Sustainability, Agri, Food and Environmental Research, (ISSN: 0719-3726), 7(2), 2019: 163-177
http://dx.doi.org/10.7770/safer-V0N0-art1476

Temporal Water Balance Analysis in Different Climatic Scenarios in Oyo State, Nigeria.

Análisis del balance temporal del agua en diferentes escenarios climáticos en el estado de Oyo, Nigeria.

Timothy Oyebamiji Ogunbode[1] and Paul Ifatokun Ifabiyi[2]

1- Department of Environmental Management and Crop Production, Bowen University, Iwo, Nigeria. Corresponding author e-mail: taogunbode@gmail.com
2- Department of Geography and Environmental Management, University of Ilorin, Ilorin, Nigeria

ABSTRACT

The study was conducted to examine water availability in different climatic scenarios in Oyo State. The data used comprised of rainfall and temperature records. The spans of the data used vary from one zone to the other: 38-year data for Ibadan and 37-year for Ogbomoso zones, both collected from NIMET Office, Ilorin while 11-year also collected from the Office of Oyo State Agricultural Development Programme (OYSADEP) Headquarters at Shaki were available for Shaki Zone. Evapotranspiration data for the three zones were empirically generated while water balance model was computed using MATLAB R2007a version in orderto determine the respective water availability and the regression analysis was used to determine rainfall trends. The results showed that rainfall amounts vary from year to year and also increasing trends in the three zones over the period examined. It was also discovered that in all the periods investigated across the zones, Ibadan has 81.58%, Shaki, 81.81% and Ogbomoso, 56.80% as wet years indicating that there is abundant water resources in Oyo State. It is recommended that strategies be put in place to exploit excess rainwater for various purposes especially by increasing the capacity of water reservoirs and dams across the State for development of pipe borne water network and also, for irrigation farming during dry spells. Further investigation is recommended on water balance and its implications for agricultural practice in the study area.

Key words: Water resources management; Water Balance; evapotranspiration; Rainfall pattern; hydrological process; Oyo State; Climate change.

RESUMEN

El estudio se realizó para examinar la disponibilidad de agua en diferentes escenarios climáticos en el estado de Oyo. Los datos utilizados comprenden registros de lluvia y temperatura. Los intervalos de los datos utilizados varían de una zona a otra: datos de 38 años para Ibadan y 37 años para las zonas Ogbomoso, ambas recopiladas en la Oficina NIMET, Ilorin mientras que 11 años también se recopilaron en la Oficina del Programa Estatal de Desarrollo Agrícola de Oyo (OYSADEP) Las oficinas centrales de Shaki estaban disponibles para la Zona Shaki. Los datos de evapotranspiración para las tres zonas se generaron empíricamente, mientras que el modelo de balance de agua se calculó utilizando la versión MATLAB R2007a para determinar la disponibilidad de agua respectiva y el análisis de regresión se utilizó para determinar las tendencias de precipitación. Los resultados mostraron que las cantidades de lluvia varían de año en año y también aumentan las tendencias en las tres zonas durante el período examinado. También se descubrió que en todos los períodos investigados en las zonas, Ibadan tiene 81.58%, Shaki, 81.81% y Ogbomoso, 56.80% como años húmedos, lo que indica que hay abundantes recursos hídricos en el estado de Oyo. Se recomienda implementar estrategias para explotar el exceso de agua de lluvia para diversos fines, especialmente al aumentar la capacidad de los embalses y represas de agua en todo el estado para el desarrollo de la red de agua por tubería y también para la agricultura de riego durante períodos secos. Se recomienda realizar más investigaciones sobre el balance hídrico y sus implicaciones para las prácticas agrícolas en el área de estudio.

Palabras clave: gestión de recursos hídricos; Balance de agua; evapotranspiración; Patrón de lluvia; proceso hidrológico; Estado de Oyo; Cambio climático.

INTRODUCTION

Knowledge of the available water in space and time is a prerequisite for efficient water resource management. This, however, is under the influence of several factors including climatic and anthropogenic (see for instance, Olajuyigbe, 2010; Ogunbode and Ifabiyi, 2014). Many failed projects in water planning are partly attributed to inadequate knowledge of water balance-related data. In Nigeria, water balance studies are still limited and this has had tremendous negative implications on many water resource development projects as many of such projects depend on crude and unreliable data. Examples of such projects include dam failures (see Umaru et al., 2010), poor crop yield (see Lal, 1991 and Hoogeveen et al., 2015), poor flood control (see Guntner et al., 2004; Ufoegbune et al., 2011), irrigation failure (see also Arora, 2006;Ufoegbune et al., 2011) among others.

According to Ufoegbune et al. (2012), water balance refers to quantitative expression of the hydrological process and its various components over a specified area and period time. It also refers to a balance between the input of water from precipitation, snowmelt and flow of water by evapotranspiration, groundwater recharge and stream flow. Water balance also implies an accounting of the inputs and outputs of water (Ritter, 2006). Techniques of water balance, one of the main subjects in hydrology according to UNESCO (1974), are necessary to calculate an area's drainable surplus which is defined as the quantity of water that flows into the groundwater reservoir in excess of the quantity that flows out under natural conditions. Ufoegbune et al. (2011) had noted that meaningful planning to utilize and conserve water resources in any area should be based on the assessment of its available water resources which is done through water balance analyses. For instance Suryatmojo, et. al. (2013) observed that understanding the water balance changes in the forested area is important for managing the sustainability of water resources and anticipating potential disturbance caused by the implementation of a particular forest management system (see also, Du et al., 2016). Gbadegesin and Olorunfemi (2007) also noted that analysis of the water balance information and management guidelines may be linked with the implementation process and water supply. According to Ayoade (1983), the original source of water is precipitation, thus the water resources of a given country is related to rainfall. Furthermore, Ayoade stated that the yearly amount of rainfall incident on the land area of Nigeria is about 1400mm. Of this total, about 1070mm is lost through evapotranspiration processes leaving a balance of 330mm for surface and subsurface ruuoff.

Sokolov and Chapman (1974), Jasrotia et al (2009) and Hoogeveen et al (2015) revealed water balance analysis is generally conducted on annual basis. However, it may be carried out within any other given period for any specific purpose. Such calculation could be done for research purposes by the use of secondary data. Several approaches to the determination of water balance have been developed by scholars. These include Thornthwaite equation, Penman equation and Penman-Monteith equation. Some of these methods involve many components whose data generation could be prone to errors especially in developing nations. Thus, most of these water balance models have been modified for ease of computation in different locations and under different conditions, for instance Papadopoulou et al (2003).

Water balance is computed by the hydrologic equation which is basically a statement of the law of conservation of mass as applied to the hydrologic cycle. In its simplest form, the equation reads: *Inflow = Outflow + Change in storage*. However, a general water balance model which takes into consideration the components of hydrologic cycle is as given below:

$P = Q + E + \Delta S/\Delta t$ where P is Precipitation, Q is Runoff, E is Evapotranspiration,

$\Delta S/\Delta t$ is Change in storage (in soil or the bedrock) per unit change in time (see Sokolov and Chapman, 1974). Also, water balance can be illustrated using water balance graph which plots levels of precipitation and evapotranspiration often on a monthly scale.

Generally, water balance method has four main characteristics (Sokolov and Chapman, 1974). Firstly, it can be assessed for any subsystem of the hydrologic cycle, for any size of area, and for any period of time; secondly, it is used to check whether all flow and storage components involved have been considered quantitatively. Also, it can serve to calculate the one unknown of the balance equation, provided that the other components are known with accuracy and lastly, it can be regarded as a model of the complete hydrologic process under study which means it can be used to predict what effect the changes imposed on certain components will have on the other components of the system or subsystem.

However, the objective of this work are as follow: (i) To determine the trend of rainfall over the period of study in Oyo State; (ii) To examine spatial water availability in three different climatic scenarios across the State; and (iii) Determine the implications of spatial water balance scenario in the study area.

MATERIAL AND METHODS

Study Area: Oyo state, ranked fourteenth by size in the country according to Chete (2013), is located between latitude 7.00°N and 9.00°N and logititude 2.45°E and 4.30°E, covering an approximate total area of about 28,454km^2. Its headquaters is located in Ibadan (7°38’N and 3°91’E) and has thirty-three (33) Local Goververnment Areas (LGAs). The total population as at 2006 census was 5,591,589 (National Population Commission, 2006). It is bounded in the North by Kwara State, in the east by Osun State, in the South by Ogun State and in the West partly by Ogun State and partly by the Republic of Benin (Fig. 1). Some of the major urban centres include Ogbomoso, Oyo, Iseyin, Shaki, Okeho among others. The landscape consists of old hard rocks and dome shaped hills, which rise gently from about 500metres in the southern part and reaching a height of about 1,219metres above sea level in the northern part. Some major rivers such as Ogun, Ofiki, Otin, Oba, Oyan, Sasa, Oni, Erinle and Osun rivers flow through the State. The climate of Oyo State exhibits tropical climate of averagely high temperatures, high relative humidity and generally two rainfall maxima regimes during the rainfall period. The dry season lasts from November to February while the wet season starts from March and ends in October.

Water supply situation in Oyo State according to Kehinde and Longe (2003) is below any acceptable standard despite the fact that improved water coverage of Oyo State is 77.4% (Water and Sanitation Summary Sheet). Oyo State exhibits a typical tropical climate of averagely high temperature, high relative humidity and generally two rainfall maxima regimes during the rainfall period of March to October.

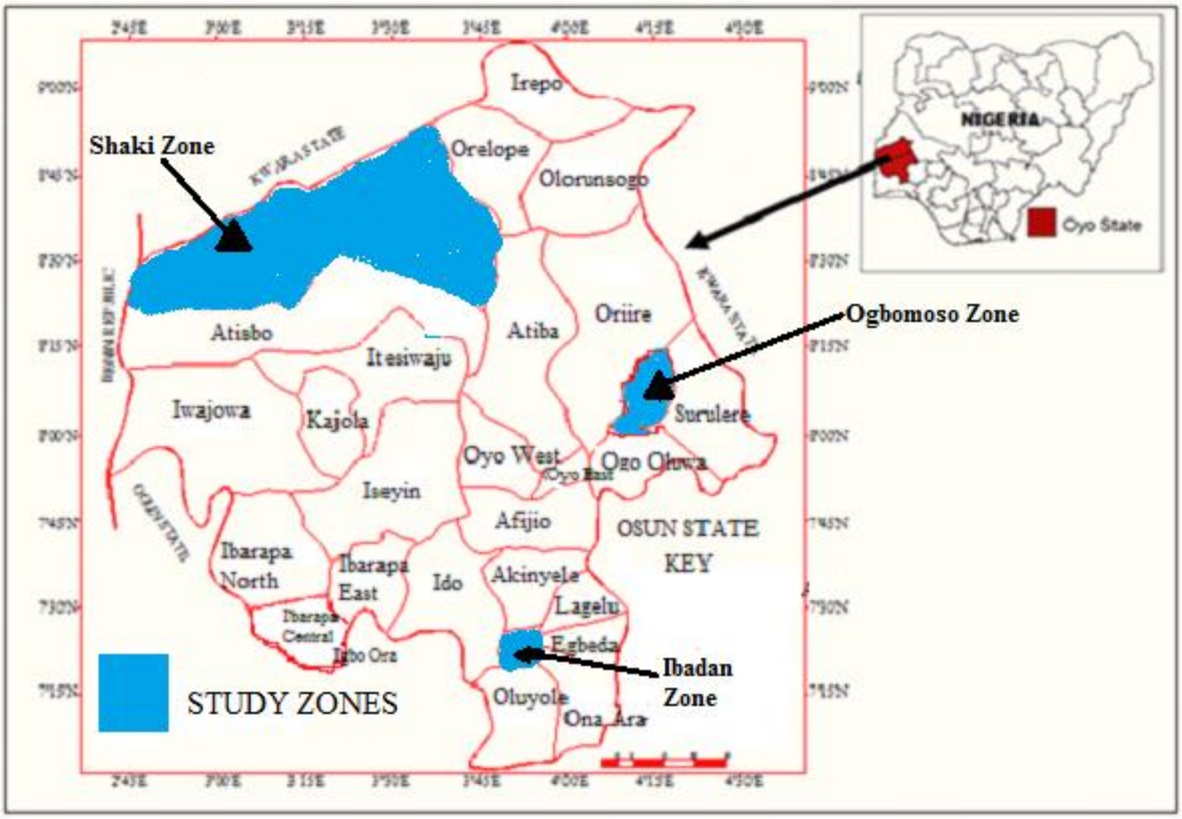

Figure 1: Map of Oyo State showing the study zones (Inset: Map of Nigeria showing the location of Oyo State)

Rainfall and Temperature Data: Three zones namely Ibadan (7°38′N and 3°91′E), Ogbomoso (8°08′N and 4°11′E) and Shaki (8° 14′N and 3° 26′E) were selected for the purpose of this study. The selection was based on spatial spread and data availability. Thirty eight-year (1970-2007) and thirty seven (1970-2006) rainfall and temperature data were available and collected for Ibadan and Ogbomoso zones while eleven-year rainfall (2001-2011) and one year temperature data (2003) was available and collected in Shaki zone for the purpose of water balance studies. The rainfall and temperature data were collected from Nigeria Meteorological Agency (NIMET). Both rainfall and temperature data for Shaki zone were collected from the Office of Oyo State Agricultural Development Programme Headquarters at Shaki.

Evapotranspiration Data: The empirical model developed by Thornthwaite was adopted to generate Annual Potential Evapotranspiration (PE) data for the three locations. The Thornthwaite's method calculates potential evapotranspiration using observed air temperature and duration of sunlight data. The rationale, according to Papadopoulou et al.., (2003) is that air temperature does, to a considerable extent, serve as a parameter of the net radiation. According to Huang et al.., (1996), this model is a shortcut of replacing a comprehensive atmospheric model, as well as some interactions by prescribing observed temperature and precipitation. Hence, evapotranspiration values were generated using equation 1

$E= 16* (10T/I)^a * \mu N/360$ ----------------------------------equation 1 where E is monthly potential Evapotransipration (mm/month),

T is mean monthly temperature (^{0}C),

I is an Empirical Annual Heat Index, the sum of 12 monthly index values i, the value of i for each month is derived from mean monthly temperatures using the formula:

i_j= 0.09* (Tj)$^{1.5}$ --equation 2

where *j* is the specific month under investigation,

N is the mean number of daylight hours in a particular month

μ is the number of days in the month

a is an empirically derived exponent which is a function of *I*, and is given by the formula: *a*= 0.016*I+0.5---equation 3

The annual water balance for each of the locations was computed with the use of *MATLAB R20077a* version. The monthly water balances in all respective zones were summed up to obtain annual values.

Water Balance Analysis: in order to assess the pattern of water availability in Oyo State, 3 zones were selected namely Ibadan, Ogbomoso and Shaki. These zones were selected first on the basis of data availbility and secondly, because of their spatial spread. However, water balance model in this work considered precipitation as main input and evapotranspiration as main water loss as adopted by Ogunbode (2015). Thus,

AWB=TAR-AWL_t, where, (equation 4)

AWB is Annual Water Balance,

TAR is Total Annual Rainfall and

AWL_t is Total Annual Water Loss via Evapotranspiration

The annual water balance for each of these zones were computed following equation 4. The years were grouped into two namely wet and dry years. The years where rainfall is higher than the evapotranspiration were categorised as wet years while the years with higher evapotranspiration (figures with negative water balance) were categorised as dry years.

RESULTS AND DISCUSSION

Water Resource Characteristics in Oyo State: the trends of variations in rainfall and the associated r^2 and equation over the period of 38years, 37years and 11years in Ibadan, Ogbomoso and Shaki respectively are shown in Figures 2, 3 and 4. These figures revealed that the amount of rainfall fluctuates from year to year in the three zones while the results of regression analysis indicate increasing trend over the period investigated. Thus, in view of this, water supply and the replenishment of other sources through rainfall in Oyo State is generally dependable.

Sustainability, Agri, Food and Environmental Research, (ISSN: 0719-3726), 7(2), 2019: 163-177
http://dx.doi.org/10.7770/safer-V0N0-art1476

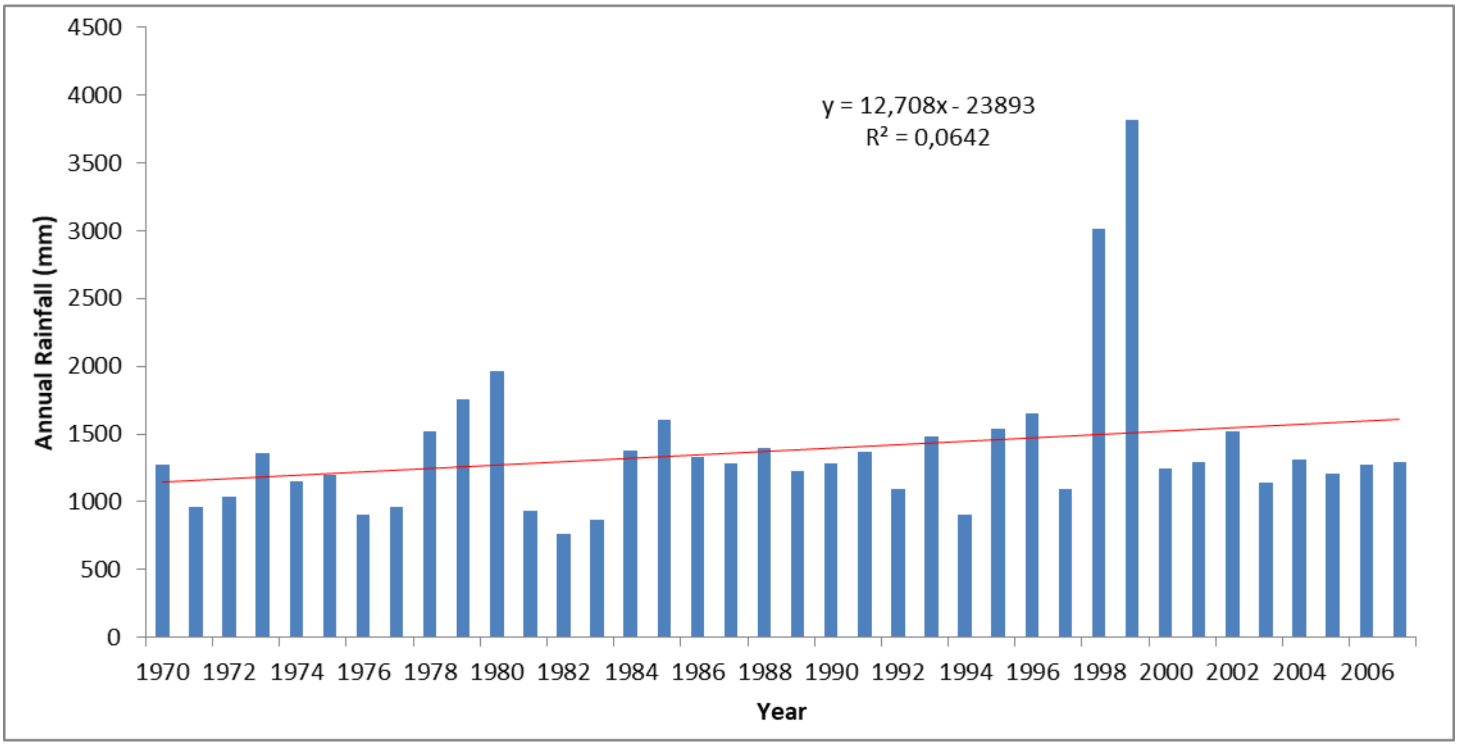

Figure 2: Mean Annual Rainfall Pattern in Ibadan (1970-2007) *(Source: NIMET)*

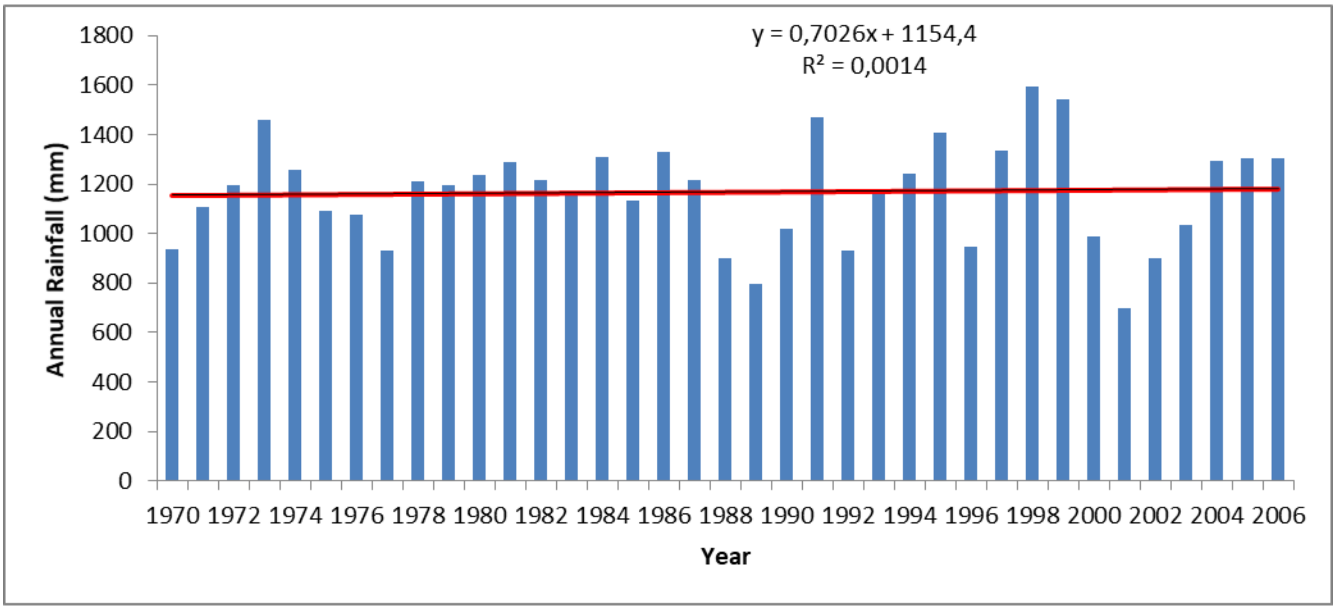

Figure 3: Mean Annual Rainfall Pattern in Ogbomoso (1970-2006)

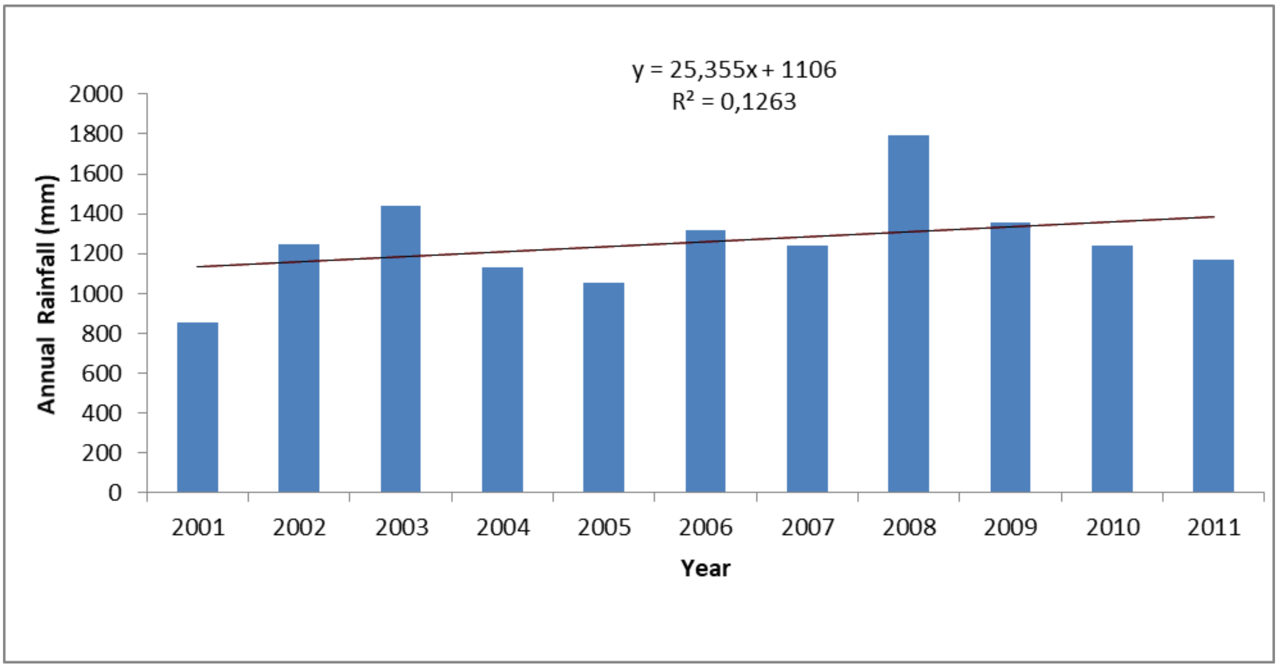

Figure 4: Mean Annual Rainfall Pattern in Shaki (2001-2011) *(Source: NIMET)*

Water Balance Analysis in Oyo State: tables 1, 2 and 3 show the annual rainfall annual evapotranspiration values and the annual water balance in Ibadan, Ogbomoso and Shaki zones. The rainfall pattern over the period indicate that the annual totals were generally above 1000mm except few years which were incidentally found to be years of water balance deficits (dry years) across the three zones. The 7 dry years out of the 38years investigated in Ibadan zone were mostly years of rainfall totals less than 1000mm.

Table 1: Annual Rainfall Total, Annual Potential Evapotranspiration and the Annual Water Balance in Ibadan, Oyo State. (1970-2007).

S/N	Year	Annual Total[1] Rainfall (mm)	PET (mm)	Water Balance (mm)	Water Supply Description
1.	1970	1275.8	1141.17	134.6	Wet year
2.	1971	960.1	1141.0	-180.9	Dry year
3.	1972	1041.0	1157.35	-116.4	Dry year
4.	1973	1359.4	1155.74	203.7	Wet year
5.	1974	1148.1	1138.74	9.36	Wet year
6.	1975	1195.7	1128.68	67.02	Wet year
7.	1976	903.5	1125.94	-222.4	Dry year
8.	1977	960.1	1237.16	-277.1	Dry year
9.	1978	1518.9	1133.45	385.5	Wet year
10.	1979	1754.5	1146.42	608.1	Wet year
11.	1980	1966.4	1128.96	837.4	Wet year
12.	1981	931.8	1145.55	-213.8	Dry year
13.	1982	760.2	1143.37	-383.2	Dry year
14.	1983	865.0	1149.39	-284.4	Dry year
15.	1984	1377.1	1146.1	23.1	Wet year
16.	1985	1602.6	1146.25	456.4	Wet year
17.	1986	1327.9	1136.42	191.5	Wet year
18.	1987	1285.1	1164.11	121.0	Wet year
19.	1988	1397.8	1146.01	251.8	Wet year
20.	1989	1223.7	1153.78	69.9	Wet year
21.	1990	1283.9	1159.73	124.17	Wet year
22.	1991	1369.3	1152.49	216.81	Wet year
23.	1992	1088.6	1150.10	-6.15	Dry year
24.	1993	1478.1	1156.57	321.53	Wet year
25.	1994	905.9	1154.83	-248.93	Dry year
26.	1995	1534.7	1159.98	374.72	Wet year
27.	1996	1653.7	1151.01	502.69	Wet year
28.	1997	1097.1	1145.87	-48.77	Dry year
29.	1998	3016.0	1146.37	1869.63	Wet year
30.	1999	3813.9	1180.02	2633.88	Wet year
31.	2000	1244.5	1151.82	92.68	Wet year
32.	2001	1289.7	1157.51	132.19	Wet year
33.	2002	1515.3	1155.25	360.05	Wet year
34.	2003	1143.0	1133.41	9.59	Wet year
35.	2004	1314.2	1156.93	157.27	Wet year
36.	2005	1204.2	1161.18	43.02	Wet year
37.	2006	1270.4	1156.33	114.07	Wet year
38.	2007	1290.6	1147.49	143.11	Wet year

[1]Source: Nigeria Meteorological Agency (NIMET)

It was observed that dryness was experienced over 2-year periods (1971-1972 and 1976-1977) while the zone experienced the longest period of dryness from 1981-1983 over the period investigated. On the other hand, cognisance was taken of the rainfall totals of 1998 and 1999 with 3016mm and 3813.9mm respectively. These years were also characterised with the highest record of water balance (1869.63mm and 2633.88mm respectively) during the period indicating excess water supply.

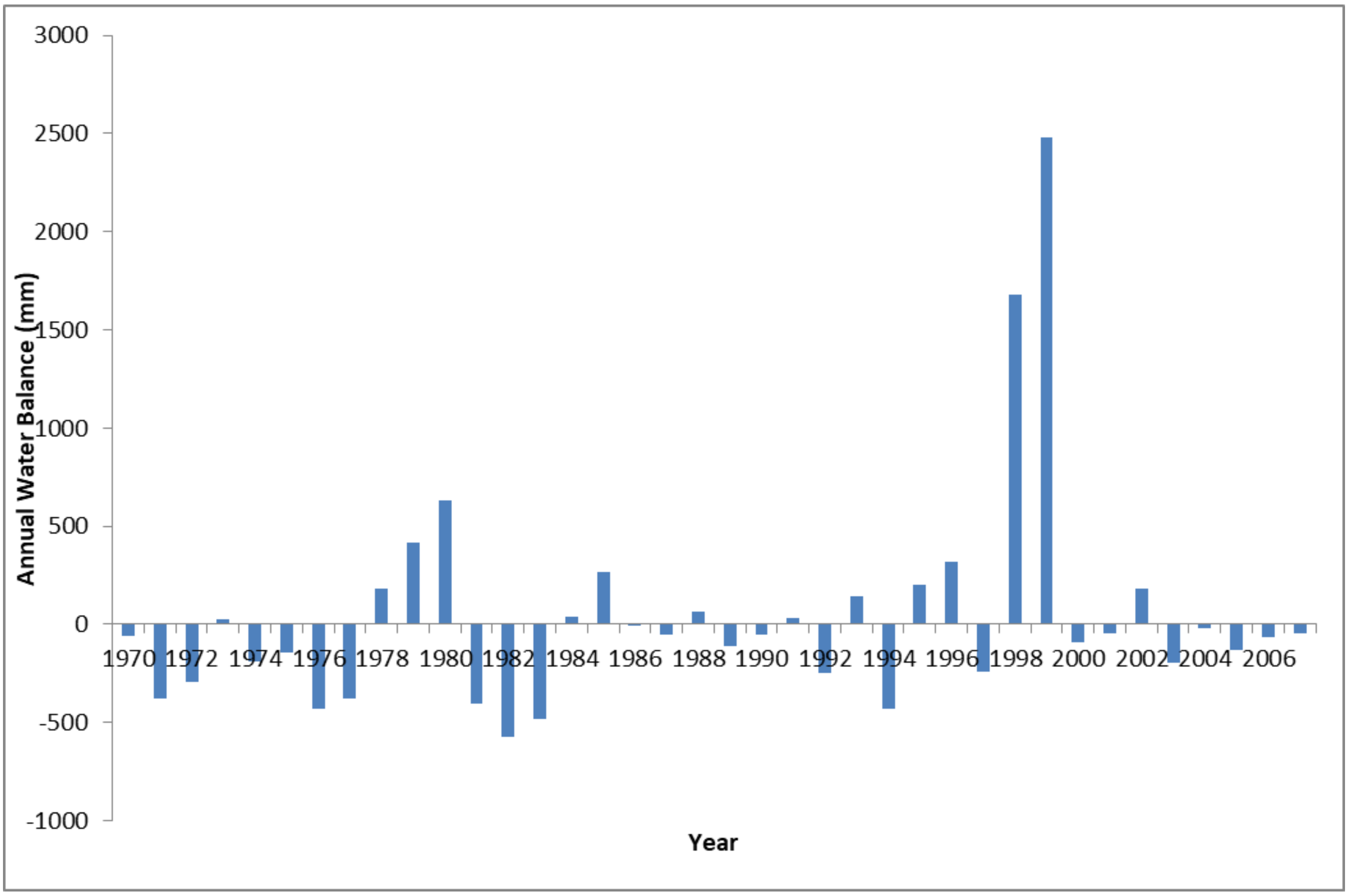

Figure 5: Annual Water Balance in Ibadan (1970-2007)

In the same vein, the water balance results for Ogbomoso revealed that 16 years out of the 37 years investigated were dry years. This is shown in Table 2.

Sustainability, Agri, Food and Environmental Research, (ISSN: 0719-3726), 7(2), 2019: 163-177
http://dx.doi.org/10.7770/safer-V0N0-art1476

Table 2: Annual Rainfall Total, Annual Potential Evapotranspiration and the Annual Water Balance in Ogbomoso, Oyo State (1970-2006).

S/N	Year	Annual Total[1]Rainfall(mm)	PET (mm)	Water Balance(mm)	Water Supply Description
1.	1970	938.3	1119.34	-181.04	Dry year
2.	1971	1106.8	1169.15	-62.35	Dry year
3.	1972	1197.3	1177.54	19.76	Wet year
4.	1973	1460.8	1183.44	277.36	Wet year
5.	1974	1256.5	1120.22	136,28	Wet year
6.	1975	1090.5	1166.02	-75.52	Dry year
7.	1976	1078.0	1166.02	-88.02	Dry year
8.	1977	928.9	1172.72	-243.82	Dry year
9.	1978	1209.4	1165.12	44.28	Wet year
10.	1979	1193.1	1156.26	36.84	Wet year
11.	1980	1237.1	1249.73	-12.63	Dry year
12.	1981	1286.9	1159.86	127.04	Wet year
13.	1982	1215.1	1158.63	56.47	Wet year
14.	1983	1157.2	1147.89	9.31	Wet year
15.	1984	1310.5	1163.52	146.98	Wet year
16.	1985	1133.3	1165.54	-32.24	Dry year
17.	1986	1328.4	1169.54	158.86	Wet year
18.	1987	1213.7	1168.37	45.33	Wet year
19.	1988	898.9	1156.10	-1413.3	Dry year
20.	1989	794	1177.80	-38.38	Dry year
21.	1990	1020.1	1162.80	-142.7	Dry year
22.	1991	1468.4	1161.77	306.63	Wet year
23.	1992	931.6	1167.42	-235.82	Dry year
24.	1993	1157.9	1154.48	3.42	Wet year
25.	1994	1242.0	1158.35	83.65	Wet year
26.	1995	1409.2	1152.45	256.75	Wet year
27.	1996	945.3	1158.90	-213.6	Dry year
28.	1997	1334.4	1159.20	175.2	Wet year
29.	1998	1595.5	1164.47	431.03	Wet year
30.	1999	1539.3	1169.54	369.76	Wet year
31.	2000	990.3	1165.50	-17.52	Dry year
32.	2001	697.1	1158.94	-461.84	Dry year
33.	2002	902.3	1170.10	-267.8	Dry year
34.	2003	1033.5	1176.61	-143.11	Dry year
35.	2004	1294.0	112.87	181.13	Wet year
36.	2005	1305.9	1163.08	142.82	Wet year
37.	2006	1303.8	1161.66	142.14	Wet year

[1]Source:Nigeria Meteorological Agency (NIMET)

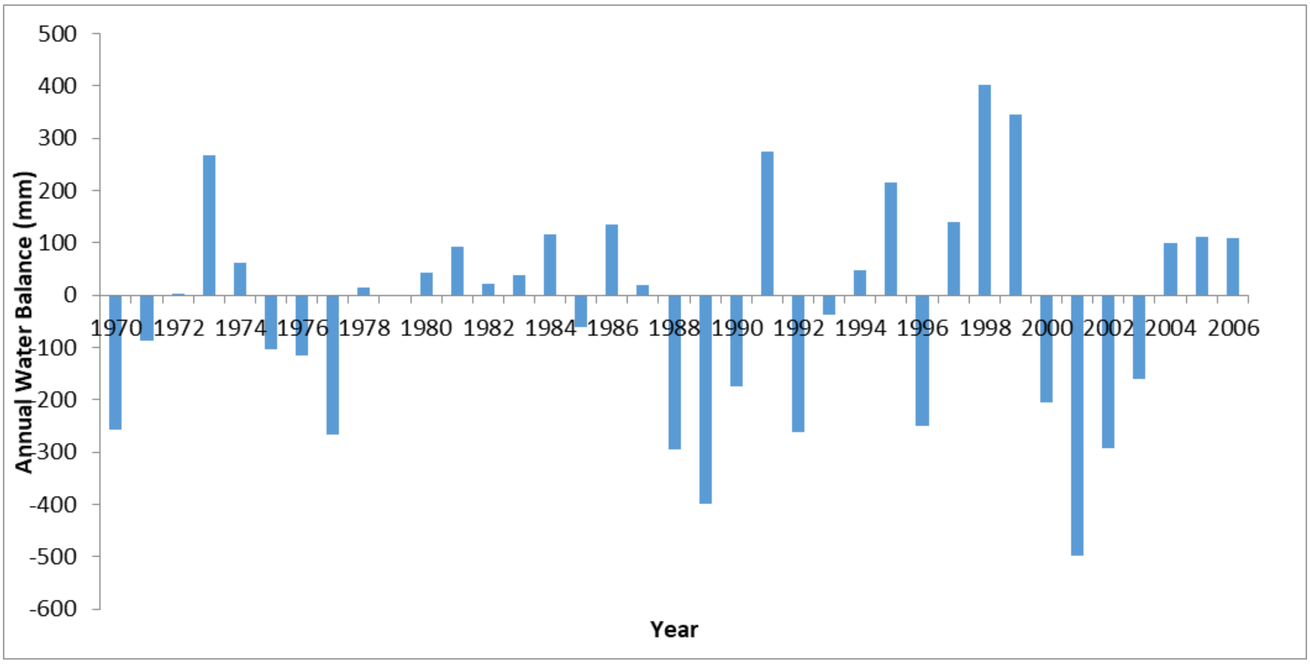

Figure 6: Annual Water Balance in Ogbomoso (1970-2006)

Table. 3: Annual Rainfall Total, Potential Evapotranspiration and the Annual Water Balance in Shaki, Oyo State (2001-2011)

S/N	Year	Annual Total[1] Rainfall (mm)	PET (mm)	Water Balance(mm)	Water Supply Description
1.	2001	852.7	1094.58	-241.9	Dry year
2.	2002	1249.7	1094.58	155.12	Wet year
3.	2003	1439.8	1094.58	345.22	Wet year
4.	2004	1133.4	1094.58	38.82	Wet year
5.	2005	1053.4	1094.58	-41.18	Dry year
6.	2006	1316.7	1094.58	222.12	Wet year
7.	2007	1239.2	1094.58	144.62	Wet year
8.	2008	1791.0	1094.58	696.42	Wet year
9.	2009	1353.4	1094.58	258.82	Wet year
10.	2010	1238.5	1094.58	143.92	Wet year
11.	2011	1171.1	1094.58	76.52	Wet year

[1]Source: Nigeria Meteorological Agency (NIMET)

The situation in Shaki as shown in Table 3 and depicted in Figure 7 was inadequate to be compared with the findings in other two zones for dearth of data.However, the result showed that 2 dry years were observed in the 11 year data analysed. These were 2001 and 2005. The situation in Shaki showed a similar result as the other two zones where the highest water loss was experienced in 2001 when rainfall was lowest in the periods investigated. The highest water surplus was also experienced when rainfall total was highest. The range value of temperature in Shaki over the period investigated was 8.7°C, which is similar to the value in Ogbomoso.

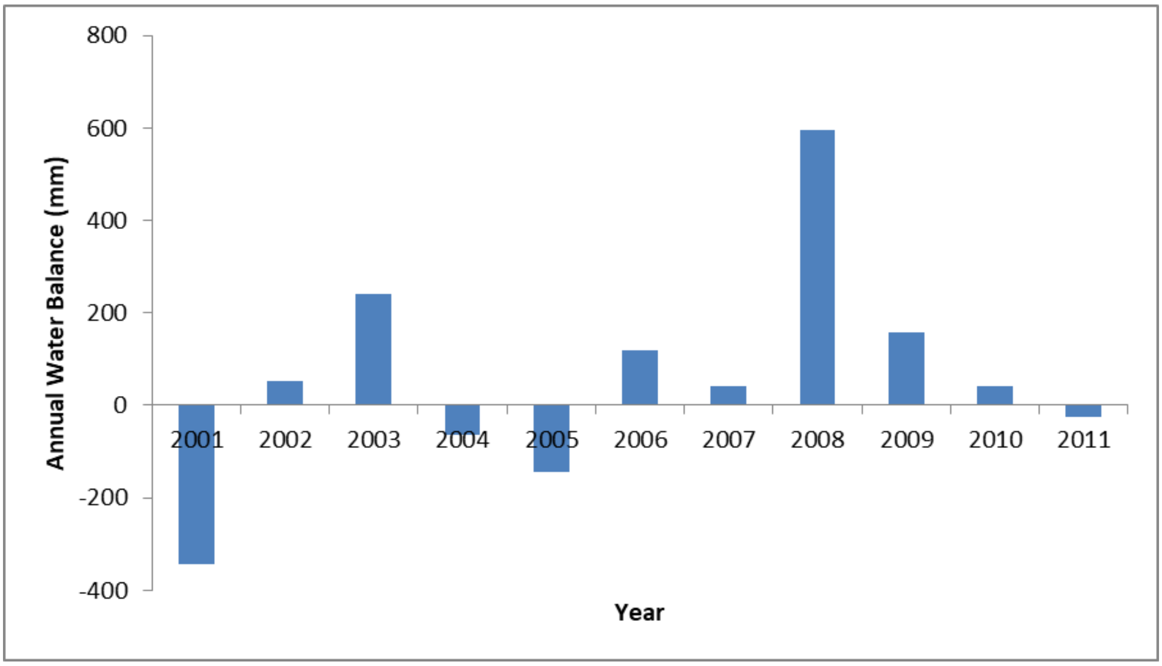

Figure 7: Annual Water Balance in Shaki (2001-2011)

The results generally revealed that Ibadan had more years of water surplus between 1970 and 2006 than what were obtained in Ogbomoso. This observation is probably attributed to the southern location of Ibadan (which implies closer to the coastal area) than does Ogbomoso. Ibadan experienced 28years of water surplus while Ogbomoso had 21 years. In the same vein, Ibadan experienced 9 years of water deficits while Ogbomoso experienced deficitsin 16 years. This showed that water supply in Ibadan is more consistent than in Ogbomoso. This scenario reflects the characteristic of rainfall pattern in Nigeria- Rainfall magnitude decreases from the coastal south towards the north as noted by Ojo (1990). Moreso, Ibadan is located to the southern part of the state (closer to the coastal fringe) when compared with the locations of Ogbomoso and Shaki which are of hinterland.

Also, the periods from 2001 to 2006 when the three zones had data, the results showed that Ibadan experienced water surplus throughout the six-year period while Ogbomoso had 3-yearseach of water deficits (2001-2003) water surplus (2004-2006). Shaki, however experienced two years of water deficit (2001 and 2005) and four years of water surplus (2002-2004, and 2006) probably due to its northern location. This implies that water supply in Ibadan is more consistent than in any of the other two zones. However, water resource management strategies should among others include continuous dredging and channelization of streams and rivers as ways of mitigating flooding in Ibadan while efforts should be geared towards conserving excess water for use during dry spells in both Ogbomoso and Shaki Zones.

Generally, it is observed that water balance over the period investigated for the zones were inconsistent as also noted by Ojo (1990). It should be noted that the years of least rainfall totals in Ibadan, Ogbomoso and Shaki coincided with the years of highest water loss in their respective periods of study. These results could partly explain that evapotranspiration rate were too high when there were less rainfall incidences. The results validate the findings of Ayoade (1983) which noted that the evapotranspiration over the land area of Nigeria is about 1070mm out of about 1400mm of rainfall in a year. The reverse was the case when the rainfall was highest as heavy torrential downpour which were largely spread over the rainy period in Oyo State (March to October) will likely reduce the rate of evapotranspiration. Atmospheric humidity will be high and even the availability of water also makes the evapotranspiration minimal.

The results have further shown that water resource is generally in abundance in Oyo State. Thus, an improved ways of utilizing rainwater especially for domestic consumption and agricultural practices should be encouraged. Even though, rainy days/time may not coincide with immediate needs in homes, effort should gear towards its conservation for its immediate future utilisation especially during dry spells. This will, however, reduce the proliferation of hand-dug wells in the State. However, there may be the need to increase the capacities of dams and other water reservoirs in the State especially in Ogbomoso and Shaki zones to conserve more water for use in the dry period and to checkmate flooding during the wet period in Ibadan zone. In addition, there is need to check the rate of evapotranspiration especially in Ogbomoso and Shaki through reaforezone programmes. This could go a long way to reduce the rate of evapotranspiration in a way.

Consideration for optimal utilization of abundant rainwater may also include its conservation for use for irrigation farming purpose especially in the period of dry season from November to March. The advantage of abundant rainwater could be channelled towards agricultural development. Planting of varying species of crops and other related practices that best suit the area in term of water requirement could be encouraged among the local farmers to enhance their livelihood.

As conclusion, this study examined the availability of water resources in three climatic scenarios in Oyo State. The results of regression analysis revealed that there were positive trends in rainfall in the three locations indicating the possibility and reliability of abundant water resources in the State. Also, the results showed that there were inconsistencies in water balance as there were years of deficit and surplus. However, the geographical locations of each of the zones have effect on water balance. While Ibadan was found to be wettest, Ogbomoso is driest over the period studied, thus supporting the general pattern of rainfall distribution in Nigeria.

It is recommended that effective water management should be put in place to exploit enormous rainwater for domestic utilization and other purposes such as increasing the capacity of the existing reservoirs and/or dams located across the State to give room for water storage, development of irrigation farming and rainwater harvests. Further research is suggested on challenges of water supply in Oyo State.

REFERENCES

Arora, V.K. (2006) Application of a rice growth and water balance model in an irrigated semi-arid subtropical environment. Agricultural Water Management, 83: 51-57.

Ayoade, J. O. (1983) Water Resources in Oguntoyinbo, J.S., Areola, O. O. and Filani, M. (ed.)A Geography of Nigerian Development. Heinemann Educational Books (Nigeria) Ltd, Ibadan: 71-88 pp.

Chete, O. (2013) A gender analysis of maize marketing by farmers in Oyo State. European Scientific Journal, 9(26): 268-279.

Du, C., Sun, F. Yu, J., Liu, X and Chen, Y. (2016) New interpretation of the role of water balance in an extended Budyko hypothesis in arid regions. Hydrology and Earth Systems Sciences, 20: 393-409.

Gbadegesin, N. and Olorunfemi, F. (2007) Assessment of Rural Water Supply Management in selected Rural Areas of Oyo State, Nigeria. African Technology Policy Studies Network (ATPS) working paper series No. 49.

Güntner, A., Krol, M. S. De Araűjo, J. C. and Browstent, A. (2004) Simple water balance modelling of surface reservoir systems in a large data-scarce semi-arid region. Hydrological Sciences,49 (5): 901-918.

Hoogeveen, J., Faures, J.M., Peiser, L., Bunke, J. and van de Glesen, N. (2015) A Global water balance model to assess water use in irrigated agriculture. Discussion Paper 12. Hydrology and Earth System Sciences, 801-838.

Huang, J., van den Dool, H. M. and Georgakakos, K.P. (1996) Analysis of Model-Calculated Soil Moisture over the United States (1931-1993) and Application to Long-Range Temperature Forecasts. Journal of Climate, 9(6): 1350-1362.

Jasrotia, A.S., Majhi, A. and Singh, S. (2009) Water Balance Approach for rainwater harvesting using remote sensing and GIS techniques, Jammu Himalaya, India. Water Resources Management, 23(14): 3035-3055.

Kehinde, M.O. and Longe, E.O. (2003) Providing Water at Affordable Cost in Developing Economies:Towards Millennium Development Goals. 29th WEDC International Conference, Abuja, Nigeria.248-250.

Lal, R. (1991) Current research on crop water balance and implications for the future.Soil-water balance in the Sudano-Sahelian Zone (Proceeding of the Niamey Workshop). IAHS Publ. 199: 31-44

Ojo, O. (1990) Recent Trends in Precipitation and Water Balance of Tropical Cities.The Example of Lagos, Nigeria.HydrologicalProcesses and Water Management in Urban Areas (Proceedings of the Duisberg Symposium, Aptil, 1998).IAHS Publication No.198.

Ogunbode, T.O. and Ifabiyi, I.P. (2014) Determinants of Domestic water use in a growing urban centre in Osun State, Nigeria.African Journal of Environmental Science & Technology, 8(4): 247-255

Ogunbode, T.O. (2015) Pattern of domestic water utilisation and management in selected rural areas of Oyo State, Nigeria. An unpublished PhD Thesis Department of Geography & Environmental Management, University of Ilorin, Nigeria. 290pp.

Olajuyigbe, A. (2010) Some factors impacting on quantity of water used by households in a rapidly urbanizing State capital in southwestern Nigeria. Journal of Sustainable Development African, 12(2): 321-337

Papadopoulou, E., Varanou, E., Baltas, E., Dassaklis, A. and Mimikou, M. (2003) Estimating Potential Evapotranspiration and its Spatial Distribution in Greece Using Empirical Methods.8th International Conference on Environmental Science and Technology, Lemnos Island, Greece, 8-10 September, 2003.

Ritter, M.E. (2006). The Physical Environment: an Introduction to Physical Geography.

Sokolov, A.A. and Chapman, T.G. (ed. 1974) Methods of Water Balance Computations: An International Guide for Research and Practice.A contribution to the International Hydrological Decade.The UNESCO Press.

Suryatmojo,H., Yamakawa, M., Kosugi, K. And Mizuyama, T. (2013) Water balance changes in the tropical rainforest with intensive forest management system. International Journal of Sustainable Future for Human Security, 1(2): 56-62.

Ufoegbune, G.C, Bello, N.J, Dada, O.F., Eruola, A.O, Makinde, A.A, and Amori, A.A. (2012) Estimating Water Availability for Agriculturre in Abeokuta, South Western, Nigeria. Global Journal of Science Frontier Research: Agriculture and Veterinary Sciences. 12(9):12-24.

Ufoegbune, G.C., Yusuf, H.O., Eruola, A.O. and Awomeso, J.A. (2011) Estimation of Water Balance of Oyan Lake in North West Region of Abeokuta, Nigeria. British Journal of Environment and Climate Change 1(1): 13-27.

Umaru, A., Ogedengbe, K. and Omobowale, M. O. (2010) Structural failures of earth dams in Nigeria: A case study of Cham Dam in Gombe State. ARPN Journal of Engineering & Applied Sciences, 5(11): 47-52.

UNESCO(1974). Methods for Water Balance Computations. Paris: Beugnet, pp. 1-127.