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STATISTICAL ANALYSIS OF RAINFALL IN THE NORTHERN SECTION OF BENIN– OWENA RIVER BASIN, S. W. NIGERIA

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ABSTRACT

Rainfall is a critical climatic index relevant to the hydrologists, climatologists, agriculturalists, civil engineers, meteorologists amongst others. A statistical analysis of rainfall distribution of the northern section of the Benin- Owena River Basin was carried out using information on the rainfall of thirty years (1981-2010) for Akure and fifty years (1961-2010) for Ado- Ekiti. Results showed that there have been fluctuations in the distribution of rainfall in the basin over the years. In Ado-Ekiti, the rainfall distribution was rather erratic. The 1991-2000 decade seemed to be the wettest and exhibited a more even distribution pattern. The decadal rainfall totals however were lower compared with the other decades. There was a sharp decline in rainfall between 1973 and 1974. The annual rainfall totals tended to exhibit a reduced trend after every ten years in Ado-Ekiti (e.g. 1964-1974, 1983-1993, and 1994-2004). The 2001-2010 decadal value of 13,848 mm and a mean of 1385 mm showed a reduced rainfall in this fifth decade. The grand total rainfall for the 50-year study period was 68, 938mm, with a mean of 13, 788mm, inter-decadal value of 265mm, and a coefficient of variation of 21mm. The CV for Ado-Ekiti seemed to indicate a more clustering of rainfall data .The seasonal variation of rainfall showed a fluctuating trend also. In the first two decades (1961 - 1980), there was one peak in the decade (1981-1990) (August/September) while the fourth decade (1991-2000) showed double maxima (June/July and September). The fifth decade showed two peaks in June/September and a reduced value in July/August. The rainfall distribution of Akure (1981-2010) also showed a wide variability. The rainfall distribution pattern in the decade 1981-1990 was fairly even. The decadal total and mean were lower than the following decade. January was dry in all the years except 1988, which was a rather wet year with rainfall in all the months. The decade 1991-2000 recorded a higher decadal total rainfall and mean. This decade exhibited a more fluctuating trend. The 2001-2010 decadal value of 16,324 mm seemed to be the highest values indicating the wettest and more uniform values in Akure during the 30 years study period.. For the entire period of study in Akure, the grand total rainfall was 45,631mm with a mean of 15,212 mm, the inter-decadal value of 175mm and a coefficient of variation (CV) of 22mm. This CV also showed a clustering of rainfall data in Akure. The months of July/September showed double peaks of rainfall in

the two decades 1991-2010 in Akure with the decade 1981-1990 showing single maxima in September.

Key Words: Rainfall, decadal total, decadal mean, distribution, basin.

INTRODUCTION

The Global Precipitation Climatology Project (GPCP) was established by the World Climate Research Program (WCRP) in 1986 with the goal of providing monthly mean precipitation data on a 2.5 x 2.5 degree latitude-longitude grid for the period 1980-2004. The GPCP has accomplished this by combining infrared and microwave satellite estimates of precipitation with rain gauge data from more than 30,000 stations. Infrared precipitation measurements are obtained from Geostationary Operational Environmental Satellites (GOES) (United States), Geostationary Meteorological Satellite (GMS) (Japan) and Meteosat (European Community) geostationary satellites and National Oceanic and Atmospheric Administration (NOAA) operational polar orbiting satellites. Microwave estimates are obtained from the

U.S. Defense Meteorological Satellite Program (DMSP) satellites using the Special Sensor Microwave Imager (SSM/I). Together these data sets will be used to validate general circulation and climate models, study the global hydrological cycle and diagnose the variability of the global climate system. Figure 1 describes mean annual global precipitation over a twenty-five year period measured in millimeters per month. The average annual precipitation of the entire surface of our planet is estimated to be about 1050 millimeters per year or approximately 88 millimeters per month. Figure 1 indicates that actual values vary spatially from less than 10 millimeters per month or to a maximum of more than 300 millimeters per month depending on the location.

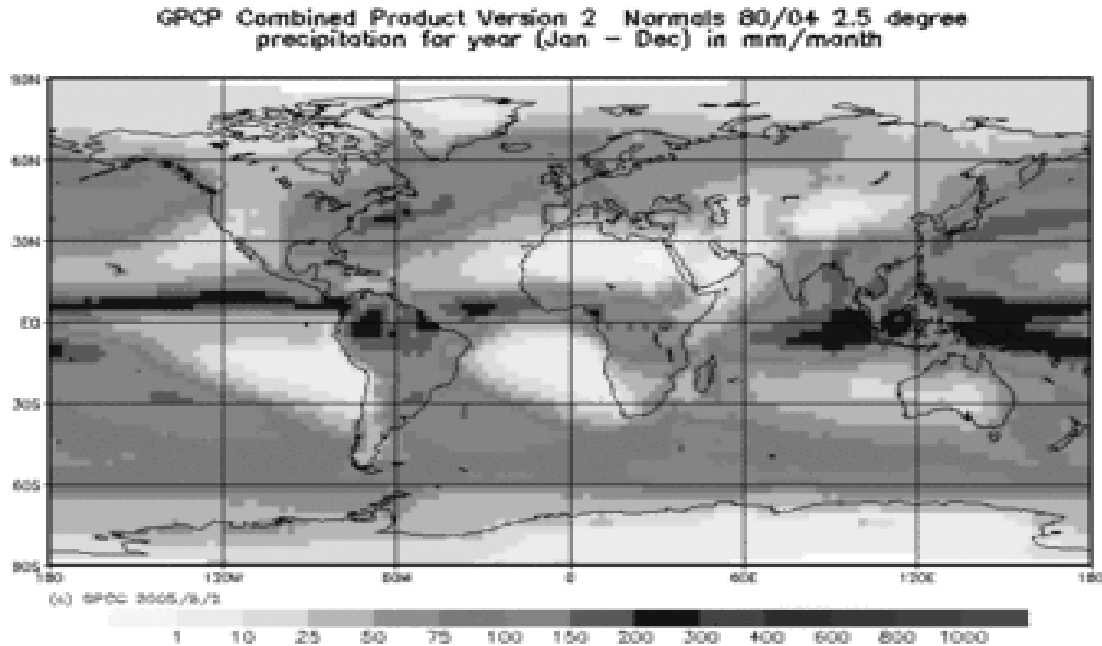


Figure 1: Mean annual global precipitation 1980-2004. (Source: [GPCC - Visualizer](#)).

The reasons for these patterns are as follow:

- The deserts in the subtropical regions occur because these areas do not contain any mechanism for lifting air masses. In fact, these areas are dominated by subsiding air that results from global circulation patterns.
- Continental areas tend to be dry because of their distance from moisture sources.
- Polar areas are dry because cold air cannot hold as much moisture as warm air.
- Areas near the equator achieve high rainfall amounts because constant solar heating encourages convection, and global circulation patterns cause northern and southern air masses to converge here causing frontal lifting.
- Mid-latitudes experience cyclonic activity and frontal lifting when polar and subtropical air masses meet at the polar front. Further, the air masses in this region generally move from West to East, causing levels of precipitation to decrease east of source regions.
- Mountain ranges near water sources can receive high rainfalls because of orographic uplift, if and only if the prevailing winds are in their favor. This can also result in a sharp reduction in rainfall in regions adjacent or on the leeward slopes of these areas. This phenomenon is commonly known as the rain shadow effect.

Table 1: Precipitation extreme weather records (Source: Michael Pidwirny, 2006)

Record	1-year Rainfall	1-month Rainfall	Average Annual Rainfall	24 hr. Rainfall	Lowest Annual Average Rainfall	Greatest 1 Month Snowfall	Greatest Snowfall Single Storm
Location	Cherrapundi, India	Cherrapundi, India	Mt. Waialeale, Hawaii, USA	Belouve, La Reunion Island	Arica, Chile	Tamarack, California, USA	Mt. Shasta, California, USA
Amount (mm)	26,470	9300	11,680	1350		9910	4800
Date	1861	1861 (July)		Feb 28, 1964		1911 (Jan)	Feb 13-19, 1959

Table 1 describes some of the precipitation extremes recorded around the world. Precipitation is a major component of the water cycle, and is responsible for depositing most of the fresh water on the planet. Approximately 505,000 cubic kilometres (121,000 cu mi) of waterfalls as precipitation each year; 398,000 cubic kilometres (95,000 cu mi) of it over the oceans. Given the Earth's surface area, that means the globally averaged annual precipitation is 990 millimetres (39 in). Climate classification systems such as the Köppen climate classification system use average annual rainfall to help differentiate between differing climate regimes. The lowest annual average rainfall of 0.8 mm was recorded in Arica, Chile. An average annual rainfall of 11,680 was recorded in Mt. Waialeale, Hawaii, USA. While a 24 hr rainfall of 1350 mm was recorded in February 1964 at Belouve, Le Reunion Island. A 1-month rainfall of 9,300 mm occurred Cherrapundi, India in July, 1861. Also, a 1-year rainfall value of 26,470 mm was recorded in the same Cherrapundi, India in 1861. These figures

all show precipitation extremes all over the world. This is an indication of variations in rainfall distribution around the globe. The objective of this paper is to offer a statistical analysis of rainfall in the northern parts of Benin-Owena River Basin, Nigeria in line with the afore-mentioned studies. Besides, IPCC (1996) has in its global concerns on climate matters made it imperative for studies to be carried out at local, regional and global scales for data to be gathered so that definite statements can be made on climatic issues. Rainfall is a critical climatic index relevant to the hydrologists, climatologists, agriculturalists, civil engineers, meteorologists, amongst others, (Ikhile et al 2011). This study is premised upon the Intertropical Convergence Discontinuity (ITD). The Intertropical Convergence Zone (ITCZ), known by sailors as the doldrums, is the area encircling the earth near the equator where the northeast and southeast trade winds come together. It is a narrow zone where the trade winds of the two hemispheres meet (ITD). The location of the intertropical convergence zone varies over time. Over land, it moves back and forth across the equator following the sun's

zenith point. Over the oceans, where the convergence zone is better defined, the seasonal cycle is more subtle, as the convection is constrained by the distribution of ocean temperatures. Sometimes, a double ITCZ forms, with one located north and another south of the equator. When this occurs, a narrow ridge of high pressure forms between the two convergence zones, one of which is usually stronger than the other. A statistical analysis of this index of climate is very relevant in the current global climate debate. This study is objective in that it uses the average monthly rainfall to extrapolate the rainfall over this portion of the basin for the period of time where the Intertropical Divergence Discontinuity predominates, as the study area only lies between latitude $7^{\circ} 00'$ to $8^{\circ} 03'N$ and longitude $4^{\circ} 50'$ and $6^{\circ} 00'E$.

THE STUDY AREA

The study area has been detailed in the works of Ikhile (2007a and 2007b). It lies between latitude $7^{\circ} 00'$ to $8^{\circ} 03'N$ and longitude $4^{\circ} 50'$ and $6^{\circ} 00'E$ (Figure 1). This includes parts of Ekiti and Ondo

States of Nigeria. The climate is the tropical continental type with alternating wet and dry seasons of varying duration. The seasons correspond to the periods of dominance of the wet tropical continental air masses. The seasonal distribution of rainfall follows the direction of the Inter-Tropical Divergence (ITD) and varies almost proportionally with distance from the coast. The wet season occurs within seven months from April to October while the dry season lasts from November to March. There is usually a break in rainfall in August. Specifically, this area has the annual mean rainfall ranging from 500 to 2,780 mm (Ikhile, 2007a). About 90% of the rain falls in six to seven months of April to October. The mean annual temperature ranges between $24^{\circ}C$ - $33^{\circ}C$. The mean number of hours of sunshine is 5-7 depending on the season. The rate of evaporation is high being the continental interior. The relative humidity is between 60%-80% per annum depending on the season of the year (dry or rainy). The mean atmospheric pressure is about 1013mb.

MATERIALS AND METHODS

The rainfall data used for this work were gathered from the Federal Ministry of Aviation, Meteorological Services (FMAMS) Oshodi, Lagos, Nigeria and the Benin City Synoptic Station in Edo State, Nigeria. The rainfall data covered a period of fifty years from 1961 to 2010 for Ado-Ekiti and thirty years (1981-2010) for Akure. Records of the rainfall data stations network show that Ado-Ekiti meteorological station has been operational as early as 1953, while that of Akure was commissioned in 1980 giving a rainfall data span of 31 years (1980 - 2010), This data period is sufficient to provide a reliable estimate of climate change scenario (Gobo and Abam, 2006; Miller, 1961) The rainfall was measured with a Stevenson's automated rain gauge installed at the Lagos and Benin City Synoptic Stations. Rainfall for the period was recorded on monthly charts. Monthly, annual and decadal totals were used. The data were subjected to transformation using mean averages via regression analysis and GIS models. The results are presented in decadal and monthly

means and displayed using charts, graphs and tables.

RESULTS AND DISCUSSION

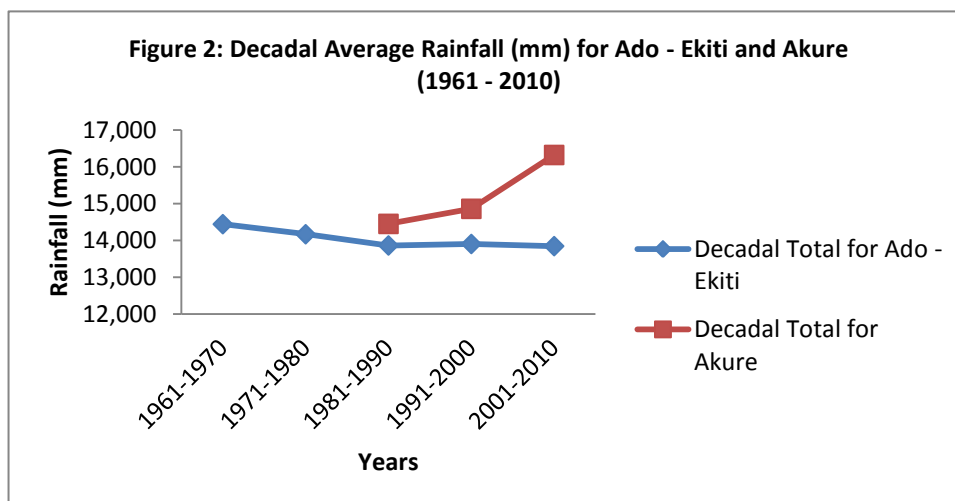
Rainfall Distribution over Akure

The decadal totals and decadal mean of rainfall over Akure from 1981-2000 is presented in Table 2 and Figure 2. The rainfall distribution pattern in the decade 1981-1990 is fairly even. The decadal total was 14,452mm and the decadal mean was 1,445mm. January was dry in all years except 1988, which was a rather wet year with rainfall in all the months. A value of 18mm (highest in the 30 year period in the month of January during the study period) was recorded in January 1988. The decade 1991-2000 recorded a higher decadal total rainfall of 14,861mm and a decadal mean of 1,486mm. The pattern of distribution was however more varied (Table 3). This decade exhibited a more fluctuating pattern similar to what was obtained elsewhere by Ikhile et al (2011). There were more uncertainties in the rainfall distribution in the drainage basin at this time as in other places (Ikhile et al 2003).

Table 2: Rainfall (mm) Distribution of Akure (1981-2010)

Decade	Decadal Total	Decadal Mean
1981-1990	14452	1445
1991-2000	14861	1486
2001-2010	16324	1632

Source: Laboratory Analysis (2006)



Source: Laboratory Analysis (2006)

Seasonal Variation in Rainfall of Akure

The seasonal variation in rainfall totals over Akure is presented in Table 3.

Table 3: Mean Seasonal Variation of Rainfall (mm) of Akure (1981 – 2010)

Decade	Wet Season				Decadal		Dry Season					Decadal	
	June	July	Aug	Sept	Total	Mean	Nov	Dec	Jan	Feb	Mar	Total	Mean
1981 - 1990	181	182	192	231	12,699	181	23	14	5	41	94	1,773	35
1991 – 2000	181	227	178	246	13,350	191	37	11	7	37	59	1,510	30
2001-2010	208	227	219	257	22,800	228	59	9	27	27	103	1,566	31

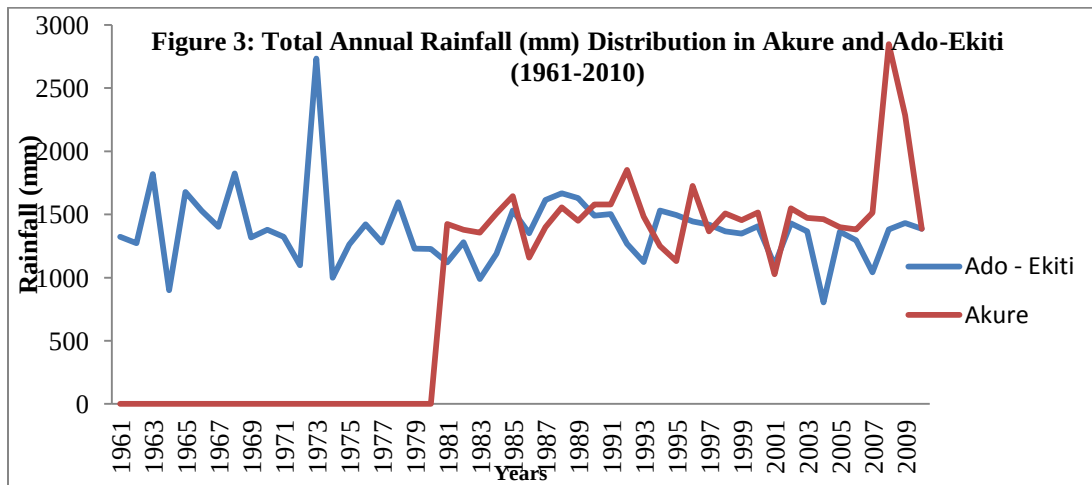
Source: Laboratory Analysis (2006)

In the decade (1981-1990) it was only in 1988 that there was no rain in November (total 233mm) while the decadal mean was 23 mm. Rainfall was experienced for four years in December (1983, 1987, 1988 and 1990) and the total was 143mm. The month of January was dry in 1981, 1983 – 1985, and 1989 while all the others experienced some rainfall. The total for the decade was 1,810 mm. February was wet with a total decadal rainfall of 406mm, but in 1984, 1985 and 1989 there was no rainfall in February. In March, the decadal total was 936mm, while it was only 1990 experienced dry year. In this decade, there was no “break”

in August rather it recorded higher rainfall than July (1,924mm and 1,822mm respectively). There was a single peak in September (2,313mm). The decadal wet season total and mean were 12,699mm and 181mm as against a total and mean figure of 1773mm and 354mm for the dry season. In the decade (1991-2000), there were double maxima of rainfall in July and September with a lower record in August (2,266mm, 2,455mm and 1,781mm respectively). The decadal totals and means of dry season against the wet season were 1510mm/302mm and 13,350mm/1,907mm respectively. In the dry season November was wet with no

year experiencing zero rainfall. The total for November was 370mm with a decadal mean of 37mm. The December month was equally wet, but (1993, 1995 – 1997 and 1999) was dry, the total decadal value was 109mm. In January, (1993 – 1994, 1996 – 1997 and 1999) had no rain, the total

decadal rainfall was 70mm. The months of February and March were wet. The following years did not experience rainfall (1993, 1998) and (1991) respectively. The decadal totals were (366mm and 594mm respectively while the decadal means were 37 mm and 59 mm for Akure (Figure 3).



The decade 2001-2010 experienced the highest rainfall in all the three decades. The total rainfall was 16,324 mm with a mean of 1,632mm. A double maximum of rainfall was experienced in July (6,262 mm) and September (7534 mm). December was the driest month (9 mm) and the rainfall progressed to 27 mm in January and February compared with the other decades, there were some fluctuations especially during the dry season (Figure 3).

Rainfall Distribution of Ado-Ekiti

The rainfall distribution of Ado-Ekiti was rather erratic. The 1991-2000 decade seemed to be the wettest and exhibited more even distribution pattern. The decadal rainfall totals however were lower

compared with the other decades. The first decade (1961-1970) had a decadal total of 1,444 mm while the decadal mean was 144 mm. The second decade (1971-1980) had more unevenly distribution pattern of rainfall. There was a sharp decline in rainfall between 1973 and 1974. The decadal total was 14,171 mm with a decadal mean of 1,417mm. In the decade 1981-1990, the decadal total was 13,866 mm with a decadal mean of 1,386mm. The last decade (1991-2000) had a decadal total of 13,907 mm, and a decadal mean of 1,390 mm.

The result of this analysis is as presented in Tables 4, 5 and Figures 2 and 3.

Table 4: Rainfall (mm) Distribution of Ado-Ekiti (1961-2010)

Decade	Decadal Total	Decadal Mean
1961-1970	14,445	1,444
1971-1980	14,171	1,417
1981-1990	13,866	1,386
1991-2000	13,907	1,390
2001-2010	13,848	1385

Source: Laboratory Analysis (2006)

Seasonal Variation in Rainfall of Ado-Ekiti

The seasonal variation of rainfall totals over Ado-Ekiti is presented in Table 5.30.

Table 5: Mean Seasonal Variation of Rainfall (mm) of Ado-Ekiti (1961-2010)

Decade	Wet Season				Decadal		Dry Season					Decadal	
	June	July	Aug	Sept	Total	Mean	Nov	Dec	Jan	Feb	Mar	Total	Mean
1961- 1970	307	174	161	237	12,265	1752	47	21	20	28	102	2179	435
1971- 1980	148	185	164	209	11,794	1684	16	11	25	74	113	2376	475
1981- 1990	190	184	203	208	12,123	1731	20	24	11	33	86	1742	348
1991- 2000	163	165	156	223	11,538	1648	496	18	10	51	108	2369	473
2001-2010	231	158	143	208	11,928	1704	35	10	19	41	87	1920	384

Source: Laboratory Analysis (2006)

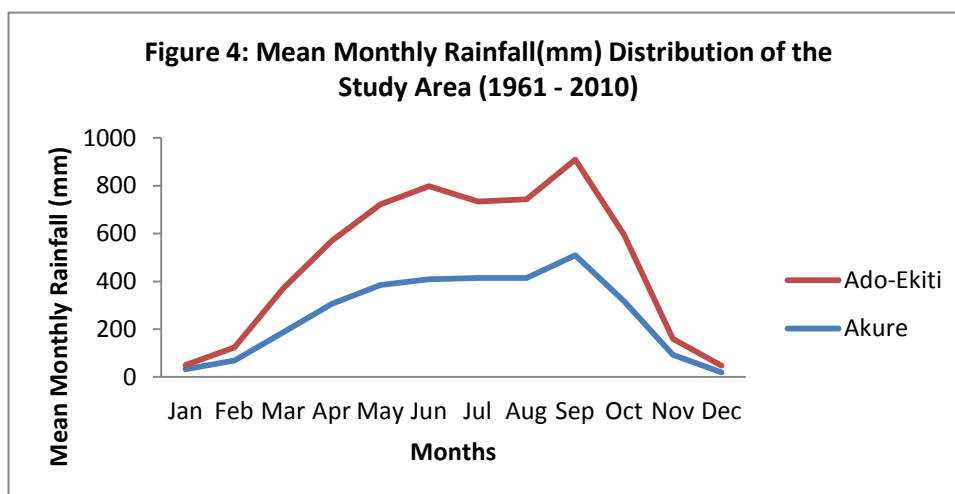
The seasonal variation of rainfall over Ado-Ekiti showed a fluctuating trend. In the first two decades (1961 - 1980), there was one peak in the decade (1981-1990) (August/September) with mean values of 203mm/208 mm while the fourth decade (1991-2000) showed double maxima (June/July with 163/165 mm and September with 223 mm). There was a reduced amount of rainfall in August with a value of 156 mm rainfall. In the decade (1961-1970), the dry season months were relatively wet. There was no year that did not experience rainfall in March in this decade; with a total rainfall for all the months of March being 1,015mm. The month of December in (1961, 1965 and 1970) recorded zero rainfall. The wet season mean and decadal totals are as

indicated in Table 5. The decade, 2001-2010 had higher rainfall values of 231 mm in June, a reduced value of 158mm/143 mm in July/August. A higher amount of rainfall was experienced in September (208 mm) (Table 5).

In the decade (1971 - 1980) the months of November and December were relatively drier. In 1972 – 1974, 1976, 1979, November month was dry while there was rain in December only in the years 1971 – 1972, 1977 and 1980. The decadal total rainfall in November and December were 157mm and 106mm respectively. Four years also recorded zero rainfall in January (1971, 1975, 1976 and 1979). The following year (1979) recorded no rainfall in February and March. The decadal total rainfall was 1,125 mm. The

wet season monthly totals/mean are as indicated in Table 5.6.7. In the (1981 - 1990) decade, the month of August recorded exceptionally high figure in contrast to other decades. The dry season was also wet with zero rainfall record in November 1982 and 1989. The decadal total was 199 mm. In the month of December, six years recorded zero rainfall (1981 – 1982, 1986 – 1987 and 1987); decadal total rainfall was 239.0mm. The following years had zero rainfall in January (1981, 1983 – 1984, and 1988 - 1989), decadal total was 326mm. The decade (1991 - 2000) witnessed the wettest dry season. About one to three years had no rainfall in all the dry season months; November (1991), December (1992),

January (1992 - 1993), February (1992) and all the years had rainfall in the month of March. The decadal totals are (496mm, 184mm, 103mm, 505mm and 1,080mm) respectively. The wet seasons witnessed two peaks in June/July and September with a reduced decadal total rainfall in August. The decadal totals are as indicated on the table. The total decadal rainfall for the dry season was 1,648mm while the wet season was 11,538mm. The decade (2001-2010) experienced generally lower rainfall in the dry season compared with all the preceding decades. The values recorded in November, December, February and March were lower than all the ther decades (Table 5).



Source: Laboratory Analysis (2006)

In this section of the drainage basin, a single rainfall peak was obtained in the study periods. In Akure this peak was recorded in September while in Ado-Ekiti it was recorded also in September (Table 5, Figures3 and 4). The pronounced August break syndrome previously recorded in the rainfall distribution

seemed to be no more in existence (Ikhile, 2007a). This is in line with the general fluctuating trends observed in recent times in global climate change issues (Ikhile 2007a, Babatolu, 2002, IPCC, 1996.1991, Olaniran, 1990. Ojo, 1987).

CONCLUSION

The rainfall distribution of Akure (1981-2010) also showed a wide variability. The rainfall distribution pattern in the decade 1981-1990 was fairly even. The decadal total and mean were lower than the following decade. This decade exhibited a more fluctuating trend. The decade 1991-2000 recorded a higher decadal total rainfall and a more varied mean monthly rainfall distribution. In the decade (1981-1990) it was only in 1988 that there was no rain in November (total 233mm) while rainfall was experienced for four years in December (1983, 1987, 1988 and 1990), total was 143mm. The month of January was dry in 1981, 1983 – 1985, and 1989 while all the others experienced some rainfall. The 2001-2010 decadal value of 16,324 mm seemed to be the highest values indicating the wettest and more uniform values in Akure during the 30 years study period.. For the entire period of study in Akure, the grand total rainfall was 45,631mm with a mean of 15,212 mm, the inter-decadal value was 175mm and a coefficient of variation (CV) of 22mm. This CV also showed a clustering of rainfall data in Akure. The months of July/September showed double peaks of rainfall in the two decades 1991-2010 in Akure with the decade 1981-1990 showing single maxima in September. The distribution of rainfall in Ado-Ekiti was rather erratic. The 1991-2000 decade seemed to be the wettest and exhibited more even distribution. All the months recorded rainfall with the exception of 1991-1993. The decadal rainfall totals however were lower compared with the other decades. The highest recorded

annual total rainfall was in 1973 (2,734.4mm) and the lowest was in 1964 (899.7mm). Annual rainfall totals tended to exhibit a reduced trend after every ten years (decade) in Ado-Ekiti (e.g. 1964-1974, 1983-1993, 1994-2004). The 2001-2010 decadal value of 13,848 mm and a mean of 1385 mm showed a reduced rainfall in this fifth decade. The grand total rainfall for the 50-year study period was 68, 938mm, with a mean of 13, 788mm, inter-decadal value of 265mm, and a coefficient of variation of 21mm. The CV for Ado-Ekiti seemed to indicate a more clustering of rainfall data. The seasonal variation of rainfall over Ado-Ekiti showed a fluctuating trend. In the first two decades (1961 - 1980), there was one peak in the decade (1981-1990) (August/September) while the fourth decade (1991-2000) showed double maxima (June/July and September). The fifth decade showed two peaks in June/September and a reduced value in July/August.

It is concluded that the rainfall distribution of this part of the basin was quite varied. Ado-Ekiti area recorded lower rainfall generally compared with Akure which is more southerly and therefore more humid than Ado-Ekiti in the extreme north of the drainage basin. Besides, up to the year 2010, the rainfall in Ado-Ekiti, especially during the dry season was lower than all the previous four decades. This is an indication of continuous declining rainfall in this area. This will certainly impact on agricultural production in the area. The river flow regime/pattern will also be impacted upon and this will affect the availability of surface water that the populace depends so heavily upon.

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