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FLUCTUATIONS IN DROUGHT OCCURRENCE AND PERCEPTIONS OF ITS POSITIVE CONSEQUENCES IN THE SAVANNA REGION OF NIGERIA

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ABSTRACT
This study is on fluctuations in drought occurrence and perceptions of its positive consequences in the Savanna region of Nigeria. Data for seventy years (1941 to 2010) on rainfall were sourced from earlier researches for eight selected stations in the study area. The Bhalme and Mooley Drought Index (BMDI) was applied to the data to determine whether or not drought occurred in a particular year. Three different moving averages were applied to the drought series values as depicted by Bhalme and Mooley Drought Index (BMDI). This was done to remove the cyclic, seasonal and irregular patterns (smoothing of the time series) and clearly indicates variations from year to year and any abrupt climatic change in the drought series. Findings revealed various drought intensities in the selected stations during the period of study. Also, a desktop review and perceptions on the positive consequences of drought was carried out with information derived from various stakeholders such as farmers, traders, miners, military personnel and others using focus group discussion, excerpts from journals and books as well as observations by the researcher. This qualitative data and information collaborated the findings of the statistical tools (BMDI and Moving Averages) in the occurrence of drought in the study area and also gave insights into benefits derived from its occurrence by various socio-economic sectors (aviation, trade and commerce, tourism, sand mining, construction, leather work and military activities) of the economy in the study region.

Keywords: Drought, Fluctuations, Common Drought Years, Moving/Running Averages, Savanna Zone, Positive Consequences.

1. INTRODUCTION

Drought has no definition acceptable to all scientists. Its definition varies from the meteorologist concerned with meteorological drought to the hydrologist that is concerned with hydrological drought and to the social scientist concerned with socio-economic drought. This means the definition varies from one researcher to another, resulting in several definitions and types (Dracup, Lee and Paulson, 1980; Paul, 2009). Some of the definitions are conceptual while others are operational. The types of drought include but not limited to; permanent, seasonal, contingent and invisible (Ayoade, 1988).For this study, the definition of drought adopted is

> *"climatic excursion involving a deficit of rainfall(meteorological drought) sufficient to cause water resources depletion (hydrological drought) adversely affects crops and livestock production (agricultural drought), causes severe disruption of the established economy(economic drought) and produce some ecological damages (ecological drought) in the affected areas"(Oladipo ,1993a)*

This means any period of below water supply in an area that has ramifications for human activities such as agriculture, manufacturing, water supply and sports can be seen as drought (Olatunde, 2013). However, the type of drought focused on in this study is seasonal, which according to Ayoade (1988) is a drought which occurs in areas with well-defined wet and dry seasons (most of the tropics). Drought may likely occur in such areas every year due to seasonal changes in atmospheric circulation pattern. As a result of this, drought and its mostly negative consequences that include cracked soil, low output of agriculture, low availability of water in soil, reservoirs, starvation, malnutrition and sometimes death have been experienced in some parts of the Savanna region of Nigeria. This has further resulted in a situation that drought is mainly seen as a hazard in the study region (Olatunde, 2013).This situation is very pronounced because drought has been occurring in this region for long and in recent decades especially since the 1970's, it has become more endemic (Oladipo, 1993). The future scenario in the region according to IPCC(2007), Tilde (2009), Oladipo (2011), Olatunde and Aremu (2013a&b) is that due to climate change with its associated global warming, drought is likely to become more pronounced and frequent. Since the occurrence of drought in this region and other regions of the world can barely be stopped, there is the need to focus also on the benefits derivable from its occurrences and at the same time not neglecting its harmful effects. In this study therefore, focus will not be on the harmful effects and how they can be mitigated as much have been done in this area. For instance, details of how to mitigate and adapt to drought conditions have received significant attention by several scholars (NIMET, 2005; Oladipo, 1992& 1993b; Aremu, 2011; Olatunde, 2012).

Various statistical tools are used in the analyses of drought occurrences. Some of those in use are the Normalised Drought Index (NDI), Bhalme and Mooley Drought Index (BMDI), Crop Moisture Index (CMI), Deciles, National Rainfall Index (RI), Palmer Drought Severity Index (PDSI), Percent Normal (PN), Rainfall Anomaly Index (RAI),Reclamation Drought Index (RDI),Standard Precipitation Index (SPI),Surface Water Supply Index(SWSI),Soil Moisture Drought Index (SMDI), Crop Specific Drought Index (CSDI) which was further divided by Meyer and Hubbard (1995) into Corn Drought Index and Soya bean Drought Index. According to Michael (2006), none of the major indices mentioned is inherently superior to another or to the rest in all

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circumstances; however, some indices are better suited than others in certain environment and for certain uses. The use of drought indices for study of drought in the study region seems to be contrary to this well stated fact by Michael (2006). This is because most of the indices used for analyses in the study region have not been able to portray historical droughts in their years of occurrences as accurately as required. That is, most of these methods especially when depicted on graphs show cyclic and seasonal patterns that are very irregular. Examples of studies on drought in the study area with irregular patterns are Oladipo, (1985&1993a); Olatunde(2013); Abaje (2013), Temidayo and Emmanuel (2014). Infact, researchers such as Wilhite (2001), Oladipo (1993a&b) and others have argued that the onset of drought is difficult to determine and recognise after a period of time especially when interrupted by short wet periods resulting in an unclear end. In this study therefore, the BMDI was used to determine the drought years and values after which three different moving averages were applied to the values in order to eliminate cyclic, seasonal and irregular patterns. In other words, the smoothening of the time series was carried out (Kendall and Stuart, 1961; Spiegel and Stephen, 1999). This was to achieve one of the objectives of this study that is, to eliminate irregular patterns and clearly depicts the drought years and show variations from one year to another and any abrupt climatic change in the drought series in the study area during the study period. This is important because drought is an insidious and creepy disaster that shows itself over time. The other objective of this study is to review the perception of the positive consequences of drought.

2. The Study Area

The study area is the northern part of the Savanna region of Nigeria that is the northern Guinea and Sudan–Sahel Savanna region. It is located between Latitude 10^0 N and 14^0 N of the Equator and Longitude 4^0 E and 14^0 E of the Prime Meridian (Figure 1). It occupies about one-third of the total area of the country. It starts from the Sokoto plains through the northern part of Hausa-land to the Chad Basins (Olatunde, 2013). The study area is bounded in the north by Niger Republic and the extreme north-east by the Republic of Chad. In the west, it is bounded by Benin Republic and in the south it is bounded by Guinea Savanna. To the east it is bounded by high lying hills of Bamenda, Biu and Mandara along the frontier with Cameroon republic. Out of the 19 Northern states in Nigeria, only the two (2) states of Kogi and Benue are not included in the study region. States such as Kwara, Niger, Nassarawa, Plateau, Taraba, Adamawa and the Federal Capital Territory, Abuja have parts of their lands in the region. The 13 states covered entirely by the region include Bauchi, Borno, Gombe, Jigawa, Kaduna, Kano, Katsina, Kebbi, Niger, Plateau, Sokoto, Yobe and Zamfara (Olaniran, 1987; Okorie, 2003). The climate of this region is the Tropical Continental (cT). The rainfall amount varies between 500 mm and 1000 mm from the north-eastern part to the southernmost part of the region. There is also inter-annual variability of rainfall of about 20 %. The temperature is also very high reaching as high as 33^0 C and as low as 18^0 C in the dry season during the night. Due to this climatic type and the presence of ferruginous soils and flat topography, the region has been called a park or grassland (FRN, 2000) it is therefore, the grazing land of Nigeria with animals like cows, goats, sheep and horses being reared extensively.

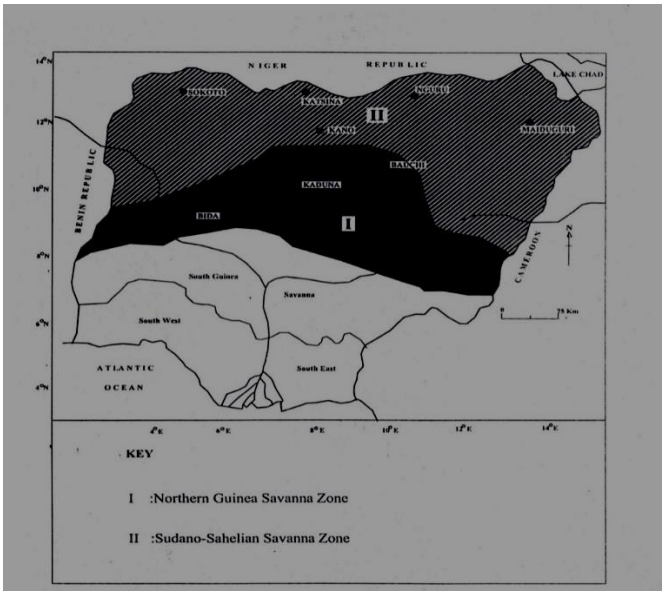

Figure 1: Northern Guinea and Sudano-Sahelian Zones of Nigeria
Source: *Olatunde and Aremu, 2016*

3. MATERIALS AND METHODS

The data used for analysis of drought series fluctuations were obtained from earlier researches (Olatunde, 1994, 2009 & 2013; Otun, 2002). Data were for a period of 70 years (1941 to 2010). Some of the stations in the study area were with missing data for some years. As a result only eight stations (Bauchi, Bida, Kaduna, Kano, Maiduguri, Sokoto, Nguru and Katsina) with complete data for 70 years (1941 to 2010) were used for analyses. This is because these stations have long and continuous period of daily rainfall record (minimum of 70 years) between 1941 and 2010. The Bhalme and Mooley Drought Index (BMDI) was used on the data to determine the dry (drought) and wet years and computed as follows:

Monthly seasonal rainfall (April to October) values for the eight (8) selected stations were used to derive the Bhalme and Mooley Drought Index (BMDI) for the assessment of drought severity (Shuaibu and Oladipo, 1993). For agricultural purposes, the months of April to October (the growing season) are considered to be the most important in drought study. This is because they are said to be the months when more than 95% of the annual rainfall total is received in the study area and also in the Savanna region of Nigeria (Anyadike, 1993).

In its general form, the BMDI for a given month K is calculated using this formula

$$IK = (MK / d) + (1 + C)\, IK \qquad (1)$$

Where;
C and d are constants
IK = drought intensity for the Kth month.
Ik-1= drought intensity for the (K-1) month.
M, the moisture index is given by

$$M = 100\,(X - \ddot{X}) / S \qquad (2)$$

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In equation (4),
X = the monthly rainfall value,
Ẍ = the long term mean monthly rainfall,
S = the standard deviation for the initial month under consideration (K-1).
Equation (1) is then given as;

$$I = M / d \quad (3)$$

The values of C and d in equation (1) for northern Nigeria are 0.43 and 38.84 respectively. These are constant values (Shuaibu and Oladipo, 1993).These values were used in equations (1) and (3) to generate monthly values of BMDI for the stations under study. From these monthly values, the means or seasonal drought index (SDI) series were obtained for each year studied in the stations. The seasonal indices were then used to classify a year into any of the following wetness/ dryness categories using the B.M.D.I classification chart (Shuaibu and Oladipo, 1993).

Table 2: BMDI Classification Chart

BMDI	CHARACTER OF ANOMALOUS MOISTURE CONDITIONS (CAMC).
4.00 or more	Extremely wet
3.00 to 3.99	Very wet
2.00 to 2.99	Moderately wet
1.00 to 1.99	Slightly wet
0.99 to – 0.99	Near normal
- 1. 00 to – 1. 99	Mild drought
- 2.00 to – 2.99	Moderate drought
-3.00 to -3.99	Severe drought
-4.00 or less	Extreme drought

***Source**: Shuaibu and Oladipo, 1993*

The method used to smoothen the BMDI values involves calculating the average for successive overlapping periods of the data (values).
For example, given a set of numbers $Y_1, Y_2, Y_3, \ldots, Y_N$
a running mean of order **N** is defined to be given by the sequence of arithmetic mean;

$$\frac{Y_1+Y_2+\cdots+Y_N}{N}, \frac{Y_2+Y_3+Y_{N+1}}{N}, \frac{Y_3+Y_4+Y_{N+2}}{N}, \ldots \quad (4)$$

The sum in the numerators in equation (4) are called moving totals of order **N** (Spiegel and Stephen, 1999)**.** Therefore, a five (5) year moving average, a 10 year moving average or 15 year moving average can be done and comparison can be made from graphs produced. In this study, five (5), 10 and 15 years moving averages were applied to the values obtained as a result of the application of BMDI. This is because drought indices are known to produce yearly variation in data that may conceal important facts relevant for example to agriculture (Aremu, 2004) but with the moving average statistical tool, cyclic, seasonal and irregular patterns will be eliminated (smoothen of the time series). Also the graphs produced from the application of the moving averages were used to make deductions.

In addition, a desktop review of perceptions and views on the positive consequences of drought in the study area was carried out. The views and opinions of various stakeholders (farmers, traders, miners, military personnel and others) in the study area as it concerns benefits derivable from the occurrence of drought were sought for using focus group discussion. Also, libraries and the internet were sources for excerpts from journals and books that were also relied on. Moreover, direct observations of the likely benefits of drought occurrence in the study area were carried out by the research. The information derived from these sources helped in the aggregation of perceptions and views on the positive consequences of drought.

4. RESULTS AND DISCUSSION

Moving averages (5, 10 and 15 years) were used to smoothen the drought series values derived from the BMDI for the eight stations used for the study. This resulted in truncated end points for the graphs drawn making mean values unavailable before the years used for the moving averages were reached. Negative values with their years are drought years while positive drought index values are wet years. The following observations were noted.

4.1. The Northern Guinea Savanna Zone

The number of common drought years (**Bauchi**) for the three moving averages was 22. Other drought years for the 5 year moving average are 1951to 1953, 1962, 1963, 1965, 1970,1971,1972,2009 and 2010. For the 10 year moving average only, the other drought years were 1965, 19701978, 1979, 2009 and 2010. The 15 year moving average showed the drought years, apart from the common years with the other moving averages, to be 1972, 1998, 1999 and 2000. For the 5 year moving average, 1983 to 1991 had values lesser than -1 meaning intense drought, other years had values greater than -1 meaning less intense drought. For 10 year moving average the intense years with values lesser than -1 include 1985 to 1993. For 15 year moving average it includes from 1990 to 1991.Other years were above -1 meaning less intense drought years (Figure 2; Appendix I).

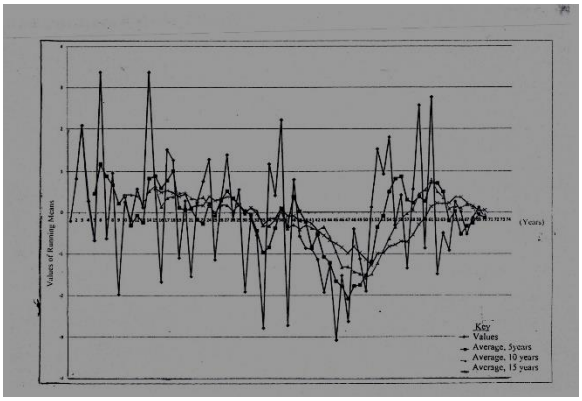

Figure 2: Seasonal Values and Running Averages (5, 10 and 15 years) for Bauchi, 1941 to 2010

Eleven years were found in **Bida** to have been drought years. That is they were common drought years for the 5, 10 and 15 years moving averages used together (Figure, 3). Other drought years for only the 5 year moving average included 1946, 1949, 1950, 1952, 1953, 1956, 1959 to 1961, 1973 to 1976, 1983 to 1989 and 2007. For the 10 year moving average only, drought

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years apart from the common years mentioned above included 1950, 1951, 1961, 1965 and 1988 to 1989. For the 15 year moving average for Bida, the other drought years were 1956, 1959, 1960, 2001 to 2005 and 2006 to 2008 (Figure, 3; Appendix I).

The **Kaduna** station showed the common drought years for the three moving averages (5, 10 and 15years) when used together to have occurred in 22 years out of the 70 years of study (Fig.4). This is about 31.4% of the study years. The other drought years for the 5 year moving average only included 1949, 1950, 1953, 1962, 1965, 1973, 1974, 1984 and1985. The 10 year moving average only other drought year was 2005. There were no other drought years for the 15 year moving average for Kaduna apart from the common ones with the other moving averages. These years 1986, 1987, 1989, 1990, 1992, 2007 and 2008 had their values lesser than -1 meaning the presence of intense drought. All other years for the moving averages were above -1, meaning a less intense drought (Figure 4; Appendix I).

In all stations in the Northern Guinea Savanna zone therefore, the common drought years (1990 -1992) for the three moving averages used together indicates them to have been clearly affected by drought. Also the years from 1986 to 2002 were dominated by droughts in those stations (Figures 2 to 4; Appendix I).

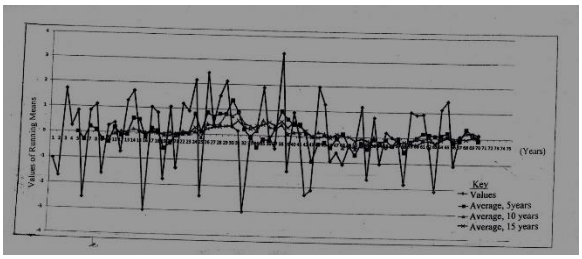

Figure 3: Seasonal Values and Running Averages (5,10 and 15 years) for Bida, 1941 to 2010

4.2. The Sudan-Sahel Savanna Zone

The common drought years were 28 for the three moving averages for **Kano** as used together. The years with drought values below or lesser than -2 (intense drought) were 1985 to 1987(Figure, 5; Appendix II). For the 10 year moving average only usage in Kano, the drought years also were 1954 to 1957, 1969, 1972, 1992, 1995 and 1996. The drought years for 15 year moving average usage apart from the common drought years with other moving averages were 1955 to 1958, 1960 to 1963, 1969, 1972, 1992, 1995 and 1996.All the values for the 15 year moving average were above / greater than -2 (less intense drought) (Figure 5; Appendix II).The absence of drought in the 2000s shows the recovery of Kano from drought in recent years (Figure 5; Appendix II.). These findings are similar to those of NIMET (2005) as regards Kano not experiencing drought. This may be due to the tree planting exercise by the people and government over the years resulting in increase in biogenic freezing nuclei and therefore more rain.

Maiduguri station has 14 years as the common drought years for the three moving averages usage together (Figure 6; Appendix II). For the 5 year moving average alone, the drought years also included 1945, 1946, 1948 to 1952, 1972 to 1976, 1983 and 2004. The years with drought values below -2 were 1985 to 1987 (Figure 6; Appendix II). This indicates intense drought years. For the 10 year moving average usage only, the drought years were also 1972, 1973, 1999, 2000, 2002 and 2003. All the drought values for the 10 year moving average were above or greater than -2. This indicates a less than intense drought occurrence. For the 15 year moving average only usage, drought years were also from 1999 to 2004. All drought values for the 15 year moving average were greater than -2 which also indicate a less intense drought occurrence (Figure 6; Appendix II).

For the **Sokoto** station, the common drought years for the three moving averages (5, 10 and 15 years) together were 24 years (Figure 7; Appendix II). Other years of drought apart from these common years for the 5 year moving average alone were 1945, 1970 and 1971. For the 5 year moving average, the intensity of drought (drought values) were greater than -1 between 1973 and 1975 indicating less intense drought and 1984 to 1990 with values below -1 indicating intense droughts (Figure 7; Appendix II). For the 10 years moving average usage only, the drought years also included 1978 to 1980. The drought years with intensity (drought values) below -1 include 1987 to 1995 (Figure 7; Appendix II) therefore intense droughts. The 15 year moving average usage alone also has the following drought years 1978 to 1980, 2000 to 2001 apart from the common drought years with the other two moving averages Years with drought values below -1 included 1987 and 1995 (Figure 7; Appendix II).

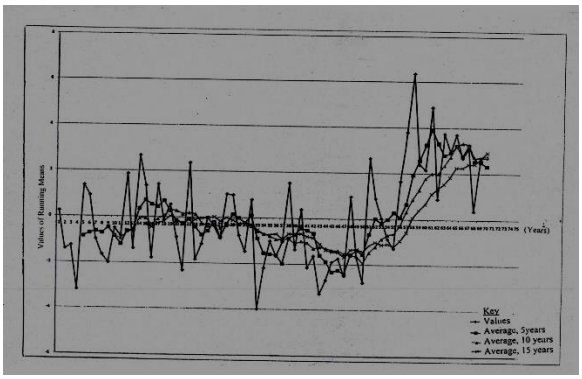

Figure 5: Seasonal Values and Running Averages (5, 10 and 15 years) for Kano 1941 to 2010

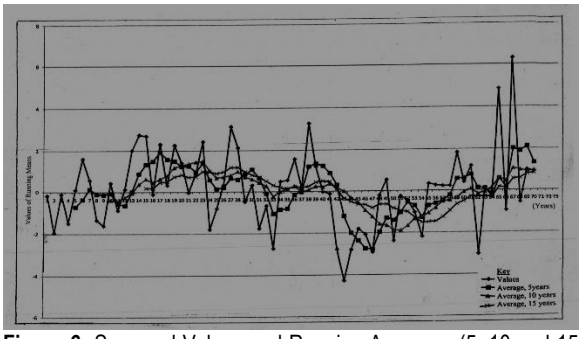

Figure 6: Seasonal Values and Running Averages (5, 10 and 15 years) for Maiduguri 1941 to 2010

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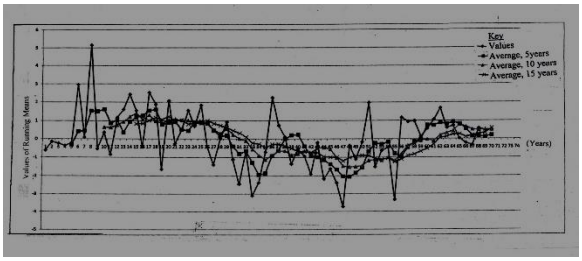

Figure 7: Seasonal Values and Running Averages (5, 10 and 15 years) for Sokoto 1941 to 2010

The three moving averages used together for **Nguru** have the following common drought years; 1983 to 2010. This means drought has continued unabated in this station since 1980s (Figure 8; Appendix II). Drought years when the 5 year moving average was used alone were from 1972 to 1977. Years with drought values below / lesser than -1 for the 5 year moving average included 1973, 1986 to 1988, 1992, 1993 and 2004 and those with drought values below / less than -2 include 1989, 1990 and 1991 (Figure 8; Appendix II). The 10 year moving average usage alone has drought years that also included 1973, 1975 to 1978, 1980 to 1982 with drought values for 1988 to 1997 below / less than -1 (Figure 8; Appendix II). The 15 year moving average alone usage for Nguru had no other drought years apart from the common ones with other moving averages used. However, the drought values from 1991 to 2000 were below -1 signifying more intense drought than those years before 1991 in the station (Figure 8; Appendix II).

For the **Katsina** station, the common drought years for the three moving averages when used together were 24 in numbers (Figure 9; Appendix II). The drought years for the 5 year moving average when used alone also included from 1969 to 1974. The years with drought values below / less than-1 included 1972 to 1975, 1985, 1986, 1988, 1993 and 1997.Those with values below -2 included 1987, 1994, 1995 and 1997(Figure 9; Appendix II). For 10 year moving average when used alone, the drought years also included 1973, 1974, 1980 to 1983 and 2002 to 2004. Years with drought values that were below / less than -1 included 1978 and from 1990 to 2001 (Figure 9; Appendix II). The 15 year moving average when used alone for Katsina showed drought years (apart from the common ones) to include 1980 to 1983 and 2003 to 2007, the years with drought values below / less than -1 included 1993 to 2001(Figure 9; Appendix II).

For all the stations in the Sudano-Sahelian zone, using the three moving averages together, the common drought years were from 1984 to 1991. This indicates that the stations in the zone experienced drought of various intensities during those years (Figures 5 to 9; Appendix II). This agrees with the work of Oladipo (1993) in which he discovered that discrete areas of Northern Nigeria the study area inclusive catch the brunt of drought on an annual basis. The entire results derived from using the moving averages agree with works of Nicholson (1986) Shuaib and Oladipo (19993), and Olatunde (2009,2013) in which they all find out fluctuations in drought series over time. However, these findings in this research clearly brings out in details the drought years and their intensities by removing irregular patterns in the drought series as found in those earlier studies.

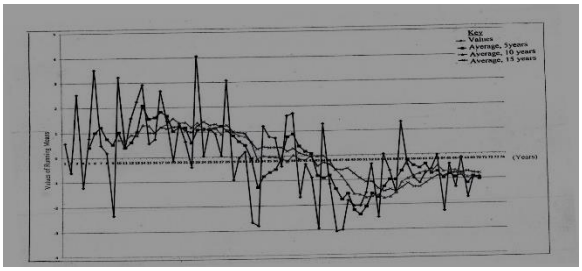

Figure 8: Seasonal Values and Running Averages (5, 10 and 15 years) for Nguru 1941 to 2010

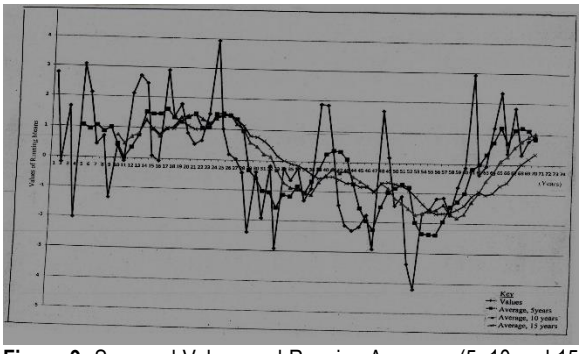

Figure 9: Seasonal Values and Running Averages (5, 10 and 15 years) for Katsina 1941 to 2010

Observations, Perceptions and Reviews on Positive Consequences of Drought

The benefits derivable from drought occurrences in the study region as perceived by stakeholders as well as from field observations and review of literature cuts across so many sectors of the economy. Some of these positive consequences of drought occurrences are enumerated thus:

- In **agriculture,** a positive side to drought occurrence is that it aids the drying of grains, such as maize, millet, sorghum, rice, pepper and so on. The seasonal drought period is also ideal for the storing of grains as the amount of moisture/water available will be low reducing the risk of spoilage (Worldbook, 2001). Another positive side to the occurrence of drought is the reduction in numbers/death of leaf eating insect pests of cowpea and other crops. Some of these insects like *Lagria Villosa, Lagria Cuprina, Caterpillars of Spodoptera Littoralis, Pulsia Signata* attack the leaves of crops during the raining season (Adeniji, Nwabeke, Ihenkwuemere, Udeogalanya, 2007). However during drought their impact on crops will be drastically reduced although the amount of crops in the study area would have reduced due to drought except in farms that are irrigated. The reduction in the impact of the insects is due to the reduction in their breeding rates as a result of low or non-availability of water. Some of these insect pests tend to be active in the temperature range 5^0 C to 60^0 C. Above this temperature; the insects die (Adelekan, Laleye and Idowu, 2006). This means they are also destroyed by the occurrence of frequent fire on grasses during droughts. Also the occurrence of drought makes it possible that crops when planted do not coincide with insect pests at their most active time during the season (Adelekan *et al*, 2006). Insect pests are also destroyed when irrigation is carried out to

ameliorate the shortage or non-availability of water during drought. Flooding irrigation also help to reduce soil inhabiting pest species through drowning (Adelekan *et al*, 2006). Some insect pests that reside on plant stems and leaves (foliage pests) may be controlled by overhead sprinkler irrigation. This technique works for the potato moth which attacks potato crop (Adelekan *et al*, 2006). Unfortunately in the study region, it is only few farms that practice this type of irrigation due to several reasons including non- availability of fund. This means this option is limited to those farms that can afford it.

- **Aviation** wise, the dry and drought (seasonal) period is a very conducive one for the operation and flying of aircrafts in this region as there are little or no clouds that will cause turbulences during flights. This is especially important in this region as landing instruments are few and far between in this part of the world.
- **Trading and Commercial activities** in open markets in the region especially in villages and towns are easily carried out during the dry and drought periods (seasonal drought) which otherwise becomes difficult during the rainy season in this region.
- **Tourist activities** can be planned for seasonal drought and dry periods, for example, the famed durbar activities. This is because there will be little or no rainfall, this will help to avoid disruptions to the activities planned especially the outdoor ones.
- Also as a result of low rainfall resulting in low or non-availability of water within river channels during seasonal droughts**, sand mining** is easily being carried out within the channels of various rivers (for example river Sokoto) in the region. This provides some income to people displaced from farms during the drought (dry) periods and years.
- **Construction** firms are also known to prefer seasonal drought and dry periods for the construction of roads, culverts and other infrastructure. These activities they prefer to carry out during the seasonal drought and dry periods in the study area.
- The **leather industry** also benefits as hide and skins derived from animals dry up faster and are easily preserved during seasonal drought and dry periods. This is because most of the operators in this business in the study area operates on very low scales and therefore rely on the intensity of the sun for the drying of the skins which is usually at its highest during the drought and dry periods.

Militarily, the seasonal drought and dry periods are said to provide the best time and environment for a test run of desert like manoeuvres by the Nigerian military in this area, thereby preparing them for operations in such environment in the future. Finally, rainfall variability provides **research and educational opportunities** to research scientists in this area

5. Conclusion and Recommendations

This study has shown that droughts of various intensities have occurred in various years during the study period as justified by the fluctuations in rainfall amount in the study region. The methods used in the study have helped to depict the drought years clearly as a result of the smoothening which helped to pin point the beginning and the end of the drought. The combination of three running averages helped to locate a more certain year or period that the drought occurred. The returning nature of the drought throughout the study period serves as a pointer to the likelihood that the same situation will very much continue into the foreseeable future. This means that various measures like the construction of dams for irrigation, agricultural insurance against drought, planting of drought resistant crops among other solutions need to be put in place to combat its occurrences and effects on the environment and people of the area. The fact that drought is a hazard is indisputable. Notwithstanding, this study has helped to explain that despite the negative consequences associated with its occurrences, drought also has certain benefits. These benefits, when properly harnessed can be leveraged on for the advancement of the people of the study region as a whole

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Appendix I: Drought Years Using 5, 10 and 15 Years Moving Averages for Stations in Northern Guinea Savanna

Year	5Year Moving Average			10 Year Moving Average			15 Year Moving Average			Description of Each Station			Description of Zone
	ba	bi	ka	ba	bi	ka	ba	bi	ka	ba	bi	ka	
1945													
1946		x											
1947													
1948													
1949		x	x										
1950		x	x		x								
1951	x				x								
1952	x	x											
1953	x	x	x										
1954													
1955													
1956		x						x					
1957													
1958													
1959		x						x					
1960		x						x					
1961		x			x								
1962	x	x	x										
1963	x												
1964													
1965	x	x	x	x	x								
1966													
1967													
1968													
1969													
1970				x									
1971	x												
1972	x						x						
1973	x	x	x	x			x			sc			
1974	x	x	x	x			x			sc			
1975	x	x		x			x			sc			
1976		x											
1977	x			x			x			sc			
1978				x			x						
1979				x			x						
1980	x			x			x			sc			
1981	x			x			x			sc			
1982	x			x			x			sc			
1983	x	x		x			x	x		sc			
1984	x	x	x	x			x	x	x	sc			
1985	x	x	x	x		x	x			sc			
1986	x	x	x	x		x	x	x	x	sc		sc	
1987	x	x	x	x		x	x		x	sc		sc	
1988	x		x	x	x	x	x		x	sc		sc	
1989	x	x	x	x	x	x	x		x	sc		sc	
1990	x	x	x	x	x	x	x	x	x	sc	sc	sc	zc
1991	x	x	x	x	x	x	x	x	x	sc	sc	sc	zc
1992	x	x	x	x	x	x	x	x	x	sc	sc	sc	zc
1993	x	x	x	x		x	x		x	sc		sc	
1994	x	x	x	x	x	x	x	x	x	sc	sc	sc	zc
1995	x	x	x	x	x	x	x	x	x	sc	sc	sc	zc
1996	x	x	x	x	x	x	x	x	x	sc	sc	sc	zc
1997	x	x	x	x	x	x	x	x	x	sc	sc	sc	zc
1998		x	x		x	x	x	x	x		sc	sc	
1999		x	x		x	x	x	x	x		sc	sc	
2000		x	x		x	x	x	x	x		sc	sc	
2001			x		x	x		x	x			sc	
2002			x			x		x	x			sc	
2003					x			x	x				
2004					x			x	x				
2005						x			x				
2006		x	x		x	x		x	x		sc	sc	
2007		x	x			x		x	x			sc	
2008			x			x		x	x			sc	
2009	x		x	x		x			x			sc	
2010	x		x	x		x			x			sc	

ba: Bauchi; bi: Bida; ka: Kaduna.; x: presence of drought in a year
sc: common drought years for the moving averages in a station.
zc:common drought years for the moving averages in all the stations used in the region.

Appendix II: Drought Years Using 5, 10 and 15 Years Moving Averages for Stations in Sudan-Sahel Savanna

Year	5Yr Moving Average					10 Year Moving Average					15Year Moving Average					Description of Station					Description of Zone
	kn	ma	so	ng	kt	kn	ma	so	ng	kt	kn	ma	so	ng	kt	kn	ma	so	ng	kt	
1945	x	x	x																		
1946	x	x																			
1947	x																				
1948	x	x																			
1949	x	x																			
1950	x	x				x															
1951	x	x				x															
1952	x	x				x															
1953	x					x															
1954						x															
1955						x					x										
1956						x					x										
1957						x					x										
1958											x										
1959																					
1960	x										x										
1961	x										x										
1962	x										x										
1963	x										x										
1964	x					x					x					sc					
1965	x					x					x					sc					
1966	x					x					x					sc					
1967	x					x					x					sc					
1968	x					x					x					sc					
1969					x	x					x										
1970	x		x		x	x					x					sc					
1971	x		x		x	x					x					sc					
1972		x	x	x	x	x	x	x			x										
1973	x	x	x	x	x	x	x	x	x	x	x		x			sc		sc			
1974	x	x	x	x	x	x		x		x	x		x			sc		sc			
1975	x	x	x	x	x	x		x	x	x	x		x		x	sc		sc		sc	
1976	x	x	x	x	x	x		x	x	x	x		x		x	sc		sc		sc	

1977	x		x	x	x	x		x	x	x	x		x		x	sc		sc		sc	
1978	x				x	x		x	x	x	x		x		x	sc				sc	
1979	x				x	x		x		x	x		x		x	sc				sc	
1980	x					x		x	x	x	x		x		x	sc					
1981	x		x			x		x	x	x	x		x		x	sc		sc			
1982	x		x			x		x	x	x	x		x	x	x	sc		sc			
1983	x	x	x	x		x		x	x	x	x		x	x	x	sc		sc	sc		
1984	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	sc	sc	sc	sc	sc	zc
1985	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	sc	sc	sc	sc	sc	zc
1986	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	sc	sc	sc	sc	sc	zc
1987	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	sc	sc	sc	sc	sc	zc
1988	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	sc	sc	sc	sc	sc	zc
1989	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	sc	sc	sc	sc	sc	zc
1990	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	sc	sc	sc	sc	sc	zc
1991	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	sc	sc	sc	sc	sc	zc
1992		x	x	x	x	x	x	x	x	x	x	x	x	x	x		sc	sc	sc	sc	
1993	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	sc	sc	sc	sc	sc	zc
1994	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	sc	sc	sc	sc	sc	zc
1995		x	x	x	x	x		x	x	x	x		x	x	x			sc	sc	sc	
1996		x	x	x	x	x	x	x	x	x	x	x	x	x	x		sc	sc	sc	sc	
1997		x	x	x	x		x	x	x	x	x	x	x	x	x		sc	sc	sc	sc	
1998		x	x	x	x		x	x	x	x		x	x	x	x		sc	sc	sc	sc	
1999			x	x	x		x	x	x	x		x	x	x	x			sc	sc	sc	
2000				x	x		x	x	x	x		x	x	x	x				sc	sc	
2001				x	x			x	x	x		x	x	x	x				sc	sc	
2002				x	x		x		x	x		x		x	x				sc	sc	
2003				x			x		x	x		x		x	x				sc		
2004		x		x					x	x		x		x	X				sc		
2005				x					x					x	X				sc		
2006				x					x					x	X				sc		
2007				x					x					x	X				sc		
2008				x					x					x					sc		
2009				x					x					x					sc		
2010				x					x					x					sc		

kn:Kano; ma:Maiduguri;so:Sokoto; ng: Nguru;kt: Katsina; x: presence of drought in a year sc: common drought years for the moving averages in a station. zc:common drought years for the moving averages in all the stations used in the region.