 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 utilization, 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.

2.3.2.1 DATE OF ONSET OF THE RAINY SEASON

The first 20–28 days are the most critical for seed germination and crop establishment. It is thus important to have one or two initial heavy rainfall (10.0 mm) to moisten and soften the soil sufficiently for seed germination and also to ensure crop survival in the following twenty days. It is for this reason that a modified definition has been proposed as follows: 'the beginning of the first two rains totaling 20 mm or more, within 7 days, followed by 2 –3 weeks each with at least 50% of the weekly crop–water requirement'. The 50% requirement 2.5mm was given by Kowal and Knabe (1972). This definition is adopted in the study.

2.3.3 RAINFALL CESSATION AND TERMINATION OF GROWING SEASON

The cessation of rainfall is a period which is characterized by the end of rainfall in a year neglecting the scanty rainfall which occasionally occurs. (Omotosho, 2000) define cessation of rainfall as from September 1 after which there are 21 or more consecutive days of rainfall less than 50% of the crop water requirement. The termination date according to Madeoye (1985) is defined as the last date on which a threshold amount is exceeded. Zargina (1987) used the minimum daily rainfall threshold of 25mm to determine the termination of the growing season. All existing cessation models except that of (Omotosho, 1992), are rainfall based and give the same dates of cessation of cessation every year, which is certainly far from reality.(Omotosho, 1992) method which is based on the vertical wind shear associated with the mid –troposhere Africa easterly jet (AEJ), is also capable of treating each year independently. However, the sparse upper-air network again limits its application. Obviously, there is a strong need for new and long range schemes based on more readily available data and which will have wider applicability.

2.4 STANDARDIZED PRECIPITATION INDEX (SPI)

The SPI is simply the transformation of precipitation timeseries into a standardized normal distribution (z- distribution). Bussay*et al.* (1998) assessed the utility of the SPI for describing draught in Hungary. They concluded that the SPI was suitable for quantifying most types of draught event. The SPI has three main advantages: the first and primary advantage is its simplicity. The SPI is based solely on rainfall and require only the computation of two parameters. The SPI's second advantage is its variable time scale, which allows it to describe drought conditions important for a range of meteorological agricultural and hydrological applications. The third advantage comes from its standardization which ensures that the frequency of extreme event at any location and any time scale are consistent. The SPI has three potential disadvantages, the first being the assumption that a suitable probability distribution can be found to model the raw precipitation data prior to standardization. An associated problem is the quantity and reliability of the data used to fit the distribution. McKee *et al.* (1993) recommend using at least 30 years of high-quality data. A second limitation of the SPI arises from the standardized nature of the index itself; namely that extreme droughts (or any other drought threshold) measured by the SPI, when considered over a long time period, will occur with the same frequency at all locations. Thus, the SPI is not capable of identifying regions that may be more 'drought prone' than others. A third problem may arise when applying the SPI at short time scales (1, 2, or 3 months) to regions of low seasonal precipitation. In these cases, misleadingly large positive or negative SPI values may result.

Table2.1. Draught classification by SPI and corresponding event probability

SPI value	Drought Category	Probability %
≥ 2	Extremely wet	2.3
1.5 to 1.99	Severely wet	4.4
1.0 to 1.49	Moderately wet	9.2
0 to 0.99	Mildly wet	34.1
0 to -0.99	Mild draught	34.1
-1.0 to -1.49	Moderate drought	4.4
-1.5 to -1.99	Severe drought	4.4
≤ -2	Extreme drought	92.3

(Mckee et al, 1993)

2.5 WAVELET ANALYSIS

A wavelet is a kind of mathematical function used to divide a given fuction into different frequency components and study each component with a resolution that matches it scale. A wavelet transform is the representation of a function by wavelets.

CHAPTER THREE

3. METHODOLOGY

3.1 DESCRIPTION OF STUDY AREA

The study area is Akure, Ondo State South Western Nigeria.Akure lies about 7.2571° North of the equator and 5.2058°East of the Meridian. It is about 700km Southwest of Abuja and 311km north of Lagos State. Residential districts are of varying density, some area such as Arakale, Ayedun Quarters, Ijoka, and Oja-Oba consist of over 200 persons per hectare, while areas such as Ijapo Estate, Alagbaka Estate, Avenue and Idofin have between 60-100 people per hectare(Adeoye, 2016). The town is situated in the tropic rainforest zone in Nigeria.

Akure is a city in south-western Nigeria, and is the largest city and capital of Ondo State. The city has a population of 484,798. The residents of the City are primarily of the Yoruba ethnic group. It lies in the southern part of the forested Yoruba Hills and at the intersection of roads from Ondo, Ilesha, Ado-Ekiti Benin and Owo. Akure is an agricultural trade centre for the yams, cassava, corn (maize), bananas, rice, palm oil and kernels, okra, and pumpkins grown by the Ondo branch of the Yoruba people. Although cocoa is by far the most important local commercial crop, cotton, teak, and palm produce are also cultivated for export. The town's industries include electronics manufacturing, soft drink, bottling among others. Akure is the site of a federal university of technology (founded in 1981), Federal College of Agriculture and School of Health Technology.

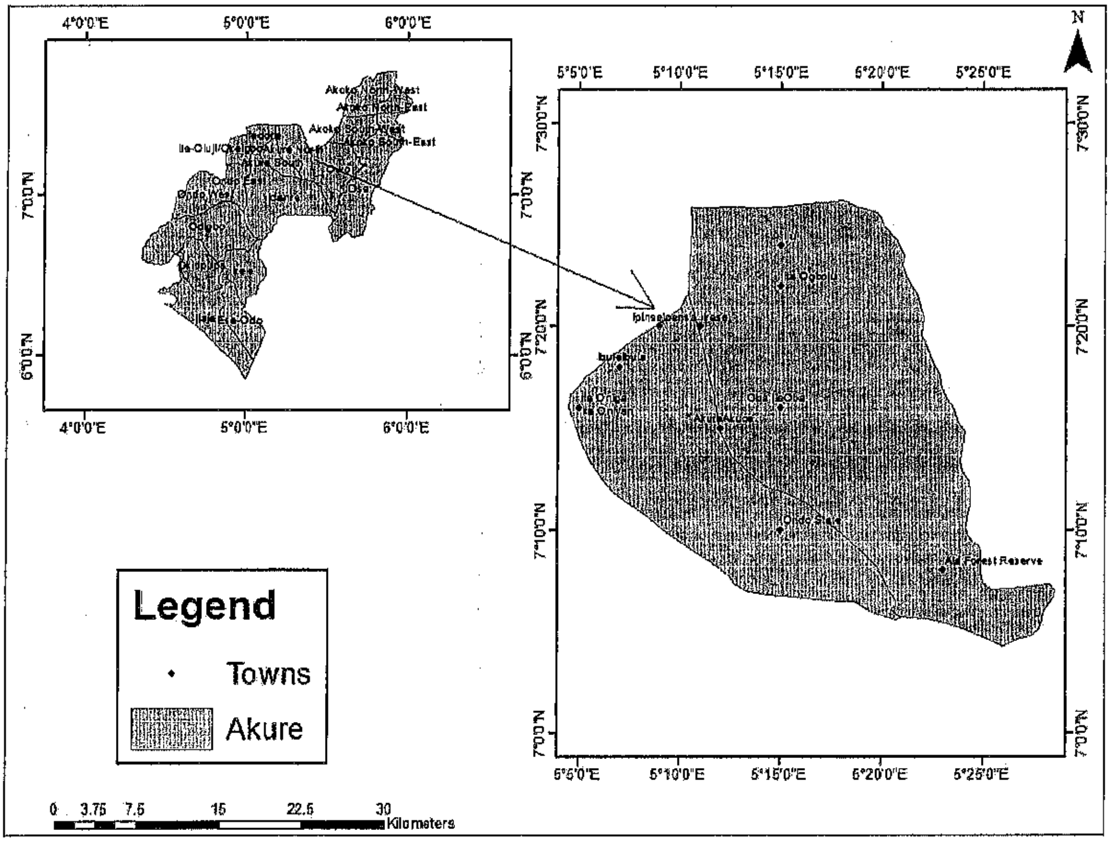


Figure 3. Map of Akure showing the Towns.

3.2 MAJOR CROPS GROWN IN STUDY AREA

Ondo State is Nigeria's chief cocoa-producing state. Other crops include rice, yams, corn (maize), coffee, taro, cassava (manioc), vegetables, cashew, banana, plantain, pineappleand fruits (Egbonwon,2015).

3.3 DATA SOURCE AND COLLECTION

Rainfall data used in this study were obtained from the archive of Nigerian Meteorological Agency (NIMET)Oshodi, Lagos. These data spanned a period of Thirty five (35) years (1970-2005). These data were used to derive the rainfall characteristics such as onset, cessation, length of growing season, which are very crucial in plant growth and development. The rainfall data was also used to determine the rainfall trend and distribution patterns of rainfall amount in the study area.

3.4 DATA ANALYSIS

The data was subjected to statistical analysis using:

3.4.1 TREND ANALYSIS

Mann-Kendall test was used to estimate and analyze trend in rainfall time series for the study area (1970-2005). The Mann-Kendall test is applicable in cases when the data values x_i of a time series can be assumed to obey the model

$$x_i = f(t_i) + \varepsilon_i \qquad (1)$$

Where f(t) is a continuous monotonic increasing or decreasing function of time and the residuals ε_i can be assumed to be from the same distribution with zero mean. It is therefore assumed that the variance of the distribution is constant in time. As a non-parametric test, no assumptions as to the underlying distribution of the data are necessary. To estimate the true slope (magnitude) of an existing trend, the Sen's non-parametric method was used (Salmi et al., 2002).

$$\sum_{k=1}^{n-1}\sum_{j=k+1}^{n}\operatorname{sgn}(x_j - x_k) \qquad (2)$$

Where x_j and x_k are the annual values in years j and k, j > k, respectively, and

$$\operatorname{sgn}(x_j - x_k) = \begin{Bmatrix} 1 \ if \ x_j - x_k > 0 \\ 0 \ if \ x_j - x_k = 0 \\ -1 \ if \ x_j - x_k < 0 \end{Bmatrix} \qquad (3)$$

If n is 9 or less, the absolute value of S is compared directly to the theoretical distribution of S derived by Mann and Kendall (Gilbert, 1987). In MAKESENS the two-tailed test is used for four different significance levels α : 0.1, 0.05, 0.01 and 0.001. At certain probability level H0 is rejected in favour of H1 if the absolute value of S equals or exceeds a specified value S α /2, where S α /2 is the smallest S which has the probability less than α /2 to appear in case of no trend. A positive (negative) value of S indicates an upward (downward) trend. The minimum values of n with these four significant levels can be reached and are derived from the probability table for S as follows:

Table 3.1: Significant level and their values (Mann-Kendall)

Significance	Parameters
Level (α)	N
0.1	≥ 4
0.005	≥ 5
0.01	≥ 6
0.001	≥ 7

3.4.2 RAINFALL ONSET DATE (ROD) AND RAINFALL CESSATION DATE (RCD)

The definitions by Omotosho et al. (2000) for determination of rainfall onset dates (ROD) and cessation dates (RCD) were applied in this study. The ROD is defined as "the first two rains totaling 20 mm or more within 7 days, followed by two to three weeks each with at least 50% of the weekly crop water requirement". The RCD is defined as "any day from 1st September after which there are 21 or more consecutive days of rainfall less than 50% of the crop water requirement". The length of growing season (LGS) is the number of days between the onset date and cessation date and it is simply determined by finding the differences between the RCD and the ROD (i.e. LGS = RCD-ROD).

3.4.3 STANDARDIZED PRECIPITATION INDEX

The Standardized Precipitation Index SPI was analyzed using the equation:

$$SPI = \frac{P_i - \overline{X}}{\sigma}$$

Where P_i is the annual precipitation for year i, $\overline{X}$ and σ are the mean annual precipitation and standard deviation for the period between 1970 and 2005

CHAPTER FOUR

4. RESULTS AND DISCUSSION

4.1 RAINFALL TREND ANALYSIS ON MONTHLY BASIS (1970-2005)

Summary statistics of the Mann-kendall test for the monotonic trend and non-parametric Sen's slope estimates for the rainfall variables from 1970-2005 on monthly basis is presented in table 4.1. Statistical significant downward trend were found in the months of February and December, which are -1.960 mm/mon/yr and -2.037 mm/mon/yr at (0.05 significant level) respectively. Also the months of June and September showed significant upward trend of 2.158 mm/mon/yr and 2.031 mm/mon/yr (0.05 significant level). No statistically significant trends were found in remaining months. Although rainfall increased in January, April, October, November (0.046mm/mon/yr, 0.880mm/mon/yr, 2.158mm/mon/yr and 0.497 0.511mm/mon/yr) and decreased in the month of March, May, July and August

Table 4.1 Mann–Kendall test statistics (Test Z) for Monthly rainfall for Akure, 1970–2005

Months	Z_{MK}	Significance	Slope
JAN	0.046		0.000
FEB	-1.960	*	-1.054
MARCH	-0.710		-0.513
APRIL	0.880		0.923
May	-0.113		-0.373
JUN	2.158	*	2.223
JULY	-0.397		-0.844
AUG	-0.255		-0.428
SEP	2.031	*	4.026
OCT	0.497		0.570
NOV	0.511		0.320
DEC	-2.037	*	0.000

* Trend is significant at $\alpha = 0.05$. Z_{MK} is Mann–Kendall trend test, Slope (Sen's slope) is the change (mm)/month

4.2. TRENDS IN ROD, RCD AND LGS

Results of the Mann-kendall statistic used to test for trends in the onset and cessation dates and length of growing season at Akure are presented in Table 4.2. The table indicates that there issignificant delay/increase trend in onset dates (0.1 level of significance). The trends in cessation dates showed a non-significant increasing trend (late retreat). However the LGS had a decreasing non significant trend thisimplies that the length of the growing season is progressively declining in the area but not at a significant rate. This also implies that the late onset of the rainy season is more pronounced than the trends in the cessation and growing season length.

Table 4.2. Statistical characteristics and trends of Onset date, Cessation date and LGS from 1971-2005.

Time series	Z_{MK}	**Significance.**	**Slope**
Onset date	1.75	+	0.556
Cessation date	0.63		0.2
LGS (days)	-0.91		-0.318
SPI	1.25		0.018

+ Trend is significant at $\alpha = 0.1$.

4.3. RAINFALL ONSET DATES (ROD)

The linear trend for the onset dates of the rainy season in the study area are shown in Fig.4.2a. It is very clear from this Figure that the onset of the rainy season is characterized by more marked 'noises' (variability) from year to year unlike in its cessation and duration. This figure clearly indicates an increasing trend line in the onset dates. This implies progressively late start of rainfall in recent years in the study area. Figure 4.2a shows that on the average, the rainy season starts from the 62 JD.

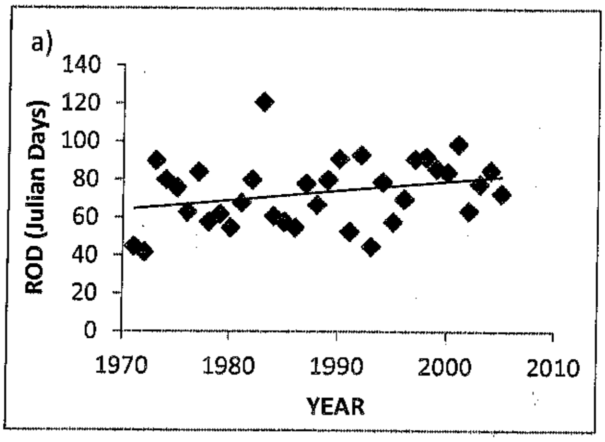
4.4 RAINFALL CESSATION DATES RCD

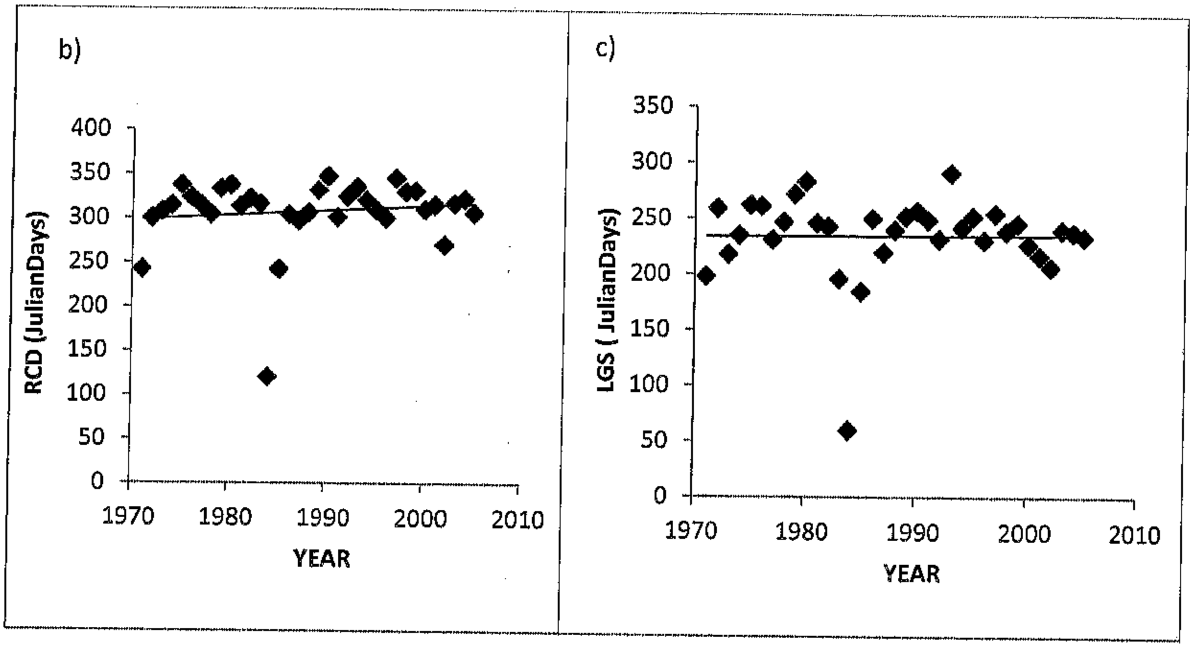
Trend in the cessation dates of the rainy season during the study period in Akure is presented in Fig. 4.2b. This Figure indicates that the mean cessation date of the rain is about 310 JD. It is also observed that the trend in cessation dates of the rains is homogenous. The figure also shows that there is slight increase in trend of cessation of rainfall

4.5 LENGTH OF GROWING SEASON (LGS)

The pattern of LGS is shown in Fig. 4.2c. A largely homogenous trend is indicated. The average LGS is about 240 Julian days. The duration of growing period from 1970-2005, ranges between Julian days 180-280. The shortest LGS is 60days which was recorded in the year 1984, while the longest LGS IS 291 days which was recorded in the year 1993.As shown if Fig 4.2c.variability in duration of the hydrological growing season is not as marked as the variability in onset and cessation of the rains.

Figure 4.2(a-c). ROD, RCD and LGS





b)
RCD (JulianDays)
400
350
300
250
200
150
100
50
0
1970
1980
1990
2000
2010
YEAR
c)
LGS (JulianDays)
350
300
250
200
150
100
50
0
1970
1980
1990
2000
2010
YEAR

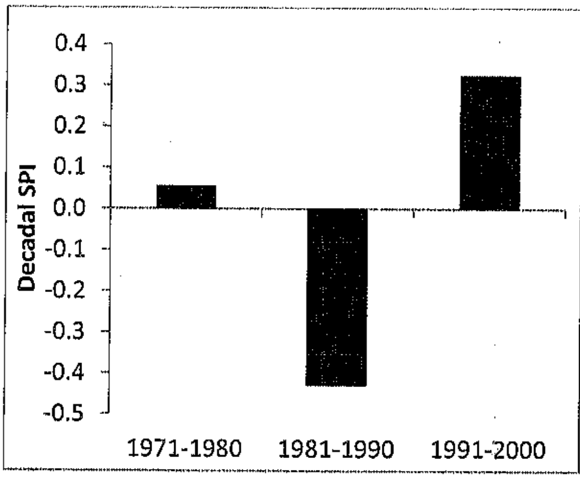
Table 4.3: Rain days, 1971 to 2005. Julian days give the number of the day of the Julian calendar of that year

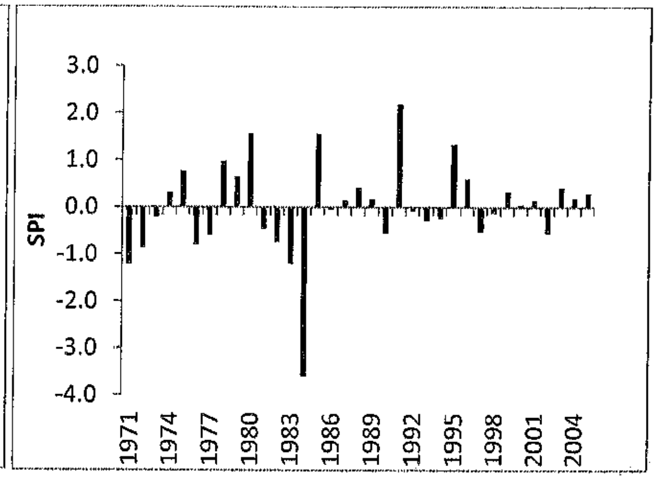
YEAR	Julian Days	ROD	Julian Days	RCD	LGS
1971	45	14-Feb	243	31-Aug	198
1972	42	11-Feb	301	27-Oct	259
1973	90	31-Mar	308	4-Nov	218
1974	80	20-Mar	315	10-Nov	235
1975	76	17-Mar	338	4-Dec	262
1976	63	3-Mar	324	19-Nov	261
1977	84	25-Mar	315	11-Nov	231
1978	58	27-Feb	305	1-Nov	247
1979	62	3-Mar	334	30-Nov	272
1980	55	24-Feb	338	3-Dec	283
1981	68	9-Mar	314	10-Nov	246
1982	80	21-Mar	323	19-Nov	243
1983	121	1-May	317	13-Nov	196
1984	61	1-Mar	121	30-Apr	60
1985	58	27-Feb	243	31-Aug	185
1986	55	24-Feb	305	1-Nov	250
1987	78	19-Mar	298	25-Oct	220
1988	67	7-Mar	307	2-Nov	240
1989	80	21-Mar	332	28-Nov	252
1990	91	1-Apr	348	14-Dec	257
1991	53	22-Feb	302	29-Oct	249
1992	93	2-Apr	325	20-Nov	232
1993	45	14-Feb	336	2-Dec	291
1994	79	20-Mar	321	17-Nov	242
1995	58	27-Feb	310	6-Nov	252
1996	70	10-Mar	301	27-Oct	231
1997	91	1-Apr	346	12-Dec	255
1998	92	2-Apr	331	27-Nov	239
1999	86	27-Mar	332	28-Nov	246
2000	84	24-Mar	311	6-Nov	227
2001	99	9-Apr	316	12-Nov	217
2002	64	5-Mar	271	28-Sep	207
2003	78	19-Mar	318	14-Nov	240
2004	85	25-Mar	323	18-Nov	238
2005	73	14-Mar	307	3-Nov	234

4.6. ANALYSIS OF STANDARDIZED PRECIPITATION INDEX (SPI)

Fig. 4shows the analysis of SPI for Akure. Based on the SPI,13 years were moderately dry,13 years were mildly wet (0 to 0.99) and 2 years was moderately wet (1 to 1.49). A year was extremely wet (≥ 2.00), and another Year was extremely dry. Decadal SPI showed that the decade 1991-2000 was the wettest decade and 1981-1990 was the driest decade at Akure.

Figure 4.2 Annual and Decadal Standardized Precipitation Index (SPI)





4.7 WAVELET TRANSFORMATION ANALYSIS

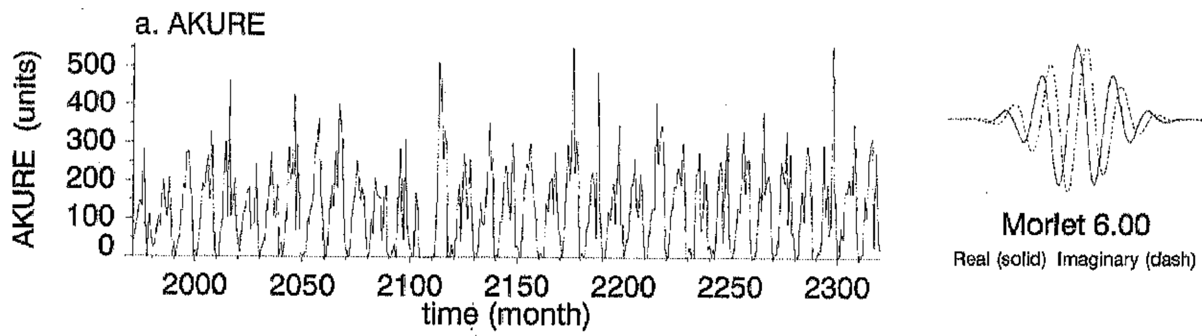


Figure 4.3 Wavelet power spectra

The wavelet power spectra for Akure rainfall are shown in Fig. 4.6a. The wavelet power is normalized by dividing each month by the GWS (Fig. 4.6b), and thus it measures the deviations from the mean spectrum. The thick black contours indicateregions that are significant (at the

10% level) above the GWS. For the data set, the power is broadly distributed, with peaks in the months 50, 150, 200 320 band. Here, the use of significance tests allows one to verify that the interdecadal variance changes The wavelet spectrum Akure rainfall (Fig.4.6a) is more uniformly distributed about all periods, as can also be seen in the GWS.

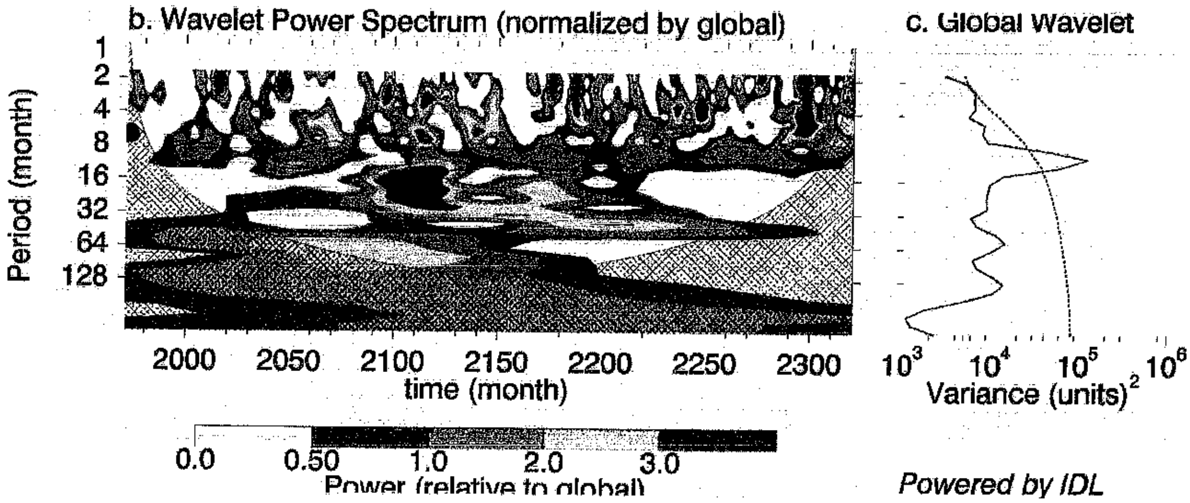


Figure 4.4 global wavelet spectral

(b) The wavelet power spectrum. The power has been scaled by the global wavelet spectrum (at right). The cross-hatched region is the cone of influence, where zero padding has reduced the variance. Black contour is the 10% significance level, using a red-noise (autoregressive lag1) background spectrum. (c) The global wavelet power spectrum (black line). The dashed line is the significance for the global wavelet spectrum, assuming the same significance level and background spectrum as in (b). Reference: Torrence, C. and G. P. Compo, 1998: A Practical Guide to Wavelet Analysis. *Bull. Amer. Meteor. Soc.*, 79, 61-78.

Wavelet power spectrum (using the Morlet wavelet) of the study area. The wavelet power at each period is normalized by the global wavelet spectrum. Cross-hatched regions indicate the ''cone-of-influence,'' where zero padding has reduced the variance. Contours are for wavelet squared coherencies of 0.5, 1.0, 2.0 and 3.0.

The GWS for Akure rainfall show the annual cycle and peaks. The areas within the cone of influence shows part of the data series that are significant. The rainfall is dominated by theannual

annual cycle, the rainfall with a power of 3 which is depicted by a red color indicate a rainfall event of three times more than the average rainfall in the study area which can be seen around 120 -160 month and can be said to likely have a return period of 16years. The area in yellow depicts a rainfall event of thrice the normal rainfall event which is predominantly between 100 – 280th month with a return period of 8years. Twice the average rainfall for the study area is shown by a green colour inside the cone of influence with a return period of 4years which is more predominant in the data series.

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATIONS

5.1. CONCLUSION

This research has brought to the fore that the rainy season has of recent been starting late, but the duration of the hydrological growing season at Akure is not increasing. The findings of this study have great implications for both surface and underground water resource management and agriculture and sustainable food security not only for Akure region but Nigeria at large. The late onset and decreasing trend in the length of the hydrological growing season at Akure are diminutive to agriculture and water resources as well as the biodiversity of the Area. This is a threat to rain-fed agriculture, food security and sustainable development. There is therefore, the urgent need for the government to come up with an implementable action plan to face this reality of Rainfall variability

5.2. RECOMMENDATIONS

Agricultural policies should be more realistic and achievable. More agricultural Research institute should be established not only in the study area but also in the entire state to develop hybrid crops, establish more scientific and research farms as well as embarking on seminars to enlighten the farmers on the current trend in farming system. Meteorological services should also be localized in the area. In addition mixed farming should be emphasized and encouraged so as to reduce the rate at which farmers wait endlessly for the government to provide fertilizers which they can hardly afford.

REFERENCES

Abrol, P.Y.; Gandhi, S.; Pant, B.G. Climate Variability and Agriculture; Narosha Publishing House: New Delhi, India, 2003.

Adebayo, A.A. (1997). The Application of Agro – Climatology to Agricultural Planning in Adamawa State, Nigeria.*Journal of Applied Science and Management, Vol. 1, No. 1*.Pg. 69.

Adefolalu, O.O. (1986). Rainfall trends in Nigeria. **Theoretical and Applied Climatology.** 37:205 – 219

Adejuwon, S.A. (1988). *An Assessment of the Patterns of Rainfall Fluctuations between* 1922 to 1985 in Nigeria.PhD Thesis, Unpublished. Ile-Ife: ObafemiAwolowo University

Afangideh A.I., Francis E. Okpiliya and Eja E.I. (2010)A Preliminary Investigation into the Annual Rainfall Trend & Patterns for Selected Towns in Parts of South-Eastern Nigeria. Journal of Sustainable Development Vol.3, No.3, pgs. 1-8. September 2010.

Ajayi A.E. and Olufayo A.A.(2002) The Sequence of Wet & Dry Days at Ibadan &Onne (Sub-Humid Zone of Nigeria). Nigeriasn Journal of Technology, Vol.21, No.1.

Akinyemi O., Ayeni O.A, Faweya O. and Ibraheem A.G. (2013) Statistical Study of Annual and Monthly Rainfall patterns in Ekiti State, Nigeria.Int. J. Pure Appl. Sci. Technol, 15(2), pp 1-7 ISSN 2229-6107.

Ati O.F., Stigter C.J., Iguisi E.O. and Afolayan J.O., (2009).Profile of rainfall change and variability in the Northern Nigeria, 1953-2002, *Res J. Environ.Earth Sci*., 1(2) ,58-63.

Audu E.B.(2012) A Descriptive Analysis of Rainfall for Agricultural Planning in Lokoja Local Government Area of Kogi State, Nigeria.Volume 2 No.12. International Journal of Science and Technolgy ISSN 2224-3577

Audu, E.B; Audu, H.O; Binbol, N.L; and Gana, J.N. (2012).Climate Change and its Implication on Agriculture in Nigeria.*The Abuja Journal of Geography and Development (in press).*

Ayoade J.O. (1974). Statistical Analysis of Rainfall over Nigeria.*Journal of Tropical Geography,* 39: 11-23.

Beer, T.; Greenhut, G.; Tandoh, S. Relations between the Z criterion for the subtropical high, Hadley cell parameters and the rainfall in Northern Ghana. Mon. Weather Rev. 1977, 105, 849–855.

Bussay AM, Szinell C, Hayes M, Svoboda M. 1998. Monitoring drought in Hungary using the standardized precipitationindex.AnnalesGeophysicae, Supplement 11 to Vol 16, the Abstract Book of 23rd EGS General Assembly, C450. April 1998, Nice; France.

Ekpoh, I.J &Nsa E (2011) Extreme Climatic Variability in North-western Nigeria: An Analysis of Rainfall Trends and Patterns, Journal of Geography and Geology Vol. 3, No. 1 [9].

Ologunorisa, T. E &Tersoo, T (2006) The Changing Rainfall Pattern and Its Implication for Flood Frequency in Makurdi, Northern Nigeria J. Appl. Sci. Environ. Mgt. September, 2006 Vol. 10 (3) 97 - 102

Enete I.C. and Ebenebe I.N., (2009) Analysis of rainfall distribution over Enugu during the little dry season (1990-2005), *J. Geog and Regional Planning*, 2(7), 182-189.

Ganiyu M.O, Akinniran T.N. and Adeyemo S.A. (2013), Rainfall Pattern & Trend on Arable Crops in Oyo State, Nigeria (1990-2009). World Rural Observations; 5(2).

Garbutt D.J., Stern R.T., Dennett M.D., Elston .J. (1981).A Comparison of the Rainfall Climate of Eleven Places in West Africa Using a Two-Part Model for Daily Rain.*Arch Meteor GeogphBiokl,* 35: 143-159.

Gu, D., and S. G. H. Philander, 1995: Secular changes of annual and interannual variability in the Tropics during the past century. J. Climate, 8, 864–876. , and , 1997: Interdecadal climate fluctuations that depend on exchanges between the Tropics and extratropics. Science, 275, 805–807. Joseph, P. V., J. K. Eischeid, and R. J. Pyle, 1994: Interannual variability of the onset of the Indian summmer monsoon and its association with atmospheric features, El Nin˜o, and sea surface temperature anomalies. J. Climate, 7, 81–105

Guhathakurta .P. and Rajeevan .M. (2006), Trends in the rainfall pattern over India, National Climate Centre, India, Research *Report No:* 2/2006.

Ilesanmi O.O. (1972a). An Empirical Formulation of the Onset, Advance and Retreat of Rainfall in Nigeria.*Journal of Tropical Geography,* 34: 17-24.

Ilesanmi O.O. (1972b). Aspect of the Precipitation Climatology of the July -August Rainfall Minimum of Southern Nigeria .*Journal of Tropical Geography,* 35: 51-59.

Ilesanmi, O.O. (1972). An empirical formation of an ITD rainfall model for the tropics: A case study of Nigeria, **Journal of Applied Meteorology**. Vol. 10, pp.882– 889.

Kane R.P. (2000). Some Characteristics and Precipitation Effects of the El Nino of 1997-1998. *Journal of Atmosphere and Solar-Terrestial Physical,* 61: 1325-1346.

Kowal, J. M. and Knabe, D.T. (1972)**An Agro- Climatological Atlas of the Northern States of Nigeria.** ABU Press Zaria 111pp

Mckee TB, Doesken NJ, Kliest J.1993. The relationship of draught frequency and duration to time scales.*In proceedings of the 8th conference on applied climatology, 17-22 january, Anheim,* CA.American Meteorology Society: Boston, MA; 179-184

National Research Council (2010) America's Climate Choices: Panel on Advancing the Science of Climate Change;.Advancing the Science of Climate Change. Washington, D.C.:

NIMET (2013) Seasonal Rainfall Prediction.

Nnoli NO. 1996. Mean onset and cessation dates of rainy season in Nigeria. In Proceedings of the 11th Nigerian Meteorological Society Conference on Climate Change and its Impact on Agriculture, IITA — International Institute for Tropical Agriculture, October, 1996, Ibadan, Nigeria; 24–125.

Obot N.I., Chendo M.A.C.,Udo S.O. and Ewona I.O. (2010).Evaluation of Rainfall Trends in Nigeria for 30years (1978-2007). International Journal of the Physical Sciences Vol.5 (14), pp.2217-2222.

Odekunle T.O. (1997). *Rainfall Charaterstics in Ondo Town, South-West Nigeria.*MSc Thesis, Unpublished. Ile-Ife: ObafemiAwolowoUniveristy.

Omotosho, J. Long-range prediction of the onset and end of the rainy season in the West African Sahel. Int. J. Climatol. 1992, 12, 369–382.

Omotosho, J. Onset of thunderstorms and precipitation over northern Nigeria. Int. J. Climatol. 1990, 10, 849–860.

Omotosho, J.; Balogun, A.; Ogunjobi, K. Predicting monthly and seasonal rainfall, onset and cessation of the rainy season in West Africa using only surface data. Int. J. Climatol. 2000, 20, 865–880.

Oladipo, E. O., (1993a). A comprehensive approach to drought and desertification in Northern Nigeria. Nat. Hazards, 8: 235-261.

Olaniran O. J. and Summer, G. N (1989) A study of climate variability in Nigeria based on the onset, retreat and length of the rainy season. *International Journal of Climate* 9, pp 252 – 269

Olaniran, O. J. (1990). Changing Patterns of Rain-days in Nigeria.Geographic Journal 221. pp. 99-107

Olaniran O.J. (1983). The Onset of the Rains and the Start of the Growing Season in Nigeria.*Nigerian Geographical Journal,* 26(1 and 2): 81-88.

Olaniran, O. J. and Summer G.N. (1990). Long-term variations of annual and growing season rainfalls in Nigeria.Theor. Appl. Climatol.(41): 41-53.

Olaniran, O.J. (1990). Changing patterns of rain-days in Nigeria.GeoJournal. 22(1): 99: 107-137.

Salmi, T., Maatta, A., Anttila, P., Ruoho-Airola, T., Amnell, T., 2002.Detecting trends of annual values of atmospheric pollutants by the Mann–Kendall test and Sen's slope estimates.Publications on Air Quality, No. 31, Helsinki, Finland.

Sawa, B.A (2002) Trends in the temporal variability of occurrence of wet and dry spells North of latitude 10^0N in Nigeria. *The Zaria Geographer.*Vol.15 (1) pp.34-41.

Seasonal Rainfall Prediction NIMET (2011) pg. 1-23.

Sivakumar, M.U.K., Maidouki, H.H. and Stem, R.D. (1993), Agroclimatology of West Africa: Niger, *INCRISAT Bulletin* 105

Stern, R.D, M.D. Dennett and I.C. Dale, 1982b.Analysing daily rainfall measurements to give agronomically useful results II: A modelling approach. Exp. Agr., 18(03): 237-253