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THE IMPACTS OF CLIMATE CHANGE ON THE DISCHARGE OF OSSE-OSSIOMO RIVER BASIN, SOUTH-WEST, NIGERIA

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ABSTRACT: The impacts of climate change of Osse-Ossiomo River Basin in the South-West of Nigeria under different climatic Scenarios were investigated using information on rainfall - temperature for forty years (1961 - 2000). Discharge information of Osse and Ossiomo rivers was collected for the period from 1989 to 1994. A number of water resources development schemes including hydroelectric and water supply projects have been planned in the southwestern of the river system of Nigeria. Results revealed fluctuating rainfall pattern with great uncertainties in the mid-1980s. Temperature shows an increasing trend and the highest temperature of 37^{o}C was obtained in 1998 during the 40-year period. There is a strong evidence of global warming using the index of temperature in the drainage basin. River discharge also indicated fluctuating trends from year to year in the decades with records. It was concluded that the river discharge pattern of Osse-Ossiomo River Basin exhibited similar behaviors as other drainage basins of the world. Climate change has impacted on the river discharge of Osse-Ossiomo. This has implication on water security, sanitation and health of the inhabitants in the river basin. Most people were forced to resort to various sources for the numerous uses of water. Statistical tests had shown that the changes in rainfall temperature and rainfall discharge were significant at the 5% level.

KEYWORDS: River basin, rainfall, temperature, discharge, Osse-Ossiomo Basin, health, sanitation.

1 INTRODUCTION

In scientific circles, the issue of whether or not climate variability and change is real is no longer debatable. It is regarded as a potentially serious and crucial problem. The main issues of concern now include the understanding of:

- How it is developing;
- The effects it will have; and
- The accurate detection of the effects.

The IPCC Third Assessment Report (IPCC, 2001) draws attention to changes in timing of stream flow caused by global warming. Over the last 100 years, the global climate has warmed by an average of 0.5^{o}C, owing in part to greenhouse gas emissions from human activities. Unless concerted action is taken to drastically reduce these emissions, climate models project that the earth will warm by another 1.4 to 5.8^{o} C over the next century. These changes will have a substantial destabilizing effect on the hydrological cycle, resulting in greater variability in precipitation, and stream flows, and increasing intensity of extreme hydrological events (IUCN, 2003). Many studies show that the rainfall decline since the 1970 across the Sahellian Zone of West Africa and had significant impacts on runoff in the region and sub-region, in most cases by reducing flow (Mahe et al., 2002, 2003, Ikhile et al., 2003). In a few cases the flow has increased (Pouyaut, 1987) depending on the nature of the drainage network and the geology.

In the light of the above observations, this investigation examines the impacts of climate change on water discharge of sub-basin of Osse-Ossiomo in the Benin-Owena River Basin of South-Western Nigeria.

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2 THE STUDY AREA

The study area has been detailed in the works of Ikhile (2007a and 2007b, 2012) and Ikhile et al (2012). It lies between latitude 6° 30′ to 7° 35'N and longitude 4 ° 50' and 6° 00'E (Figure 1). This includes parts of Ondo and Edo 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. About 90% of the rain falls in six to seven months of April to October. The mean annual temperature ranges between 24°C-33°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.

A detailed description of the Study Area can be found in Ikhile and Oyebande (2007) (Fig.1).

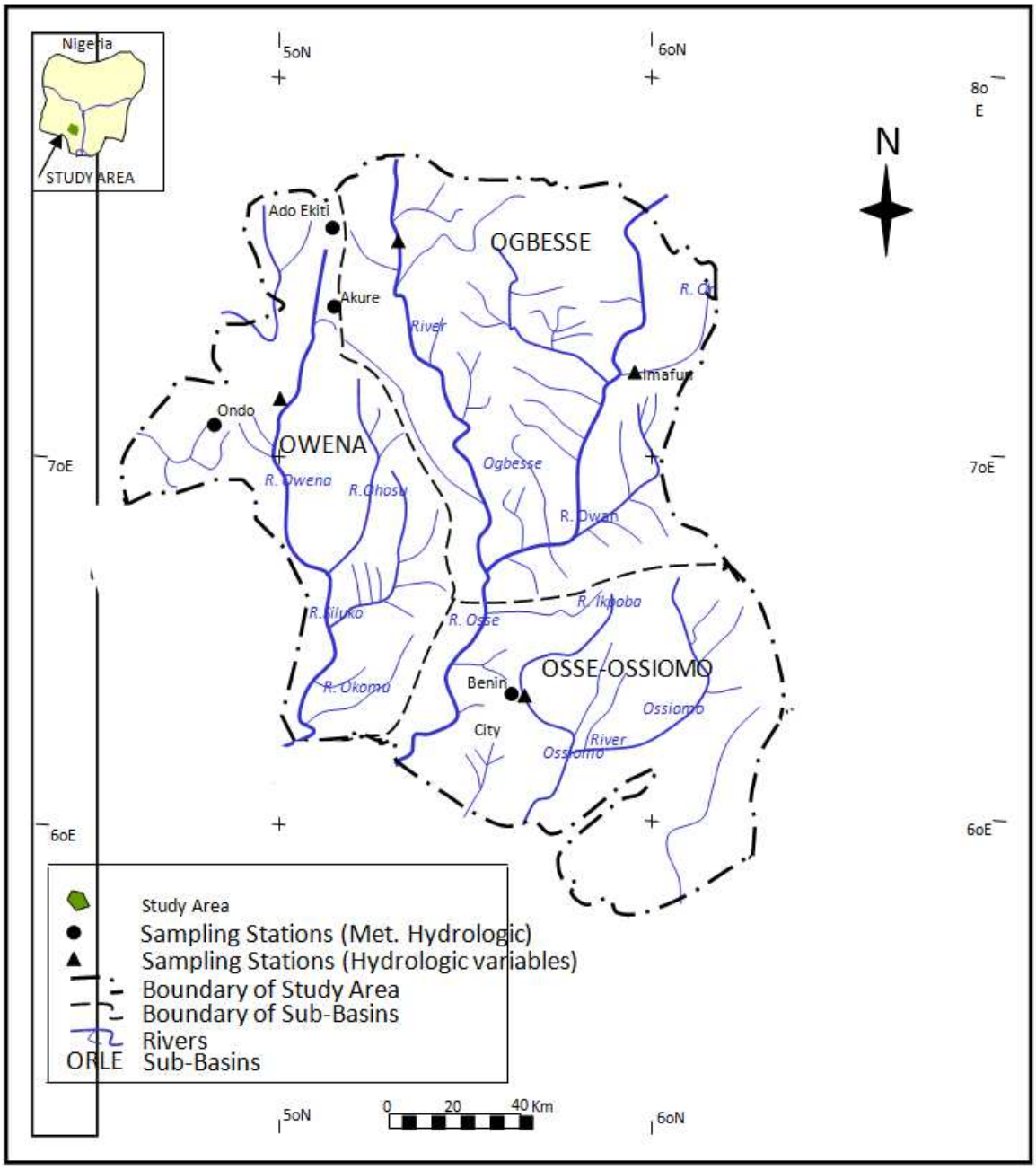

Fig. 1: Map of Osse-Ossiomo sub-River Basin showing Gauged Rivers

3 METHOD OF STUDY

Rainfall was measured with a Stevenson automatic rain gauge installed at the Benin City Synoptic station. Rainfall data for the period was recorded on monthly charts. Monthly, annual and decadal totals were used. Temperature was measured using minimum and maximum thermometers. Mean monthly and annual minima/maxima as well as decadal mean were used. These data were obtained from climatological data monitored by the Federal Ministry of Aviation, Meteorological Services Department (FMAMS) in Lagos, Nigeria. Information on river discharge was gathered from the Benin-Owena River Basin Development Authority (BORBDA) gauge river projects.

4 RESULTS AND DISCUSSIONS

4.1 RAINFALL DISTRIBUTION OF BENIN CITY

Rainfall in the decades 1961–2000 exhibited distinct patterns (Figure 2). The annual total for the decade 1961–1970 ranged between 1985 mm and 3049 mm (1964 and 1965, respectively). January was particularly dry in 1964, 1967 and 1969, with zero values of mean monthly rainfall, while it was only 1970 that had no rainfall in the month of December. The decade (1971–1980) showed a different pattern. The total annual rainfall ranged between 1702 mm (1972) and 2585 mm (1980). In this decade, most January and December months were very dry with zero rainfall values for up to five years (1973–1976, 1979). This decade was drier than the previous one. The total annual rainfall for the third decade, (1981–1990), ranged between 1227 mm and 2461 mm (1986 and 1990, respectively). Between 1985 and 1989, Decembers were completely dry with zero rainfall values and January was also dry for many years. This decade was apparently the driest of the record. A similar observation was made by Olaniran et al. (1991). December 1990 recorded an unusually high mean monthly total of 168 mm, and this was the highest ever-recorded rainfall in December between 1961–2000.

The total annual rainfall for 1991–2000 ranged between 1860 mm and 2776 mm (1993 and 1992, respectively). December and January were not as dry as previously (Ojo, 1987). The rains tended to fall in all months of the year, with the exception of 1992 and 1994 when the Decembers were dry.

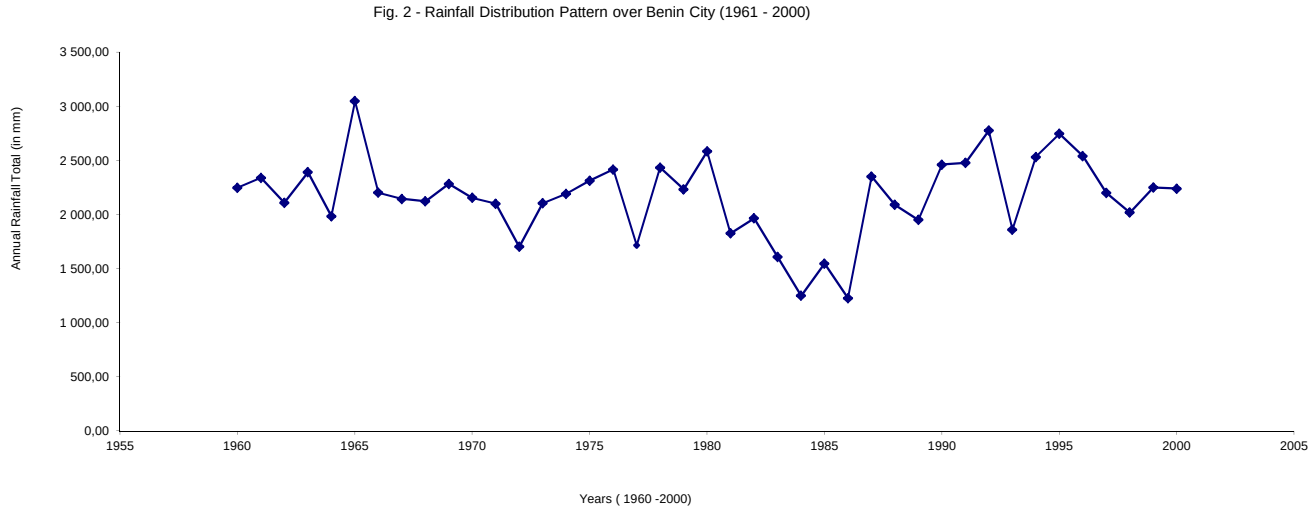

Fig.2: Rainfall distribution of Benin City (1961–2000)

Generally, the first three decades showed double maxima of rainfall with an August break. In the fourth decade (1991–2000), the August break was absent with the August months recording generally higher rainfall values than all the other decades. This means that the normal pattern was reversed in this decade. Even the December months were very wet. January was generally the driest month with a total of 682 mm of rain between 1960–2000. July was the wettest month with a total of 14 975 mm of rainfall between 1961–2000.

4.2 TEMPERATURE DISTRIBUTION OF BENIN CITY

The temperature condition for Benin City is presented in Table (1). The annual mean temperatures increased steadily from 1961 to 2000. During the 1961–1970 decade, it was 25.8°C to 27.0°C (decadal range: 1.2°C). During the 1971–1980 decade, it was 26.3°C to 27.5°C (decadal range: 1°.2C). During the 1981–1990 decade, it was 27.1°C to 27.6°C (decadal range: 0.5°C).

Table 1. Temperature condition of Benin City (1961 – 2000) (°C) (Ranges) Source: Ikhile (2007)

Decade	Annual Minimum	Mean annual Minimum	Annual Maximum	Mean annual Maximum	Annual Mean	Decadal Range
1961 – 1970	19.2 – 24.2	21.9 – 22.8	27.2 – 36.7	31.1 -31.3	25.8 – 27.0	1.2
1971 – 1980	21.0 – 24.9	22.4 – 23.3	27.0 – 34.7	30.2 – 31.7	26.3 – 27.5	1.2
1981 – 1990	18.4 – 26.3	22.2 – 23.8	27.6 – 36.0	31.3 – 32.1	27.1 – 27.6	0.5
1991 – 2000	21.0 – 25.5	23.3 – 23.9	27.4 – 37.0	31.2 – 31.8	27.2 – 28.2	1.0

In this decade, the climate of Nigeria was described as playing a climatic drama (Ojo, 1987). The climate fluctuations were larger and the weather became more unpredictable. The last decade, 1991–2000, has been the warmest with annual mean temperature ranging from 27.2°C to 28.2°C (decadal range: 1.0°C). The air temperature appears to exhibit a persistent increasing tendency in Benin City coupled with decreasing rainfall. This may be an indication of global warming and climate change. There is a statistically significant relationship between mean annual rainfall and air temperatures in the study period at a 0.01 confidence level.

The temperature distribution for the period 1961–2000 showed a wide variation and a gradual warming of the environment. For the decade 1961–1970, the annual minimum ranged from 19°C to 24°C (January 1967 and February 1970) and the minima slightly increased over the following decades. The 1981–1990 decade showed the greatest extremes of temperature, recording the lowest and highest annual minimum temperatures for the whole period of study. The mean annual minimum followed a similar pattern. The annual maximum for 1961–1970 ranged from 27°C to 36°C (July 1961 and March 1962) and remained approximately constant over the following decades. The year 1998 recorded the highest temperature of 37.0°C during the 40-year period. This is in line with Odjugo (2000). The annual mean maximum followed a similar trend.

4.3 RAINFALL/RUNOFF (DISCHARGED) VARIABILITY

The mean annual water level for Ikpoba River from (1991-1994) ranged between 184 (January, 1991) – 368 (March, 1994) cm, that is 346 – 865cm annual total (Tabl. 2, Fig. 3). The discharge ranged between 14.2 (January, 1991) to 51 (August, 1991) m^3s^{-1} (Tabl. 3, Fig. 4). The runoff ranged between 0.039 (January, 1991) – 0.628 (March, 1994) 10^9m^3 (Tabl. 4, 4a, Fig. 5). Specifically in 1991, the variation of water level, discharge and runoff was less varied. In 1992 the variation was pronounced with very low water levels and discharge of 195cm recorded in July and a corresponding low discharge of 17 m^3s^{-1} and 0.078 10^9 m^3 respectively. In 1993, the variation in the mean monthly and annual was more varied, with double peaks of 298cm and 299 cm in May and September and discharge was 38 m^3s^{-1} and 39 m^3s^{-1} respectively. This is in line with the rainfall records at this time. In 1994, the flow pattern was single peaked in September (325cm), a discharge of (50m^3s^{-1}) in September. The mean annual runoff followed the same pattern as in 1993 (0.073 and 0.090 10^9m^3) respectively. In these years, lots of variations were recorded in the flow pattern of Ikpoba River in response to the variation in rainfall. The climate was regarded as playing climatic drama (Ojo, 1987).

Table 2. Water Level of Ikpoba River (1989 - 1994) (Annual Mean / Total)(cm)

	1989		1990		1991		1992		1993		1994	
	Annual Mean	Annual Total	Annual Mean	Annual Total	Annual Mean	Annual Total	Annual Mean	Annual Total	Annual Mean	Annual Total	Annual Mean	Annual Total
January			161.5	323					250.5	770	237.5	475
February	179.5	353	155.5	311	184	368	226.5	452	245.5	491	228	457
March	170	340	157	314	188	376	243	485	255	510	346.5	465
April	165.5	340	170.5	341	219	438	257	514	246	492	241.5	483
May	174.5	331	182.5	365	249	498	255	510	258	516	259	518
June	174.5	349	218.5	437	269	538	259	518	258.5	517	263	526
July	178.5	351	220	440	292	584	243	486	253.5	507	283	566
August	190.5	381	197.5	395	309.5	619	273.5	547	266	532	304	608
September	207	414	219	438	335	670	275.1	551	272.5	545	319.5	639
October			231	462	306.5	613	275	550	258.5	517	286	572
November			226.5	453			267	534	253.5	507	274.5	549
December			251	502			240	480	242.5	485	256.5	513

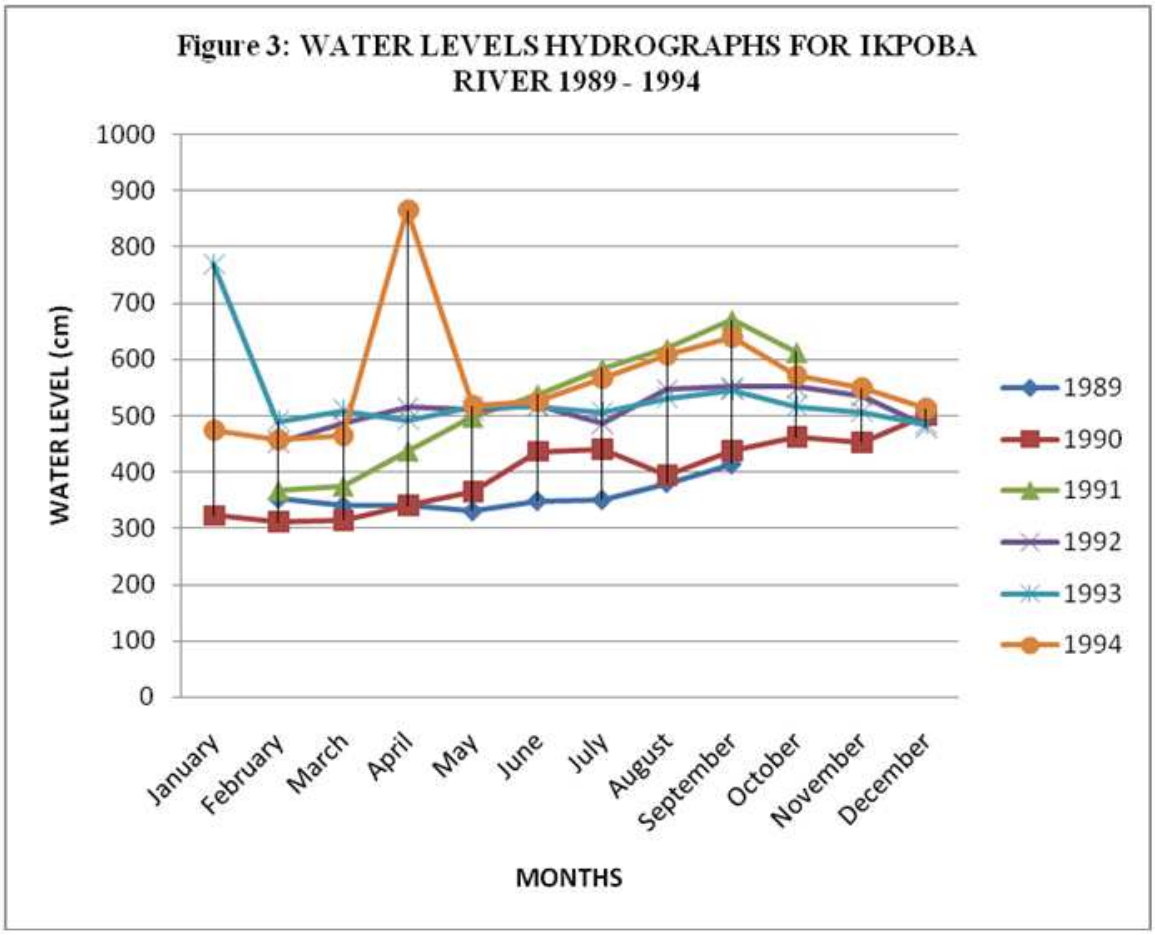

Fig.3: Water Levels Hypographs for Ikpoka river 1989-1994

Table 3. Discharge of Ikpoba River (1989 – 1994) (Annual Mean / Total) (m^3s^{-1})

	1989		1990		1991		1992		1993		1994	
	Annual Mean	Annual Total	Annual Mean	Annual Total	Annual Mean	Annual Total	Annual Mean	Annual Total	Annual Mean	Annual Total	Annual Mean	Annual Total
January	12.17	393.7	12.14	374.24	14.2	453.2	22.1	640.6	27.4	849.4	24.78	768.2
February	11.9	338.8	11.01	308.23	16	447.4	23.7	735.4	25.99	737.72	21.83	611.3
March	11.73	363.6	12.37	383.46	20	618.9	27.2	821.2	26.55	823.05	23.36	724.2
April	12.52	375.6	12.02	360.45	27.9	837.5	22.6	815.2	24.56	736.8	27.45	851.1
May	13.22	409.8	12.94	401.78	32	1023.3	29.1	978.8	27.44	850.64	30.76	922.8
June	15.27	458.1	20.05	621.03	38.8	1162.6	34.4	903.1	30.87	926.1	36.68	1137
July	18.8	572.5	21.42	663.93	43.5	1349.1	30.3	931.4	27.85	863.35	39.27	1218
August			16.45	510.4	51	1530.8	33.6	1065.3	31.77	984.87	43.64	1309
September			19.07	572572	43.6	1306.7	34.6	1004.5	34.86	1045.8	33.8	1180
October			24.59	762.44			34.3	1064.5	28.43	881.25	33.41	1002
November			25.14	754.2			31.2	936.8	27.44	822.35	27.7	858.7
December			20.25	777			25.07	775.2	23.87	739.85		

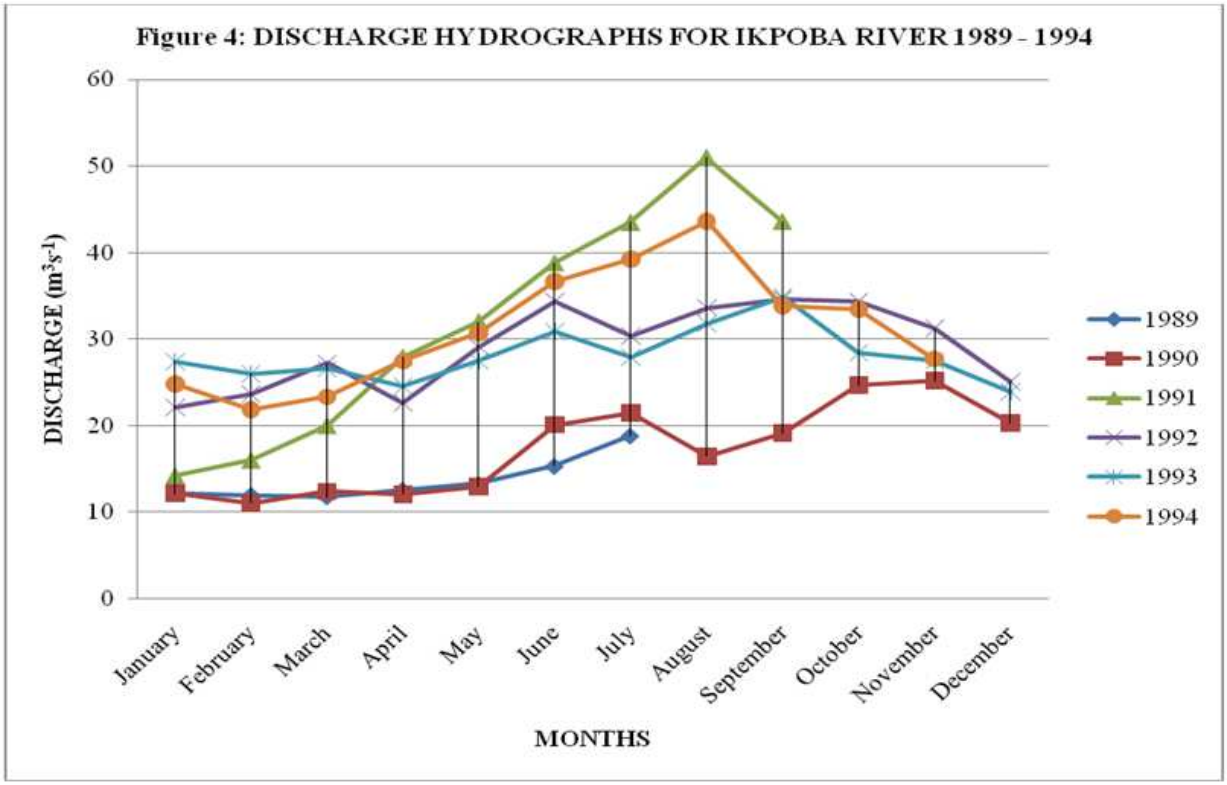

Fig.4: Discharge Hydrographs for Ikpoba River 1989-1994

Table 4. Runoff of Ikpoba River (1989 - 1994) (Yearly Total (cubic meter/sec) cm

Months	Years					
	1989	1990	1991	1992	1993	1994
January			0.04		0.073	0.088
February			0.04	0.055	0.063	0.053
March			0.05	0.064	0.071	0.628
April			0.07	0.07	0.064	0.063
May			0.09	0.071	0.073	0.073
June			0.1	0.085	0.08	0.079
July			0.12	0.078	0.075	0.098
August			0.13	0.092	0.085	0.105
September			0.11	0.087	0.09	0.113
October				0.092	0.078	0.102
November				0.081	0.071	0.088

Table 4a: Runoff of Ikpoba River (1989 - 1994) Yearly Total (m)

	1991	1992	1993	1994
January	39		73	88
February	39	55	63	53
March	53	64	71	628
April	72	70	64	63
May	88	71	73	73
June	100	85	80	79
July	117	78	75	98
August	132	92	85	105
September	113	87	90	113
October		92	78	102
November		81	71	88
December		67	64	74

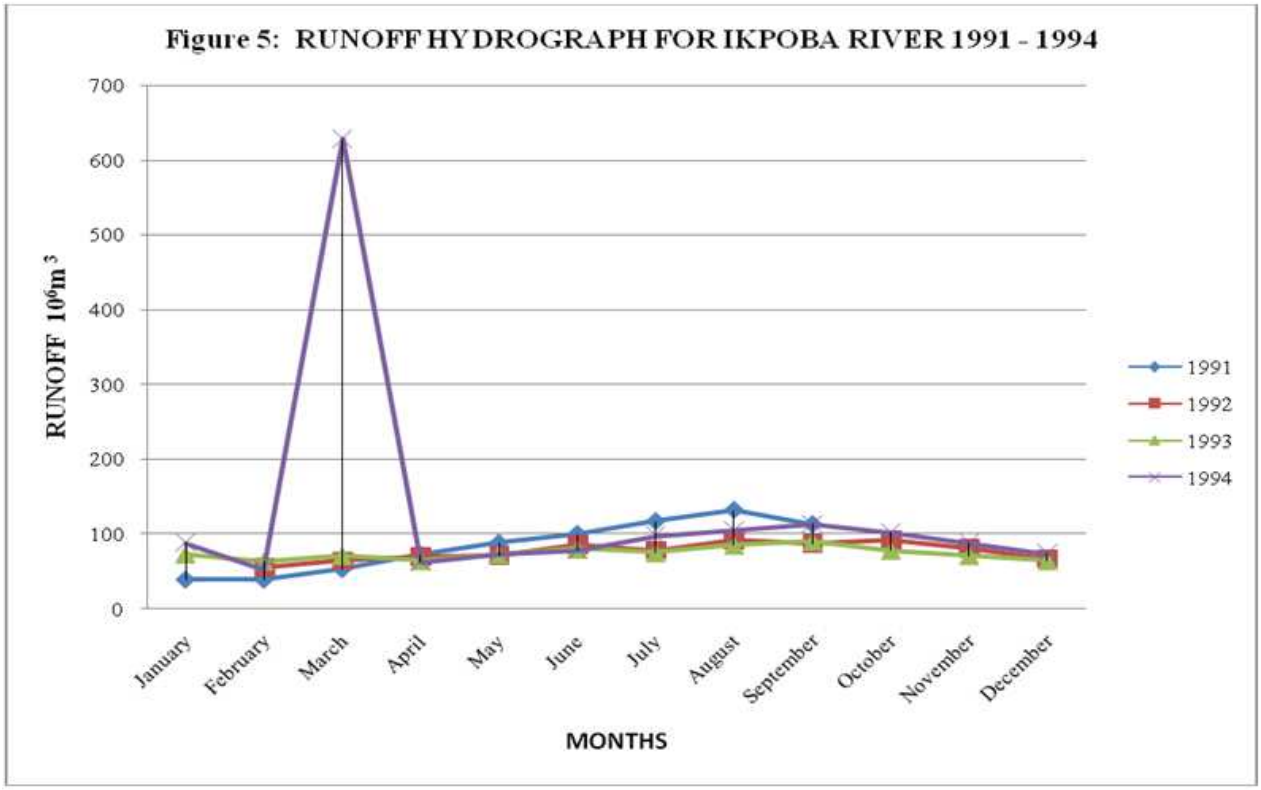

Fig.5: Runoff Hydrographe for Ikpoka River 1991-1994

5 CONCLUSION

This had examined the impacts of climate change on water discharge of sub-basin of Osse-Ossiomo in the Benin-Owena River Basin of South-Western Nigeria.

We observed that the pattern of water level, discharge and runoff for the second half of the decade show similar fluctuating trend as in rainfall pattern.

Generally it was observed that the flow pattern of rivers in the sub-basins were a reflection of the observed rainfall distribution patterns. In very dry years, the hydrologic performance of the rivers was low. A similar dramatic pattern in 1991 – 2000 in water discharge was observed. It is concluded that climate charge has impacted on the basin hydrology and as well as water resources availability and management. In this last decade concerted efforts were geared towards effective control and management of the water resources. Dams were constructed within these sub-basins to assist in the regulation and effective management of the water resources. The dams constructed within this decade were Owena, Ero and Oye. Climate change has impacted on the river discharge of Osse-Ossiomo River Basin, S. W. Nigeria. This has implication on water security, on sanitation and health of the inhabitants in the river basin. Most people were forced to resort to various sources of water including ponds and other unreliable sources for the numerous uses of water. This had a negative impact on water security and consequent health and sanitation of the people. It has been said that water is life and the none availability of it or poor quality of it is detrimental to health. It is hereby advocated that more mitigative measures be adopted in the basin to ensure safe water for the people. There is statistically significant relationship between rainfall and water discharge at 0.05 confidence level and temperature and water level at 0.05 confidence level.

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