



## Decadal Assessment and Distribution of Rainfall Anomaly Index (1991 – 2020) for Benin City, Edo State, Nigeria

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**ABSTRACT:** This study was designed to provide valuable insight into the temporal patterns of rainfall in Benin City, Edo State, Nigeria using rainfall data from 1991 – 2020 (30 years) collected from Nigerian Meteorological Agency (NIMET), airport station, Benin City. The data were assessed based on 10 years interval (decade) identified as decadal A (1991-2000), decadal B (2001-2010) and decadal C (2011-2020). The data was analysed descriptively using charts and graphs. Also, Rainfall Anomaly Index (RAI) was determined for each decadal. Findings from the study reveal that rainfall pattern changes significantly based on statistics for each decadal. In decadal A, rainfall usually began in the month of July to October, June to September in decadal B while May to September in decadal C with rainfall going above the annual precipitation (2679 mm) for the City. The rainfall anomaly over the city revealed that there was a composite nature in which some dry years were mixed with wet years and vice versa and this occurred in all decades. RAI revealed that decadal C recorded the highest number of years (7) of intense rainfall compared to decadal A and B. The trend for the average annual rainfall showed a significant trend based on the decade. The average annual rainfall increased with time (decade) as the trend rose from 1886.9 mm in decade A to 1890.0mm in decade B and 2078.8 mm in decade C. The year of greatest positive value was 2016 (decadal C), with an average RAI of 6.53 classified as extremely humid. Based on these findings, the study concludes that the climate in Benin City has significantly changed.

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Global climate is reported to have witnessed a drastic change at least over the last century. The effect of this change has resulted in changes and shifts in the patterns of the climate elements, particularly precipitation, humidity, and temperature across the globe (Adefolalu, 2007). The Intergovernmental Panel on Climate Change reported that the global mean surface temperature has increased by 0.76°C in the last 150 years and will continue to witness an upward trend in the range of 1–6°C by the end of the 21st century if nothing is the basis of climate change which the world is battling to resolve; these changes are extreme weather conditions, sea level rise, and a shift and erratic precipitation pattern observed in recent times

(Adefolalu, 1986). The trend in rainfall pattern has shown a slightly positive trend, though variability still exists on some regional and local scales in terms of intensity, amount, and shifts (Adefolalu *et al.*, 2007; Adejuwon, 2004). These variabilities and changes in climate have significant impacts on the livelihood and well-being of people, particularly those in rainfall-dependent regions. Climate variability and change pose a serious threat to many countries, especially the most vulnerable and poor developing ones in Sub-Saharan Africa. It is important to note that West Africa is a part of the world. Nigeria suffered from the most significant rainfall variability in the second half of the 20th century (Dai *et al.*, 2004; Spinoni *et al.*, 2014).

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Based on Le Barbé *et al.*, (2002), the average difference in the mean inter-annual rainfall between wet and dry periods in the West African Sahel region is 180mm/year. Several studies have demonstrated a significant increase in extreme rainfall events with a high wet–dry sequence risk in the past two decades in this region (Descroix *et al.*, 2013, 2015; Sighomnou *et al.*, 2013). An example is the urban flooding of Ibadan City in Oyo State on 26<sup>th</sup> August 2011 (Agbola *et al.*, 2012). Nigeria, as a developing nation is particularly sensitive to the effects of climate change. A large part of the economy of the country depends on rainfall for its agricultural practices which in most cases is the major economic driver. As critical as the effect of climate change is, it is not clear whether Nigerians are aware of what climate change is or its effects. Perhaps the biggest obstacle is the lack of awareness and knowledge as Ishaya and Abaje, (2008) put it. In Benin City, essential climatic elements particularly rainfall, temperature, and humidity are neither incorporated into its complex environmental planning processes nor utilized in its continuous urban development activities. The dynamic nature and characteristics of the climate in the study area have not been assessed from authentic scientific perspectives. Therefore, based on the irregularity and seasonality of rainfall, monitoring using the use of climatic indexes is necessary. Based on this, it is possible to develop a monitoring system of the characteristics of dry and rainy periods (Da Silva *et al.*, 2009). According to Santos *et al.* (2015), emphasized the importance of developing and encouraging regional policies that seek to reduce adverse effects on hydrological systems. Therefore, adequate knowledge about Benin City's climatic characteristics through effective monitoring is essential. In light of this context, the Rainfall Anomaly Index (RAI), developed by Rooy, (1965), is used to classify the positive and negative severities in rainfall anomalies within Benin City. RAI is considered an index of remarkable procedural simplicity because it requires only precipitation data (Freitas, 2005; Fernandes *et al.*, 2009). According to Rooy, (1965), RAI can be used to analyze the frequency and intensity of the dry and rainy years of the study area. Currently, the climate of Benin City has not been assessed adequately by environmentalists on beneficial scientific guidelines (Edema *et al.*, 2015). Specifically, the planning authorities have not considered the essence of rainfall in the city's development process. Hence, the urgent need to bridge this development vacuum based on permanent recognizance, incorporation and utilization of climatic elements. The purpose of this study, therefore, is to conduct a decadal assessment and distribution of rainfall anomaly index from 1991 – 2020 for Benin City, Edo state, Nigeria.

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## METHODS AND METHODS

*Study Areas:* Benin City is located on latitude 06° 19' 00" E to 6° 21' 00" E and longitude 5° 34' 00" E to 5° 44' 00"E with an average elevation of 77.8 m above sea level. Benin City is a pre-colonial city, the capital of the defunct Bendel State and the present-day Edo State. Benin City is underlain by the sedimentary formation of the Miocene-Pleistocene-age often referred to as the Benin formation (Odemerho, 1988). The city is located in the humid tropical rainforest belt of Nigeria with a population of 1,841,084 according to the world population review 2022 with a projected population of about 2.5 million by 2030 at a 3.32% growth rate. The rainy season in Benin begins in March/April and ends in October/November. Rainfalls are of high intensity and usually double maxima with a dry little spell. The map of Benin City is presented in figure 1.

*Data Type and Source:* The study relied primarily on secondary rainfall data of Benin City for 30 years (1990-2020) obtained from NIMET, Airport Station, Benin City. At NIMET Station, observation is made at fixed observing hours. The years were divided into three decadal: The main synoptic hours are 0000 (midnight), 0600 (6am), 1200 (noon) and 1800 (6 pm) Greenwich mean time. Additional observations are made at other times between the four main times, often hourly or at three hours intervals. This procedure is in line with World Meteorological Organization (WMO) standards (WMO, 2008). Daily rainfall, humidity and temperature measurements were taken by NIMET meteorologists and averages were drawn to give daily readings which were inputted as data into the computer for record keeping. The rainfall data of the study area was taken using a rain gauge. The amount of rain that falls at a specified time is expressed as the depth of water it would produce on a large, level impermeable surface. Data were expressed in millimeters. Rainfall measurement is carried out daily. Before rainfall measurements, certain precautions are taken against the effects of obstructions, wind, splashing and evaporation for accurate data collection.

*Data Analysis:* For the study, quality-controlled monthly rainfall data over thirty years (1991–2020) were extracted from the archive of the Nigerian Meteorological Agency (NIMET). The annual rainfall values were computed for the monthly rainfall amount using equation 1.

$$A_R = \frac{1}{12} \sum_{i=1}^{12} R_i \dots \dots \dots 1$$

Where R is the amount of monthly rainfall, i is the months of the year, and AR is the amount of annual

rainfall. The amount of mean monthly rainfall ( $\overline{RR}$ ) for the period under consideration (30 years) was also computed using equation 2, while j is the period of thirty years.

$$\overline{RR}_j = \frac{\sum_{j=1}^{30} R_j}{30} \dots\dots\dots 2$$

To analyze the rainfall data, the study employed basic statistical techniques such as the computation of totals

and means to give meaning to the rainfall data and to have a fair look at the general pattern and characteristics of rainfall in Benin City. Also, the study made use of graphs and charts to explicitly explore the rainfall data. Mean (Average) annual precipitation was then calculated for decadal A (1991 -2000), decadal B (2001 – 2010) and decadal C (2011 – 2020) using Microsoft Excel.



Fig. 1: A Map of Benin City

From the rainfall data, the Annual Rainfall Anomaly Index (RAI) was calculated to analyze the frequency and intensity of the dry and rainy years in the studied area. In addition, the monthly RAI was calculated for specific years of the historical series aiming to analyze the distribution of rainfall in the years of greatest anomaly. RAI, developed and firstly used by Rooy (1965), adapted by Freitas (2005) and Costa and Rodrigues (2017), constitutes the following equations:

$$RAI_p = 3 \left[ \frac{N - \bar{N}}{\bar{M} - \bar{N}} \right] \text{ for positive anomalies} \dots\dots\dots 3$$

$$RAI_n = -3 \left[ \frac{N - \bar{N}}{\bar{X} - \bar{N}} \right] \text{ for negative anomalies} \dots\dots\dots 4$$

Where: N = current monthly/yearly rainfall, in order words, of the month/year when RAI will be generated (mm);  $\bar{N}$ = monthly/yearly average rainfall of the historical series (mm);  $\bar{M}$ = average of the ten highest monthly/yearly precipitations of the historical series (mm);  $\bar{X}$ = average of the ten lowest monthly/ yearly precipitations of the historical series (mm).

Positive anomalies have their values above average and negative anomalies have their values below average.

Table 1: Standard Classification of Rainfall Anomaly Index Intensity

	RAI range	Classification
Rainfall Anomaly Index (RAI)	Above 4	Extremely humid
	2 to 4	Very humid
	0 to 2	Humid
	-2 to 0	Dry
	-4 to -2	Very dry
	Below -4	Extremely dry

Source: Freitas (2005) adapted by Costa and Rodrigues (2017)

## RESULTS AND DISCUSSION

A decadal assessment of the yearly rainfall statistics is presented in Table 2. However, from the temporal-spatial distribution of rainfall in Benin City shown in Figure 2, it is possible to perceive that in decadal A, the rainy season begins in the month of July and lasts until the month of October. Decadal B (Figure 3) follows the same pattern with the rainy seasons beginning in the month of June to October while in decadal C (Figure 4), it can be revealed to begin in the month of May to October. It can be observed that the

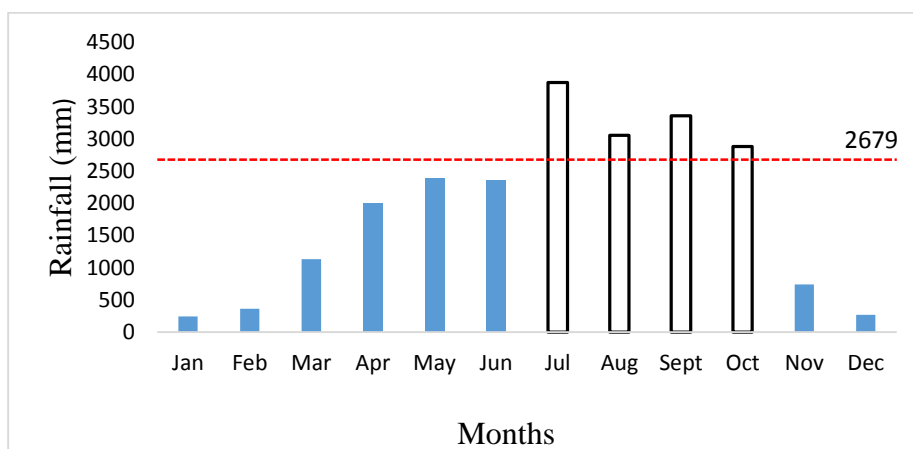
amount of rainfall recorded were higher than the annual rainfall (2679 mm) in Benin City (Fig. 2, 3 and 4). The month of July in decadal A, September in decadal B and also, September in decadal C presented the highest precipitation values, around 3871.6 mm, 3449.8 mm and 3762.8 mm respectively corroborating the report of Floyd *et al.*, (2016). The driest period of the month was observed in decadal A to be from November to June with the minimum precipitation of 244.2 mm, in the month of January (Fig. 2). However, in decadal B, the driest period of the month was from

October to May with December observed to be with the minimum precipitation of 152.5 mm (Fig. 3) while in decadal C, the driest period was from October to April with January (178.5 mm) with the minimum precipitation (Fig. 4). This indicates that there has been an increase in the number of rainy months. This result is in agreement with the report of Egor *et al.*, (2015) that there has been a slight increase in the amount of rainfall received over a period of time in Benin City.

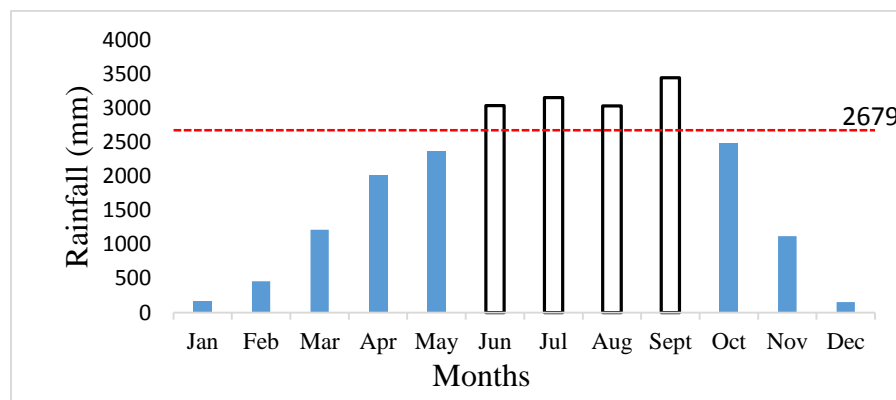
**Table 2:** Yearly descriptive statistics of rainfall for Benin City, Edo State, Nigeria

Decadal A					Decadal B					Decadal C				
Year	Mean	Std. Dev.	CV (%)	RAI	Year	Mean	Std. Dev.	CV (%)	RAI	Year	Mean	Std. Dev.	CV (%)	RAI
1991	216.5	184.7	85.3	1.9	2001	170.2	133.2	78.3	-2.4	2011	207.0	148.5	71.7	1.1
1992	168.0	160.0	95.2	-2.6	2002	213.3	147.4	69.1	1.6	2012	215.7	156.7	72.6	1.8
1993	155.1	114.5	73.9	-3.8	2003	161.5	114.7	71.0	-3.2	2013	220.2	164.5	74.7	2.2
1994	211.0	168.5	79.9	1.4	2004	194.0	148.8	76.7	-0.1	2014	137.3	124.2	90.5	-5.5
1995	222.4	163.8	73.7	2.4	2005	167.8	157.4	93.8	-2.6	2015	220.2	164.5	74.7	2.2
1996	190.5	158.5	83.2	-0.4	2006	196.5	155.2	79.0	0.1	2016	268.1	180.8	67.5	6.5
1997	183.4	96.9	52.9	-1.1	2007	215.9	145.2	67.3	1.9	2017	200.8	134.8	67.1	0.5
1998	168.2	146.3	87.0	-2.5	2008	160.5	125.5	78.2	-3.3	2018	179.6	138.4	77.0	-1.5
1999	185.2	145.1	78.4	-0.9	2009	174.8	106.8	61.1	-1.9	2019	259.0	179.1	69.2	5.7
2000	186.7	134.9	72.3	-0.8	2010	235.6	178.6	75.8	3.6	2020	171.1	118.5	69.3	-2.3

*Note:* Std. dev – Standard Deviation, CV- Coefficient of Variation, RAI – Rainfall Anomaly Index



**Fig. 2:** Climatological distribution of the precipitations for Benin City for decadal A



**Fig. 3:** Climatological distribution of the precipitations for Benin City for decadal B

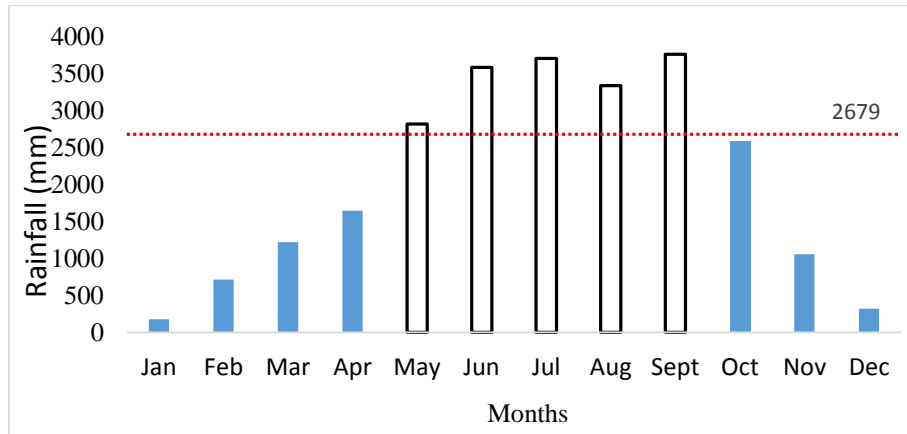


Fig. 4: Climatological distribution of the precipitations for Benin City for decadal C

The drought years and the rainy years, during the period of assessment for each of the decadal can be visualized using Rainfall Anomaly Index (Rai) (Figure 5), enabling us to identify periods where these events were more intense and/or lasting. Decadal A ranges between 1991 and 2000, decadal B 2001 – 2010 while decadal C 2011 – 2020. The positive values observed in Figure 5 represent rainy or wet years and the negative values represent the dry years, with different degrees of intensity. For the whole period under investigation, a total of 14 years were observed to be wet years with most of the rainy years in decadal C while 16 years observed to be dried years (Fig. 5). In decadal A, three (3) rainy years were observed, four (4) were observed in decadal B and seven (7) rainy years were recorded for decadal C. This revealed the increasing trend in rainfall over the years and this corroborates the report of Egor *et al.*, (2015). RAI in decadal A varies from humid to very humid while the

negative RAI varies from very dry to dry. In decadal B, the number of rainy days increased to four (4) varying from humid to very humid while the negative RAI varies from dry to very dry. However, in decadal C, the number of rainy days increased to seven (7) ranging from humid to extremely humid (Figure 5). This is also in agreement with Floyd *et al.*, (2016) who reported significant increasing trend in rainfall between 1981 and 2015 in Benin City. In all the decadal, the periods that remained the longest with droughts were from 1996 to 2000 observed in decadal A (Figure 4). The year 2014 (decadal C) was the year with the highest negative value, with an RAI of -5.47, classified as extremely dry. The year of greatest positive value was 2016 (decadal C), with an average RAI of 6.53 classified as extremely humid. Araujo *et al.*, (2009) and Da Silva *et al.*, (2009) found similar results for the Paraiba river basin of Brazil.

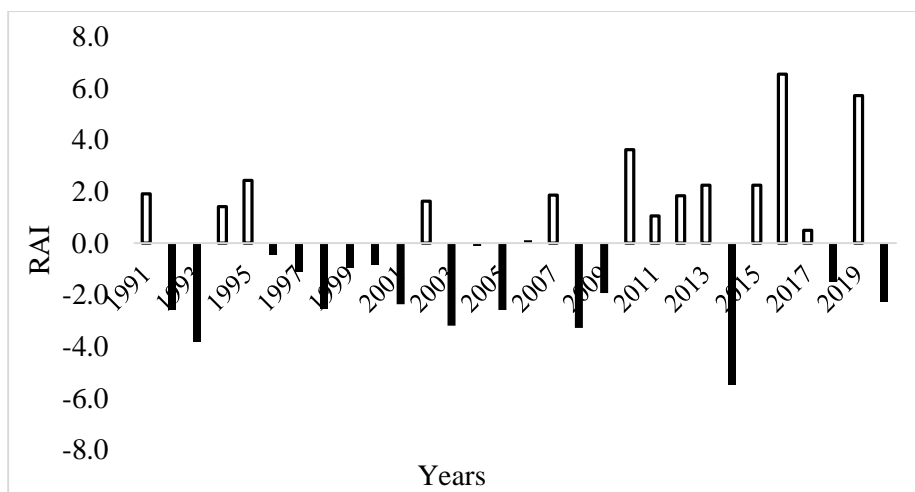


Fig. 5: Rainfall Anomaly Index (RAI) for Benin City, Edo State.

The study reveals over the years there has been a gradual increase in levels of rainfall. The implication of this could be in two forms. The implications could be good for Agriculture, Water Resources and Food Security where farmers would take the advantage of the long growing seasons by adopting multiple cropping systems because of the availability of water while on the other hand, it could lead to soil erosion as well as flooding.

*Conclusions:* The temporal rainfall pattern suggests a fluctuating and significant increase in trend of rainfall over the decades. However, at present, the climate of the City indicates a tendency towards wetter conditions. The implications of the increase in wet conditions for Agriculture and water resources, Livelihood and Food security will certainly be different. Farmers can take the advantage of the long growing seasons by adopting multiple cropping and farming systems. An increase in rainfall means increasing recharge of surface and underground water, creating a favorable condition for irrigation agriculture.

## REFERENCES

- Adefolalu, DO (2007). "Climate change and economic sustainability in Nigeria", Paper presented at the International Conference on Climate Change and Economic Sustainability held at Nnamdi Azikiwe University, Enugu, Nigeria. 12-14 June 2007 pp 1-12.
- Adefolalu, DO; Pam, JL and Habbi, HM (2007). Climate change and safety of air transportation-a Nigerian perspective. In: Proceedings of the international conference on the impacts of extreme weather and climate on socio-economic development in Africa held at the Federal University of Technology, Akure, Nigeria, 11-15 Nov 2007, pp 1-15.
- Adefolalu, DO (1986). Rainfall trends in Nigeria. *Theoretical and Appl. Climat.* 37:205-219.
- Adejuwon, SA (2004). Impact of climate variability and change on crop yield in Nigeria. A paper presented at the stakeholders' workshop on assessment of impacts and adaptation to climate change, (AIACC) conference, Ile-Ife, 15pp.
- Agbola, BS; Ajayi, O; Taiwo, OJ; Wahab, B.W (2012). The August 2011 Flood in Ibadan, Nigeria: Anthropogenic Causes and Consequences. *Int. J. Disaster Risk Sci.* 3(4): 207-217.
- Alcântara, CJ; Rodrigues, P (2017). Space-time distribution of rainfall anomaly index (RAI) for the Salgado Basin, Ceará State –Brazil. *Ciência e Natura*, 39(3): 627-634.
- Araújo, L; Neto, J; Sousa, F (2009). Classificação da precipitação anual e da quadra chuvosa da bacia do rio Paraíba utilizando índice de Anomalia de Chuva (IAC). *Ambiente E Agua - An Interdisciplinary J. of Appl Sci.*, 4: 93-110.
- Dai, A; Lamb, P; Trenberth, K.E; Hulme, M; Jones, PD; Xie, P (2004). The Recent Sahel Drought Is Real. *Int. J of Climat.* 24(11): 1323-1331.
- Da Silva DF; Sousa FA; Kayano MT; Galvêncio, JD (2009). Influência da variabilidade climática global e de suas escalas temporais sobre a precipitação no Alto Mundaú (PE). *Rev. Bras. Geogr. Fís.* 2(3): 64-82.
- Descroix, L; Niang, A; Dacosta, H; Panthou, G; Quantin, G; Diedhiou, A (2013). Evolution des pluies de cumul élevé et recrudescence des crues depuis 1951 dans le bassin du Niger Moyen (Sahel). *Climatologie.* 10: 37-50.
- Descroix, L; Niang, A; Panthou, G, Bodian, A; Sane, Y; Dacosta, H; Malam A; Vandervaere, J; Quantin, G (2015). Évolution récente de la pluviométrie en Afrique de l'ouest à travers deux régions: la Sénégalie et le Bassin du Niger Moyen. *Climatologie.* 12: 25-43.
- Edema, O; Mark, E; Urooj, A; Jamie, B (2015). Climate Change Preparedness: A Knowledge and Attitudes Study in Southern Nigeria. *Environments* 2(4): 435-448
- Fernandes, D; Heinemann, A; Paz, R; Amorim, A; Cardoso, A (2009). Índices para a Quantificação da Seca. Santo Antônio de Goiás, Embrapa Arroz e Feijão, 2009.
- Floyd, AC; Oikpor, R; Ekene, B (2016). An Assessment of Climate Change in Benin City, Edo State, Nigeria. *FUTY J. of Envir.* 10: 87-94.
- Freitas, M (2005). Um sistema de suporte à decisão para o monitoramento de secas meteorológicas em regiões semiáridas. *Rev. Tecnol.* 19: 84-95.
- Ishaya, SI; Abaje, IB (2008). Indigenous people's perception of climate change and adaptation strategies in Jemaa local government area of

- Kaduna State, Nigeria. *J. Geog. Regional Planning*. 1(8): 138-143.
- Le Barbé, L; Lebel, T; Tapsoba, D (2002). Rainfall variability in West Africa during the years 1950–1990. *J. Climate*. 15(2):187–202.
- Odemerho, FO (1988). Benin City: A Case Study of Urban Flood Problems.’ In Sada, P.O. and Odemerho, F. O. (eds) .Environmental Issues and management in Nigerian Development, Evans Brothers, Ibadan.
- Rooy, M (1965). A Rainfall Anomaly Index Independent of Time and Space. Note 14: 43p
- Santos, E, Araújo, L and Marcelino A (2015). Análise climática da Bacia Hidrográfica do Rio Mamanguape. *Rev. Bras. Eng. Agríc. Ambient.* 19(1): 9–14.
- Sighomnou, D; Descroix, L; Genthon, P; Mahe, G; Moussa, IB; Gautier, E; Mamadou, I; Vandervaere, J; Bachir, T; Coulibaly, B; Rajot, J; Issa, OM; Malam Abdou, M; Dessay, N; Delaitre, E; Maïga, OF; Diedhiou, A; Panthou, G; Vischel, T; Yacouba, H; Karambiri, H; Paturel, JE; Diello, P; Mougín, E; Kergoat, L; Hiernaux. P (2013). The 2012 flood in Niamey: a paroxysm of the Sahel paradox? *Sci. Planetary Change. Drought*. 24(1):3-13.
- Spinoni, J; Gustavo, N; Hugo, C; Paulo, B; Jargen, V (2014). World drought frequency, duration and severity for 1951–2010. *Inter. J. Climatol.* 34 (8), 2792–2804.