Multi-decadal variability of rainfall and water resources in Nigeria

OLUSEGUN ADEAGA
Department of Geography, University of Lagos, Nigeria
oadeaga@yahoo.com

Abstract The over-dependence of the economic development process within sub-Saharan Africa on water calls for detailed assessment of the probable impact of climate change on hydrology and water resources within the region. This paper examines the effect of total annual and decadal rainfall fluctuations on the hydrological regime within Ogun-Oshun River Basin Development Authority (Nigeria).

Key words decadal rainfall analysis; rainfall anomalies estimation; hydrological regime; water resources

INTRODUCTION

The hydrology of large parts of sub-Saharan Africa is characterized by temporal and spatial variability of rainfall which has engendered in the region an uneven areal distribution of fresh-water resources over space and time (Ojo, 1987).

Unfortunately, the human activities within the region are highly dependent on water, with little or no resilience to hydrological hazards (flood and droughts) which have major impacts on both the natural and human environments, causing loss of life, damage to infrastructure and socio-economic activities (Gash *et al.*, 2001).

Also, it is expected that per capita renewable freshwater supply will drop by 80% in Africa by the year 2025 while the greater part of Sub-Saharan Africa will be experiencing a water scarcity situation (UNEP, 2000). The scarcity situation is due to the stress on the limited available water supply in Africa which can be attributed to both natural and human threats (Gash *et al.*, 2001). The natural threats include the present trends in climate change and variability, shrinking of major water bodies (for example, Lake Chad basin) and desertification. The human threats include increased water demand occasioned by the growing population and their socio-economic activities: rapid urbanization, depletion of water quality status, environmental degradation and deforestation, as well as unsustainable management and financing of investments in water supply and sanitation. It should be noted that Nigeria has the eighth largest national population in the world and about a quarter of the total population of all the countries in Sub-Saharan Africa.

Thus, if available water resources within the region are to be wisely managed for the growing population in the 21st century and beyond (Shiklomanov, 1998), assessing the temporal fluctuations of hydroclimatic processes and most especially rainfall, which constitutes the main source of water input, and estimation of the regional water balance is of great importance (Ojo, 1987).

The aim of this study is to examine the probable impact of annual and decadal fluctuations of total rainfall on the hydrological regime and water resources within the Ogun-Oshun River Basin Development Authority (southwestern Nigeria). The basin is a classic example of a basin that is rapidly being modified in its hydrology and morphology by rapid urbanization and increased population growth rate.

STUDY AREA

The Ogun-Osun River Basin Development Authority falls within Nigeria's Hydrological Area VI with an annual runoff of 35.4×10^9 m^3, or depth of runoff of 352 mm per year, with an average annual growth rate of about 1.7% (Federal Dept. of Water Resources, 1986). The basin lies approximately within latitudes 6.25°N and 9.25°N of the equator and longitudes 2.70°E and 5.0°E of the Greenwich Meridian, with a total drainage area of about 56 000km^2 (Fig. 1). It is bounded in the north and east by the Lower Niger and Benin-Owena River Basin Development Authority respectively, in the west by Republic of Benin and in the south by the Atlantic Ocean.

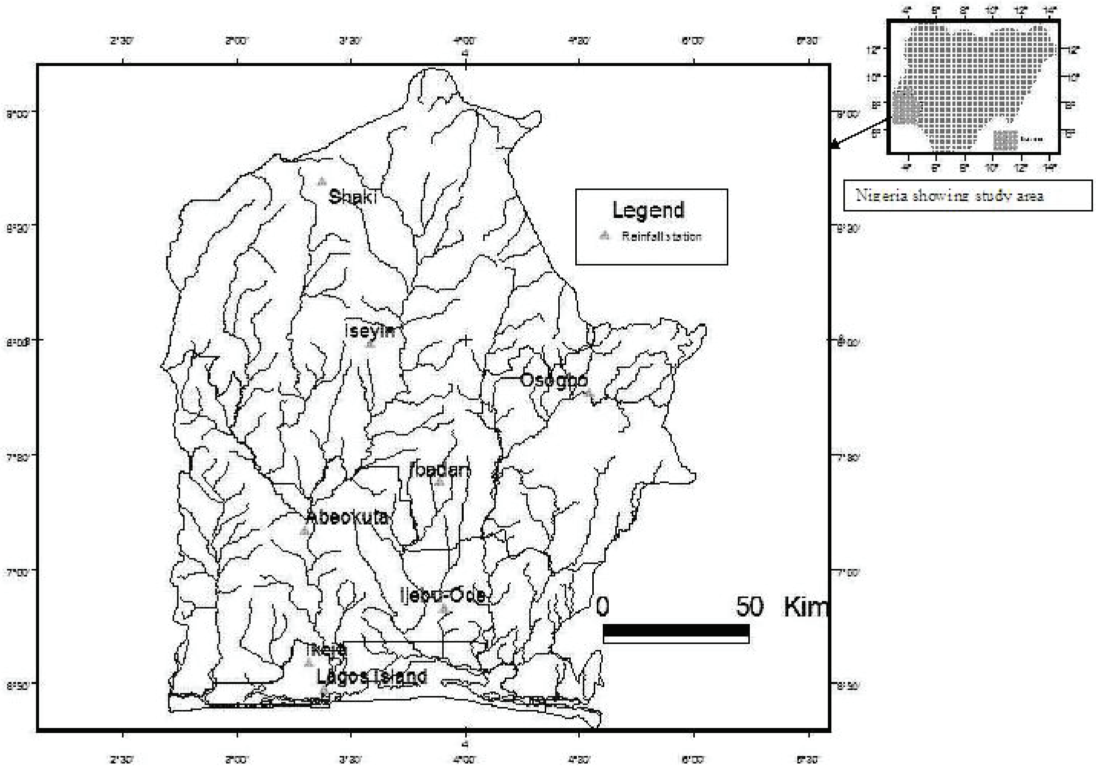

Fig. 1 Ogun-Oshun River Basin Development Authority and major settlement.

Major rivers draining the basin include the Ogun and Osun and their tributaries, Sasa, Ona, Ibu, Ofiki, Omi, Oba and Yewa. The lower portion of the basin is also drained by a network of lagoons, creeks and swamps, as well as rivers.

Climatologically, the drainage basin is located within the tropical rainy climate (Af) zone in accordance to Koppen's climate classification and is under the influence of the tropical continental (cT) and the tropical maritime (mT) air masses. Associated with the tropical maritime air mass are southwesterly winds, while the northeasterly winds are associated with the dry and dusty tropical continental air mass. The narrow zone of convergence of the two air masses is called the Intertropical Convergence Zone (ITCZ) and it usually shifts seasonally with the pressure belts and isotherms. (Iloeje, 1976).

Population density within the drainage basin is about 214 per km^2 with the lower portion of the basin having population density of about 1723 per km^2 in 1991 (Federal Dept. of Water Resources, 1986). Also, the lower portion of the drainage basin which forms Lagos State is the economic and commercial nerve centre of the nation, with over 2000 industries and 65% of the country's commercial activities, in addition to two of the nation's largest seaports, Apapa and Tin-Can (Nigeria Direct, 2006).

Thus, the drainage basin is faced with an increasing per capita water demand, with the estimated water supply requirement for the year 2030 being about 33×10^6 m^3 and 1128.7×10^6 m^3 for Ogun and Lagos areas, respectively (Lagos State Water Corporation, 2000). Also, there is greater pressure on available freshwater resources due to the alarming population growth rate, on the order of about 2.7% average annual growth, in the basin (National Population Commission, 1991). This has often resulted in massive uncoordinated surface and groundwater withdrawals and encroachment on river flood plains.

METHODOLOGY

The methodology entails rainfall data sourcing from the Nigerian Meteorological Agency (formerly Nigerian Meteorological Station, Oshodi) and the decadal analysis was restricted to four

Table 1 Data adopted, their sources and characteristics.

Data	Station	Duration of data	Remark
Rainfall	Ikeja	1944–2003	
	Lagos Island	1941–2000	
	Abeokuta	1981–2000	
	Ijebu-Ode	1974–2003	
	Ibadan	1941–2003	
	Osogbo	1941–2000	Missing years (1948–1956)
	Shaki	1984–2000	
	Isheyin	1982–2000	

Source: Nigerian Meteorological Agency, Oshodi.
`

stations due to the nature of the available rainfall data. Table 1 summarizes the data characteristics and details of the synoptic rainfall stations within the Ogun-Oshun River Basin Authority. The following analyses were carried out, in order to estimate the multi-annual and temporal fluctuations in rainfall totals and its effect on water resources development within the drainage basin.

Normalized distribution analysis was carried-out in order to identify and rank the relationship between the long-term mean annual and the annual total rainfall at the different synoptic stations within Ogun-Oshun River Basin Development Authority (OORBDA).

The normalized distribution (Z) is mathematically expressed as;

$$Z = {(\overline{X} - \mu)}/{\delta} \quad (1)$$

where, $\overline{X}$ is sample annual rainfall mean for the rainfall station, μ is the long-term mean and σ the standard deviation of long-term annual rainfall in the drainage basin.

The effect of rainfall on the hydrological regime of the Ogun-Osun River Basin Development Authority was validated using the indices of precipitation (rainfall) stability (*RRS*) and instability of the hydrological regime (*IHR*) (Blazejczyk *et al.*, 2005).

The *RRS* is defined as;

$$RRS = RRavg / (RR\max - RR\min) \quad (2)$$

where, *RR*max is the maximum annual total rainfall, *RR*min is the minimum annual total rainfall, and *RR*avg is the average annual total rainfall.

While, the IHR is mathematically expressed as

$$IHR = (dRR\max - dRR\min) / RRavg \quad (3)$$

where, *dRR*max is the greatest positive year-to-year difference in rainfall, and *dRR*min is greatest negative year-to-year difference in rainfall.

RESULTS

The pattern of rainfall anomalies within Ogun-Oshun River Basin Development Authority of selected stations for the period (1944–2000) shows that the wettest year for the coastal stations (Ikeja and Lagos Island) was 1968 (Fig. 2). Also, fluctuation in annual rainfall totals at selected stations for decadal analysis has similar rainfall amplitude (Fig. 3).

Table 2 shows the various probabilities of the occurrence of wet and dry years. For example at Ikeja station, the probability that the current year will be a wet year given that the previous year was wet is 0.63, and the probability of a wet year being followed by a dry year is 0.18. Similarly, the probability that the current year will be dry year given that the previous year is dry is 0.54 while the probability of a dry year being followed by a wet year is 0.2.

The decadal analysis (Table 3) shows that there were relatively wet conditions in the 1950s and relatively dry conditions in the 1980s, while in the 1960s, phenomenally wet years occurred at all the stations with a slight increase in the mean decadal rainfall in the 1990s. The wet decades were periods of sufficient rainfall, most especially in the 1950s, with surplus water for development. The only exception is at Ibadan station, where the 1950s were relatively drier than

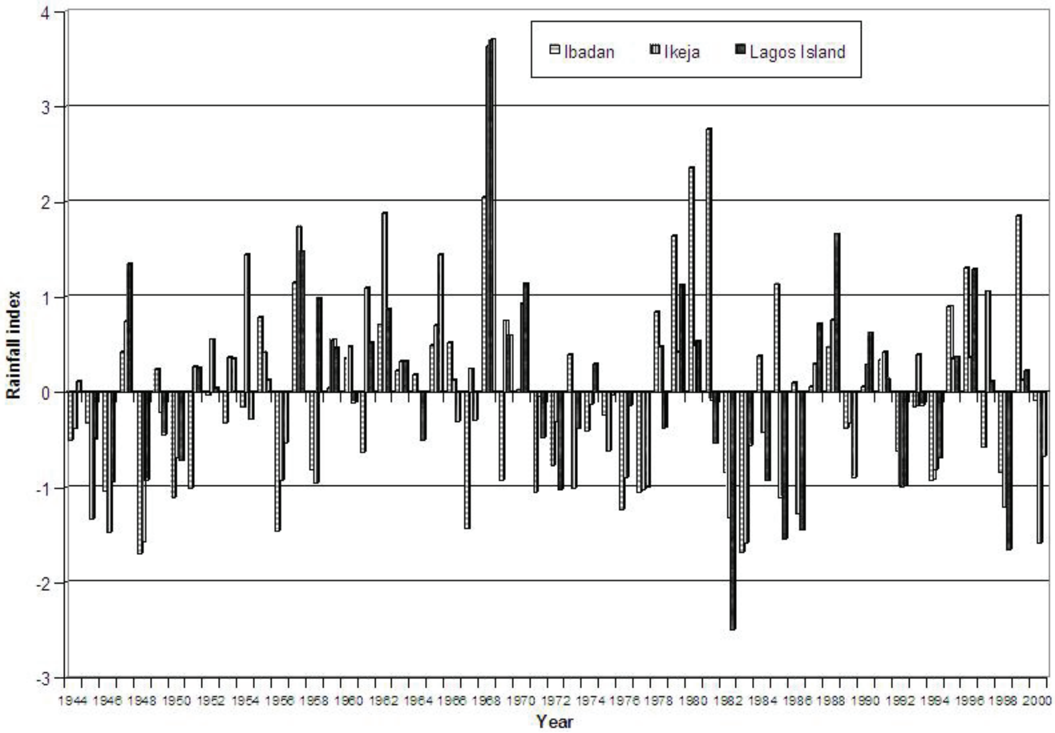

Fig. 2 Annual rainfall variability index in Ikeja and Osogbo Stations (OORBDA).

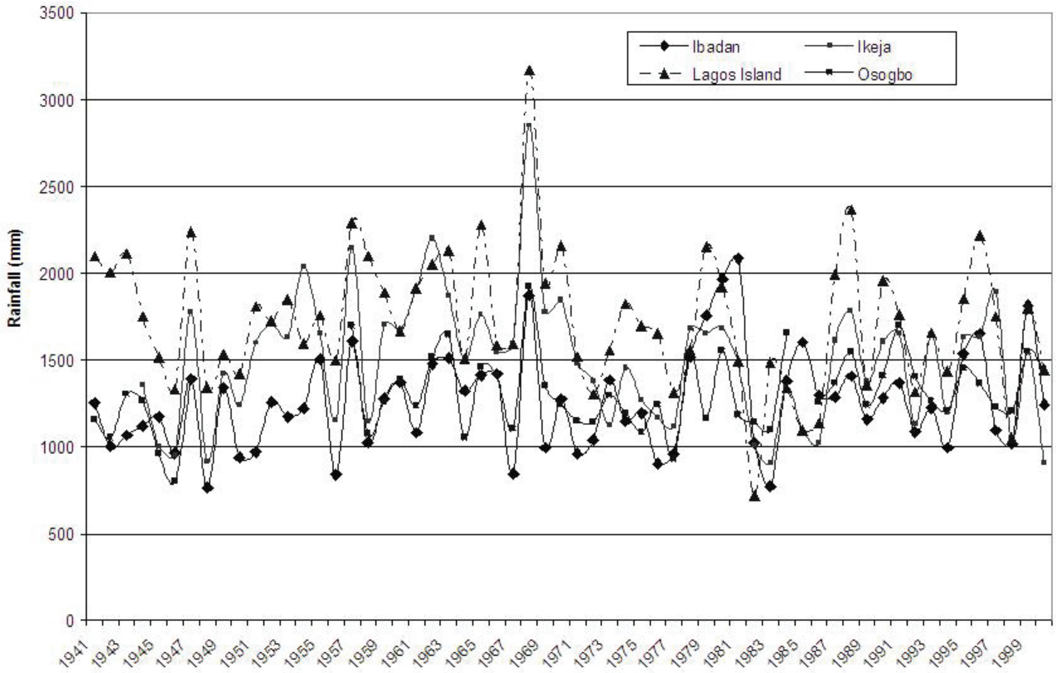

Fig. 3 Fluctuations in annual rainfall totals in several stations in Ogun-Oshun River Basin Development Authority (OORBDA).

other decades and the 1980s were relatively wetter; the station also had an increasing decadal rainfall trend of about +34 mm. Decreasing trends in decadal rainfall of about 95, 70 and 3 mm were recorded, at Lagos Island, Ikeja and Osogbo stations, respectively. The decreasing trend, most especially in the coastal region, calls for a more secured plan in order to match and scale water demand to the natural supply rate average. This is necessary, if the increasing per capita water demand and average annual population growth rate (OORBA, 1990), is to be sustainably managed within a strategic water resources plan.

Table 2 Probability of wet/dry year occurrence within Ogun-Oshun River Basin Development Authority.

	Probability			
Station	Wet/wet	Wet/Dry	Dry/Dry	Dry/wet
Ikeja	0.63	0.18	0.54	0.2
Lagos Island	0.45	0.23	0.48	0.2
Abeokuta	0.36	0.15	0.44	0.1
Ijebu-Ode	0.59	0.17	0.54	0.17
Ibadan	0.55	0.19	0.47	0.21
Osogbo	0.48	0.22	0.55	0.24
Shaki	0.44	0.24	0.5	0.24
Isheyin	0.55	0.14	0.45	0.18

Table 3 Decadal-scale mean rainfall fluctuations in selected station in Ogun-Osun river basin development Authority.

Station	Decadal scale 1950s	1960s	1970s	1980s	1990s
Ikeja	1602.68	1868.54	1418.02	1344.93	1514.04
Lagos Island	1834.86	2019.21	1619.54	1443.07	1648.77
Ibadan	1182.3	1331.35	1214.18	1405.19	1316.88
Osogbo		1409.65	1199.02	1320.75	1378.3

Table 4 Characteristics of precipitation at selected stations within Ogun-Oshun River Basin Development Authority, 1944–2000.

Station	*RR*max (mm)	*RR*min (mm)	*RR*avg (mm)	*dRR*max (mm)	*dRR*min (mm)	*RRS*	*IHR*
Ikeja	2850.7	908.8	1519.71	1071.9	–1258.5	0.78	1.53
Lagos Island	3169	721.2	1726.46	1225.4	–1578.1	0.71	1.62
Ibadan	2084.9	766.8	1269.48	1062.6	–1028.6	0.96	1.65
Osogbo	1921.5	803.9	1306.40	618.3	–814.6	1.17	1.10

The relative variability of the decadal rainfall within the drainage basin is low and of the order of about 13% and 7% at the coastal stations (Ikeja and Lagos Island) and northern stations (Ibadan and Osogbo), respectively. The decadal rainfall distribution along the coast varies more than the hinterlands. This is critical to water resources development within the drainage basin, considering the anticipated socio-economic influx and its associated increase in per capita water demand within the coastal area, especially Lagos. The coastal area is also prone to flood-inducing activities, due to its location and nearness to large water bodies like lagoons and the Atlantic Ocean (Oyebande, 1990). This calls for a need to update and review the existing water master plan and storm water drains, through better understanding of the interrelationship between the various components of the drainage basin and development of an appropriate mechanism for hydrological extreme event prediction and forecasting.

The indices of precipitation (rainfall) stability (*RRS*) and instability of the hydrological regime (*IHR*) (Table 4) for selected stations in relation to the year-to-year fluctuation in rainfall shows that the lowest value of rainfall stability was recorded at Lagos Island while lowest instability of hydrological regime was recorded at Osogbo station. The low stability at the coastal stations, calls for a radical reformation and a proper water resources assessment plan and expansion of the existing water resources system. This is necessary in order to improve access to potable water for the populace, which in Nigeria is about 32% (Hanidu, 1990). Such provision will also prevent stretching the available water resources and cope with increasing demand and pressure from competing water uses, most especially in the densely populated region (such as Lagos, Ibadan and, Abeokuta) within the drainage basin.

CONCLUSIONS

Decadal rainfall distribution analysis within the Ogun-Oshun River Basin Development Authority (Nigeria) shows that there were relatively wet conditions in the 1950s and relatively dry conditions in the 1980s and a slight increase in the mean decadal rainfall in the 1990s.

The effect of total annual rainfall fluctuations among the selected stations on the hydrological regime of Ogun-Oshun River Basin Development Authority (Nigeria) shows that Osogbo station had the most stable hydrological regime. The relative decreasing decadal trend, higher variability and instability of the hydrological regime of the coastal rainfall stations (Ikeja and Lagos Island) calls for a robust water resources development within the Ogun-Oshun River Basin Development Authority. This is necessary in consideration of the anticipated socio-economic influx and its associated increase in per capita water demand within the coastal zone.

An easily accessible information network for rainfall forecasting also needs to be put in place for effective dissemination of information and disaster preparedness as well as the protection of available water resources within the basin and its environment.

Finally, an adequate planning policy scheme and its implementation will go a long way toward withstand the pressure that accompanies rapid and often unplanned growth such as that being witnessed in the basin.

REFERENCES

Blazejczyk, K., Kasperska-Wolowicz, W., Labedzki, L., Kunert, A. (2005) Multi-annual fluctuations in precipitation and their hydrological and ecological consequences at regional scale. In: *Regional Hydrological Impacts of Climatic Change-Hydroclimatic Variability* (ed. by S. Franks, T. Wagener, E. Bøgh, H. V. Gupta, L. Bastidas, C. Nobre & Carlos De Oliveira Galvão), 65–70. IAHS Publ. 296. IAHS Press, Wallingford, UK.

Gash, J. H. C., Forsberg, M., Odada E. O., Oyebande, L. & Schulze, R. E. (2001) Freshwater resources research in Africa. In: *Freshwater Resources in Africa* (ed. by J. H. C. Gash, E. O. Odada, L. Oyebande & R. E. Schulze) (Proc. Workshop Nairobi, Kenya, October 1999, Biospheric Aspects of the Hydrological Cycle), 3–8.

Federal Dept. of Water Resources (1986) National Water Resources Masterplan, Draft Preliminary Plan, Nigeria.

Hanidu, J. A. (1990) National growth, water demand and supply strategies in Nigeria in the 1960s. *Nigerian Association of Hydrogeologists (NAH)* **2**(1). Oct. 1990.

Iloeje, N. P. (1976) *A New Geography of Nigeria* (metric edn). Longman, Nigeria

Lagos State Water Corporation (2000) Challenges and issues of privatization of state water institutions in Nigeria; mobilizing finance for water supply in Nigeria. Lagos Water Conference, November, 2000.

National Population Commission (1991) Population Census of Nigeria.

Nigeria Direct (2006) The Official Information Gateway of the Federal Republic of Nigeria. http://www govt_state_lagos_aspx.htm

Ogun-Osun River Basin Authority (OORBA) (1990) Technical Report.

Ojo, O. (1987) Rainfall trends in West Africa. In: *The Influence of Climate Change and Climatic Variability on the Hydrologic Regime and Water Resources* (ed. by S. I. Solomon, M. Beran & W. Hogg), 37–43. IAHS. Publ. 168. IAHS Press, Wallingford, UK.

Oyebande, L. (1990) Aspects of urban hydrology and the challenges for African urban environment. *African Urban Quarterly* **5**(1/2), 39–63.

Shiklomanov, I. A. (1998) *World Water Resources, A New Appraisal and Assessment for the 21st Century*. UNESCO, Paris, France.

United Nations Environment Programme (UNEP) (2000) *Global Environment Outlook – Past, Present and Future Perspectives.* Earthscan, UK, USA.