RUHUNA JOURNAL OF SCIENCE
Vol 9(2): 127-139, December 2018
eISSN: 2536-8400
http://doi.org/10.4038/rjs.v9i2.40

© Faculty of Science
University of Ruhuna

Rainfall trends and variability over Onitsha, Nigeria

A.J. Oloruntade*, K.O. Mogaji and O.B. Imoukhuede

Department of Agricultural and Bio-Environmental Engineering Technology, Rufus Giwa Polytechnic, Owo, Ondo State, Nigeria

*Correspondence: johntades1@yahoo.com; ORCID: 0000-0001-6156-6823

Received: 27th March 2018, Revised: 15th October 2018, Accepted: 25th October 2018

Abstract. Analysis of trend and variability in rainfall can provide the necessary information required for water resources planning and management in any geographical setting. Therefore, the present study applied standard tests to investigate rainfall trends and variability using monthly, seasonal and annual series over Onitsha, Nigeria between 1971 and 2008. Rainfall variability index revealed the year 1983 as the driest (-2.38) and 1997, the wettest (+2.0), with more dry years observed between 2000 and 2008. Variability was relatively low annually as compared to seasonal and monthly series. September (15.8%) has the highest contributions to total annual rainfall, while January contributed the least (0.6%). Seasonally, about 40% of the annual rainfall was received in June-July-August (JJA), while the lowest rainfall was during December-January-February (DJF) (3.75%). Trends were mostly insignificant on monthly basis with 5 of the 12 months exhibiting negative trends, while only January depicted positive significant trend ($p < 0.05$). Similarly, only JJA exhibited insignificant upward trend while other seasons showed downward trends that are also not significant. On the annual basis, an insignificant negative trend was observed for the period under study. Hence, farmers and water resources managers may need to develop appropriate management strategies which include construction of more water storage and diversion structures such as reservoirs and dams to combat recurrent flooding during summer seasons and potential future water scarcity in the area.

Keywords. Onitsha, rainfall, trend analysis, variability index

1 Introduction

Information regarding rainfall trend and variability is an important requirement for the planning and management of water resources. Irrigation planning and management is an area of water resources engineering that requires adequate knowledge of rainfall variation and its temporal pattern. Given that recent changes in climate have intensified global variability of the hydrological cycle, creating uncertainties regarding the prediction of future climatic conditions and the associated impacts, studies of long-term climate series have become increasingly necessary (Houghton *et al.* 1996). Moreover, the planning, design and operation of most water storage reservoirs are based on the historical pattern of water availability, quality and demand, with the assumption of normal climatic behaviour which can no longer hold under a changing climate (Abdul Aziz and Burn 2006). Nevertheless, Oguntunde *et al.* (2011) reported that understanding the behaviour of rainfall as a major component of the hydrological cycle, may be of profound social and economic significance. In this regard, hydrologists and water resources engineers need up-to-date knowledge of the behaviour of rainfall through statistical analysis.

Besides, reported cases of extreme rainfall events such as flood across the country in recent years call for a clear understanding of the variability and trends of rainfall. This is even more important considering the huge socio-economic losses that accompany flood events. For instance, during the flood disaster of the year 2012 alone, a newspaper report showed that properties valued at over 40 billion Naira (219.6 million USD) were lost in about nine local government areas of Kogi State including Lokoja, while the inhabitants of the 332 communities affected by the floods were also put at a further risk of diseases outbreak as a result of their exposure to contaminated water and water-borne pathogens ('The Punch' 2012). Also, for a country where agriculture plays a major role in employment and food availability, meeting rising future demands for food and potable water, requires a more judicious use of water in both irrigated and rain-fed agriculture (Smith 2000). In addition, sustainability of food production will be contingent upon the effective allocation of water resources, given that fresh water for human consumption and agriculture is gradually becoming scarce by the day.

Several studies that have been carried out on rainfall time series across the world show both negative and positive trends. Nevertheless, analysis of trend is a leading step towards attributing changes in climate to such factors as climate variability, greenhouse gases (GHG) and changes in the built-up environment (Blake *et al.* 2011). Many studies have examined the monotonic trend of rainfall and its abrupt changes at different locations across the world (e.g. Xu *et al.* 2010, Wang *et al.* 2011, Anghileri *et al.* 2014). Moreover, analysis of time series at different time scales around the world have revealed that rainfall is either decreasing or increasing, depending on the location (Mondal *et al.* 2012). Shahid (2010) examined the trends of annual and seasonal rainfall of Bangladesh during 1958–2007 period and reported significant increases in the average annual and pre-monsoon rainfall. It was found that while the number of wet months increased, dry months decreased over the greater parts of the country. Jones *et al.* (2015) analysed variability of precipitation in the Upper Tennessee River Basin and observed statistically significant increasing or decreasing trends in 11% of the 78 sub-basins during the 50-year period covered. Although, there were variations in trends of monthly precipitation volumes, significant increases were most pronounced in the summer and autumn. In Europe, an overall insignificant decreasing trend was recorded over the lower altitudes stations in the agricultural zone of Pieria and Aison River basin, Greece, while a decrease of precipitation was detected in spring on the basis of station and regional analysis (Karpouzos *et al.* 2010). However, a few significant positive trends were detected only in remote stations during March, April and October in a study conducted in Turkey by Yavuz and Erdogan (2012) using data from more than 100 gauging stations spanning through the period 1975–2009.

Studies on variability and trend in rainfall at both spatial and temporal scales are not many over Africa and particularly in the West Africa sub-region. Across Nigeria, different trends have been reported by numerous scientists (e.g. Adefolalu 2007, Abaje *et al.* 2010, Akinsanola and Ogunjobi 2014), subject to the agro-climatic zone, while some of the studies have also testified to the occurrence of critical climatic events in forms of flood and drought, which are compatible to the prevailing changes in climate. For instance, Abaje *et al.* (2010) in a study over Kafancha in the Guinea Savanna ecological belt of Nigeria found significantly drier conditions in the months of June and October for the sub-periods 1974-1983 and 1999-2008, respectively. It was further revealed that the reduction in annual rainfall was predominantly as a result of the substantial decline in July, September and October rainfall, which are the critical months for agricultural production in the area. Oguntunde *et al.* (2011) analysed rainfall trends over Nigeria (1900-2000) and reported that about 90% of the entire landscape of the country exhibited negative rainfall trends but only 22% showed significant changes at 5% level. Furthermore, Akinsanola and Ogunjobi (2014) studied rainfall and temperature variability over Nigeria and observed alternately decreasing and increasing trends in mean annual precipitation. However, in view of the geographical diversity of Nigeria, trend analyses that are specific to any sub-regional setting in the country is a worthwhile scientific undertaking. Meanwhile, considering that rain-fed agriculture is important for food production and employment in West Africa, planning of water resources and agricultural projects usually depends on long-term records of many rainfall variables (Tarhule and Woo 1998). Hence, the objective of the present study is to examine trend and variability of rainfall over Onitsha, Nigeria, with a view of suggesting ways for flood mitigation and agricultural water management.

2 Materials and Methods

2.1 The study area

Onitsha is a city in South-Eastern Nigeria located on Latitude 6°10′ N and Longitude 6°47′ E (Figure 1), with a population of about 561,000 (National Population Commission, 2006), spread over a land mass of about 36.19 km^2. It falls within the rain forest belt and it is the last gauging station along the Niger River basin before its final exit to the Atlantic Ocean. The city of Onitsha enjoys the typical tropical climate of Nigeria that is usually influenced by three main wind currents - the tropical maritime (MT) air mass, the tropical continental (CT) air mass and the equatorial easterlies (Ojo, 1977). Rainfall commences around March/April, reaching its peak during July to September and finally stopping in November/December. Mean annual rainfall ranged between 1200 mm and 2000 mm with a maximum temperature of 34.7 °C and a relative humidity of 65%. As the commercial nerve center of the eastern part of the country, both natural landscape and hydrological processes of the city have been severely altered by human activities, which include urbanization, river dredging and road constructions. In recent times, destructive floods of high magnitudes have been recorded in the area which many have attributed to climate and possibly, changes in land use. Apart from the usual buying and selling activities in the city, fishery, agriculture with the cultivation of cassava, maize and other cereal crops form the main livelihoods of the people.

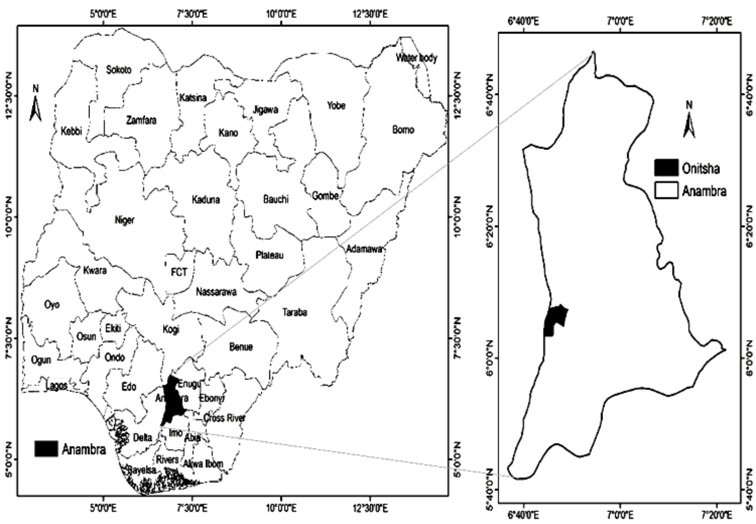

Fig. 1. Map of Nigeria showing Onitsha in Anambra State

2.2 Dataset

This study used rainfall data obtained from the new high resolution Global Gridded rainfall data set (CRU TS 2.1) provided by the Climate Impacts LINK project of Climate Research Unit (CRU), University of East Anglia, UK (Mitchell and Jones, 2005). The CRU dataset comprises of monthly 0.5° latitude/longitude gridded series of climatic parameters over the periods 1901-2008. New *et al.* (2000) and Conway *et al.* (2009) provide in-depth information on the quality control and interpretation of CRU data, given the general poor spatial and temporal coverage of meteorological stations in Africa. Moreover, the CRU dataset is preferred for the present study because it has been used in many previous studies over Nigeria with reliable results (e.g. Oguntunde *et al.* 2011, 2012, Oloruntade *et al.* 2017). Kahya and Kalayci (2004) posited that for a reliable examination of climatic trend, a period of 30 years is usually taken as adequate to arrive at an acceptable conclusion. Hence, the use of 38 year data (1971-2008) is assumed adequate for the present study.

2.3 Data analysis

Exploratory data analysis and descriptive statistics

The use of exploratory data analysis (EDA) helps to gain an understanding of the direction and mode of change in hydro-climatic variables. Apart from the well-known mathematical techniques, it is commonly included in extensive trend detection (Anghileri *et al.* 2014). EDA refers to any technique of data analysis besides formal statistical methods. It employs graphical tools such as time series and scatter plots, and it is intended to ensure improved understanding of the existing data and the fundamental processes involved in its changes. In addition, simple descriptive statistics which include the mean, standard deviation (SD) and coefficient of variation (CV) are also calculated to obtain an initial understanding of the data.

Rainfall variability index

Rainfall index which is computed as the standardized departure of precipitation, helps to categorize the rainfall time series into various climatic periods such as very dry year, normal year and wet or very wet years. It was computed as,

$$\delta_i = (P_i - \mu)/\sigma \qquad (1)$$

where δ_i is rainfall variability index for year i, P_i is annual rainfall for year i, μ and σ are the mean annual rainfall and the standard deviation for the period between 1948 and 2008. Moreover, following the World Meteorological

Organization (WMO 1975), rainfall time series can be classified into various climatic regimes (Table 1).

Table 1. Classification of climate regime based on variability index (WMO 1975)

Performance	Rainfall Regime
$P < \mu - 2.\sigma$	extremely dry
$\mu - 2.\sigma < P < \mu - \sigma$	dry
$\mu - \sigma < P < \mu + \sigma$	normal
$P > \mu + \sigma$	wet

Non-parametric trend test

The rank-based nonparametric Mann–Kendall (M-K) test has been widely used to assess the significance of monotonic trends in hydro-meteorological time series (e.g. Gan 1998, Kumar *et al.* 2010, Anghileri *et al.* 2014). It has been suggested that, for the assessment of trends in climatic data, the M-K test should be applied (WMO 1988). It is commonly chosen above other methods in view of its skill in dealing with non-normally distributed data, outliers and missing values in series and its high asymptotic efficiency (Gan 1998). To estimate the true slope of an existing trend, the Sen's non-parametric technique, well-adjudged for its skillfulness (Zhao *et al.* 2008) as proposed by Sen (1968) was used and more details of the method are given in Xu *et al.* (2007).

Trend free pre-whitening

Application of Mann-Kendall (M–K) test requires that the time series does not contain any serial correlation. Significant positive serial correlation influences the power of M–K and thereby leads to major source of uncertainty. To eliminate or minimize this effect, pre-whitening of the original dataset before using the M–K test is recommended (Abdul Aziz and Burn 2006). The procedure is adequately outlined in Kumar *et al.* (2010) and many other authors. The M–K test was thereafter applied to identify trend in the final (or pre-whitened) series.

3 Results and Discussion

3.1 Summary of EDA and descriptive statistics

Annual and seasonal time series plots depict the pattern of rainfall over Onitsha for the entire period of study (Figure 2). Inspection of the plots revealed a general decline in the annual rainfall over the study period. This indicates a possible drying condition which may cause a reduction in available water in the study area for domestic, industrial and agricultural water uses, most especially irrigated and rain-fed agriculture.

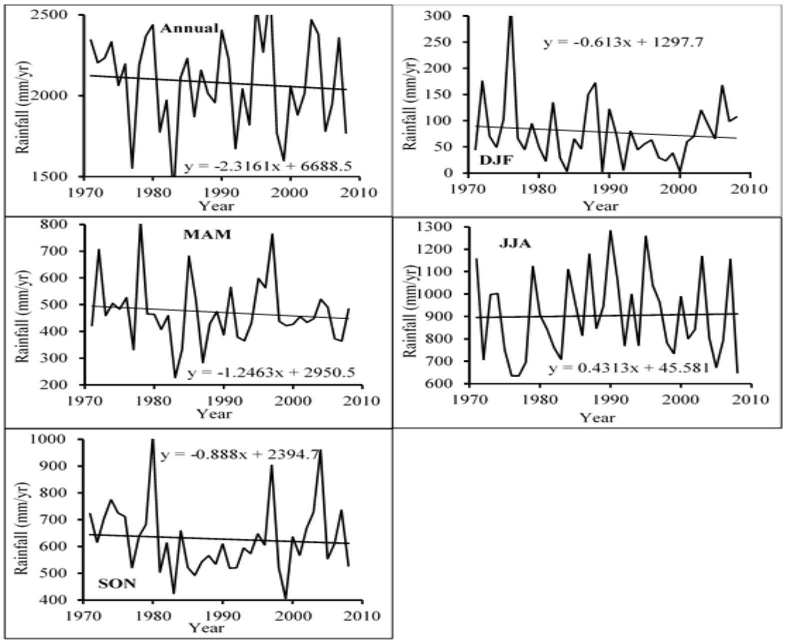

Fig.2. Annual and seasonal time series of rainfall over Onitsha, Nigeria

Muhire *et al.* (2014) suggested that a decline in rainfall leads to a shortage of water for agriculture and, therefore, reduction in crop production. However, to confirm the present level of water availability in the area, additional study which may require further analysis of runoff/ discharge is needed. On the positive side, reduction in annual rainfall can lead to fewer occurrences of flood events. Similarly, when rainfall is considered by seasons, - December-January-February (DJF), March-April-May (MAM), June-July-August (JJA) and September-October-November (SON) – apart from JJA which displayed increasing/positive trend, decreasing rainfall trends have been observed during the remaining seasons. Similar to the present result, Salami *et al.* (2014) had earlier analysed trends in hydro-meteorological variables covering about six stations in Nigeria and found a significant reduction in rainfall and runoff in five stations. Consequently, the study concluded that the reduction may have led to decreasing water resources availability. Nevertheless, increasing summer rainfall exacerbates flooding which can lead to loss of lives and properties, including farmlands (Oloruntade *et al.* 2017). However, the decrease in rainfall was most obvious in annual series followed by MAM, SON and DJF, respectively. Meanwhile, reduction of rainfall during the spring season (MAM) may imply delay in rainfall onset which can also affect the resumption of agricultural activities and shortening of the growing season.

A summary of the descriptive statistic of the long-term (temporal) series also showed that mean monthly rainfall varied from 329 mm/yr (September) to 12 mm/yr (January), seasonal mean ranged from 904 mm/yr (JJA) to 78 mm/yr (DJF), while the annual mean was 2081 mm/yr (Table 2). Likewise, standard deviation (SD) ranged between 117 mm/yr (August) and 18 mm/yr (January), it also hovered between 184 mm/yr (JJA) and 61 mm/yr (DJF), whereas the SD for the annual series was 292 mm/yr. With respect to the monthly coefficient of variation (CV), the highest was 147 % (January) while the lowest was 22% (June), seasonal CV ranged from 79% (DJF) to 20% (JJA), while the annual CV was 14%. The result showed that rainfall has been more varied during the month of January and in the summer (DJF) season. In addition, rainfall variability was higher both on monthly and seasonal bases than inter-annually over Onitsha. This has implications for rain-fed agriculture in the area, as farmers may have to evolve better water resources management plans to ensure sustainable agricultural production. Meanwhile, high rainfall variability will alter the quantity, quality and supply of river water (Wilby *et al.* 2006, Whitehead *et al.* 2009), and can have implications for hydropower generation (Hamududu and Killingtveit 2016, Oliveira *et al.* 2017).

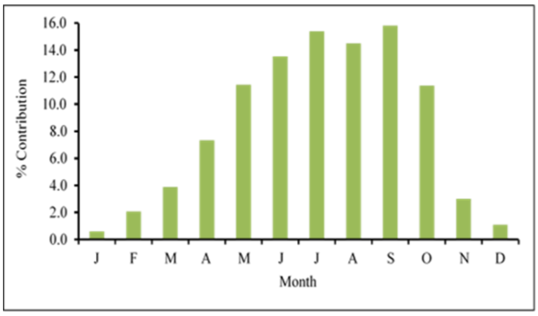

Fig.3. Percentage contribution of monthly rainfall to the annual series over Onitsha, Nigeria

Moreover, the highest monthly contributions to the annual total rainfall (Figure 3) are in September (15.8%), followed by June (15.4%) and August (14.5%). This is contrary to the results of the study by Oloruntade *et al.* (2017) over the Niger-South Basin using similar data (1948-2008), who reported a higher percentage of rainfall contribution from August rainfall as compared to September. However, the present result may be due to the possible delay in rainfall onset in the area which ultimately resulted in the forward shift of the summer rainfall. In addition, annual rainfall was dominated by the amount received between March and November, with about

80% of the rainfall received during the period. Surprisingly, the percentage contribution of February (2.07%) to the annual rainfall is higher than that of January (0.60%), the least amongst the months. On seasonal basis, JJA had about 43.43%, MAM, 22.64%, DJF contributed the least (3.75%), while SON recorded (30.18%). Overall, JJA seasonal intensity dominated the rainfall of the basin on the long-term basis. Hence, it can be concluded that the flood events that have been recorded in the study area during September and October months may have been caused by the high rainfall intensity which usually persists from July to September. Besides, high rainfall variability during the summer months may require additional efforts towards effective strategies for flood mitigation in the area.

3.2 Rainfall variability (δ)

Annual rainfall variability indices covering 1971 to 2008 period are presented in Figure 4. The result show three distinct periods which may be described for the station as: (1) from 1971 to 1982 (12 years) a seemingly random succession of 9 ‘‘normal’’ years, 2 “dry” years and 1 “wet” year, (2) from 1983 to 1998 (16 years), a series of 1 “extremely dry” year, 2 “dry” years, 10 ‘‘normal’’ years, and 3 “wet” years and (3) from 1999 to 2008 (10 years) of 3 “dry” years, 5 ‘‘normal’’ years and 2 “wet” years. The results are in agreement with the findings in earlier studies (e.g. Nicholson *et al.* 2000, Oguntunde *et al.* 2011).

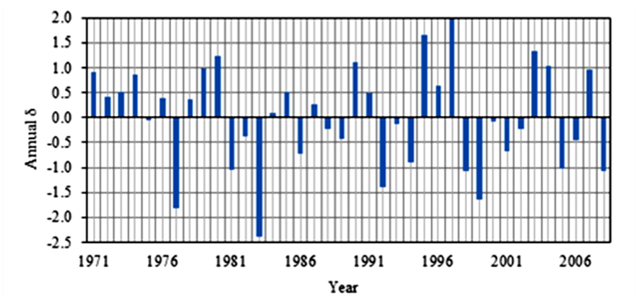

Fig. 4. Annual rainfall variability over Onitsha, Nigeria.

Moreover, following the classification of rainfall regimes by WMO (1975) as shown in Table 1, only 1983 can be classified as “extremely dry” while 7 other years (18%) were “dry” among the 38 years. The “wet” years are 1980, 1990, 1995, 1997, 2003 and 2004 amounting to about 16% of the entire series. On the other hand, the remaining 24 years exhibited “normal” conditions which constituted about 63% of the whole series. The results showed that rainfall has been normal over Onitsha for many years during the period under study and this may likely persist to the future. However, the occurrence of occasional wet years during which rainfall was above normal calls for adequate planning against summer flooding.

3.3 M-K trend analysis

For the analysis of the trend using Mann-Kendall test, a spreadsheet (Makesen 1.0) developed at the Finnish Meteorological Institute (Salmi *et al.* 2002) was used. The results showed insignificant negative trends in five of the 12 months in a year (Table 2).

Table 2. Descriptive statistics and trend test for monthly, seasonal and annual rainfall series over Onitsha.

Rainfall series	Mean (mm/yr)	SD (mm/yr)	CV (%)	Test Z (mm/yr)	M-K (mm/yr)	Change (mm/yr)
January	12.41	18.22	146.79	2.06	**0.15**	5.70
February	43.02	40.71	94.62	-0.82	-0.37	-13.88
March	80.57	44.99	55.84	-0.43	-0.20	-7.60
April	152.62	60.46	39.61	0.00	0.02	0.95
May	237.93	55.37	23.27	-0.98	-0.86	-32.51
June	281.88	62.03	22.00	0.60	0.58	21.92
July	320.17	90.78	28.35	0.38	0.44	16.83
August	301.52	117.05	38.82	-0.68	-1.70	-64.60
September	328.93	90.51	27.52	-0.63	-0.71	-26.93
October	236.73	75.04	31.70	0.25	0.25	9.61
November	62.31	62.89	100.93	1.38	0.61	23.05
December	22.63	30.74	135.88	0.82	0.08	3.17
DJF	78.06	61.45	78.73	-0.03	-0.01	-0.38
MAM	471.12	119.67	25.40	-0.55	-0.88	-33.25
JJA	903.58	184.23	20.39	0.20	0.49	18.63
SON	627.97	130.81	20.83	-0.52	-1.14	-43.46
Annual	2080.73	291.61	14.01	-0.83	-4.00	-152.00

Bold font is significant at $p< 0.05$

Trends slope ranged from 0.61 mm/yr (November) to -1.70 mm/yr (August), but significant ($p< 0.05$) positive trend (slope= 0.15) was observed in January. The magnitude of change ranged between 23.05 mm/yr (November) and -64.60 mm/yr (August). Generally, insignificant trends in either way show that rainfall on monthly basis has been relatively uniform over the period of study. On the seasonal basis, apart from JJA which recorded an upward trend (slope= 0.49 mm/yr), trends in other seasons were downward; however, there was no significant trend in all cases. Insignificant annual rainfall trends may be due to high inter-annual variability. The magnitude of change ranged between -18.63 mm/yr (JJA) and -43.46 mm/yr (MAM). On the annual basis, trend was insignificantly negative (slope = -0.83 mm/yr) and the magnitude of change was -152.00 mm/yr. This shows that over the study area, there has been reduction in the amount of annual rainfall received, indicating a drying condition. Decreasing rainfall trends may lead to depletion in water availability for domestic, agricultural and industrial purposes. This might also cause reduction in the volume of water in surface water bodies such as streams, rivers and lakes in the area, thereby triggering increasing or over-exploitation of groundwater resources. This condition may also hamper river navigation and hence impedes water transportation and conveyance of harvested fishes and other agricultural products. On the other hand, the insignificant upward trend in summer rainfall presents an opportunity for rainwater harvesting which can be utilized for small-scale irrigation farming during the winter season (Goud *et al.* 2015). Miao *et al.* (2012) in a similar study over the tropical climate of Beijing, China observed an increasing summer rainfall.

4 Conclusions

The study investigated trends and variability in monthly, seasonal and annual rainfall time series during the period 1971 to 2008 over Onitsha. The general result of this study indicated that it has been mostly drying over the whole landscape since the previous three decades of the last century and the situation may have continued in the 21st century. Generally, increased rainfall in the summer months especially September has also been persistent with the likelihoods of floods and gully erosion in the area. In this regard, we suggest construction of additional water storage and diversion structures such as reservoirs and dams to mitigate recurrent flooding during summer seasons. Meanwhile, given the projection of the Intergovernmental Panel on Climate Change (IPCC, 2007) for the present century, the decreasing trend observed in this study is attributable to both direct and indirect impacts of climate change. However, in view of the rapid urbanization rates in the study area, the intermittent floods being presently witnessed may have also been hastened by changes in land use/cover. Nevertheless, the results of the present study could serve as a source of information needed by farmers and water resources managers for effective planning and as well provide the basis for in-depth climate change impacts studies on water resources in the area.

Acknowledgements

The authors are grateful to Dr. B. J. Abiodun of Environmental and Geographical Sciences Department, University of Cape Town, South Africa for providing the data used in this study. Comments of anonymous reviewers on the initial manuscript are acknowledged.

References

Abaje IB, Ati OF, Iguisi EO. 2010. An Analysis of Rainfall Trends in Kafanchan, Kaduna State, Nigeria. *Research Journal of Environmental and Earth Sciences* 2 (2): 89-96.

Abdul Aziz OI, Burn DH. 2006. Trends and variability in the hydrological regime of the Mackenzie River Basin. *Journal of Hydrology* 319 (1): 282-294.

Adefolalu DO. 2007. Climate change and economic sustainability in Nigeria. In: Paper presented at the *International Conference on Climate Change and Economic Sustainability* held at Nnamdi Azikiwe University, Enugu, Nigeria, 12–14 June, 2007.

Akinsanola AA, Ogunjobi KO. 2014. Analysis of Rainfall and Temperature Variability over Nigeria. *Global Journal of Human-Social Science (B) Geography,Geo-Sciences, Environmental Disaster Management* 14 (3): 10-28.

Anghileri D, Pianosi F, Soncini-Sessa R. 2014. Trend detection in seasonal data: from hydrology to water resources. *Journal of Hydrology* 511: 171–179.

Blake R, Grimm A, Ichinose T, Horton R, Gaffin S, Jiong S, Bader D, Cecil LD. 2011. *Urban climate: Processes, trends, and projections. Climate Change and Cities: First Assessment Report of the Urban Climate Change Research Network. In:* Rosenzweig C, Solecki WD, Hammer S, Mehrotra AS. Eds., Cambridge University Press, Cambridge, UK, 43–81 pp.

Conway D, Persechino A, Ardoin-Bardin S, Hamandawana H, Dieulin C, Mahé G. 2009. Rainfall and water resources variability in sub-Saharan Africa during the twentieth century. *Journal of Hydrometeorology* 10: 41-59.

Gan TY. 1998. Hydroclimatic trends and possible climatic warming in the Canadian Prairies. *Water Resources Research* 34 (11): 3009–3015.

Goud S, Biradar V, Janagoudar BS, Shanwad UK, Sreenivas AG. 2015. Implications of rainfall distribution pattern and its variability for crop planning of crops: A study in North Eastern transitional zone of Karnataka. *Karnataka Journal of Agricultural Sciences Spl. Issue* 28 (5): 746-752.

Hamududu BH, Killingtveit A. 2016. Hydropower Production in Future Climate Scenarios: the Case for the Zambezi River. *Energies* 9 (502): 1–18.

Houghton JT, Meiro Filho LG, Callander BA, Harris N, Kattenburg A, Maskell K. 1996. *Climate change 1995: the science of climate change*. Climatic Change 584 pp.

IPCC 2007. *IPCC Fourth Assessment Report: Climate Change 2007*. Geneva, Switzerland.

Jones JR, Schwartz JS, Ellis KN, Hathaway JM, Jawdy CM. 2015. Temporal variability of precipitation in the Upper Tennessee Valley. *Journal of Hydrology: Regional Studies* 3: 125-138.

Kahya E, Kalayci, S. 2004. Trend analysis of streamflow in Turkey. *Journal of Hydrology* 289: 128–144.

Karpouzos DK, Kavalieratou S, Babajimopoulos C. 2010. Trend Analysis of Precipitation Data in Pieria region (Greece). *European Water* 30: 31-40.

Kumar V, Jain SK, Singh Y. 2010. Analysis of long-term rainfall trends in India. *Hydrological Sciences Journal* 55: 484–496.

Miao LI, Jun X, Dejuan M. 2012. Long-term Trend Analysis of Seasonal Precipitation for Beijing, China. *Journal of Resources and Ecology* 3 (1): 064-072.

Mitchell TD, Jones PD. 2005. An improved method of constructing a database of monthly climate observations and associated high-resolution grids. *International Journal of Climatology* 25: 693–712.

Mondal A, Kundu S, Mukhopadhyay A. 2012. Rainfall Trend Analysis by Mann-Kendall Test: A Case Study of North-Eastern Part of Cuttack District, Orrissa. *International Journal of Geology, Earth and Environmental Sciences* 2 (1): 70-78.

Muhire I, Ahmed F, Abutaleb K. 2014. Spatio-Temporal Trend Analysis of Projected Temperature and Precipitation Data over Rwanda. *Journal of Meteorology and Climate Science* 12 (1): 70-89.

National Population Commission 2006. The Nigeria Population Commission (NPC) Official Result for 2006 Population and Housing Census Figures, Bureau for National Statistics, Abuja. http://www.nigerianstat.gov.ng, accessed 23rd January, 2016.

New M, Hulme M, Jones PD. 2000. Representing twentieth century space-time climate variability. Part II: Development of a 1961–90 Mean monthly terrestrial climatology. *Journal of Climate* 13: 2217–2238.

Nicholson SE, Some B, Kone B. 2000. An analysis of recent rainfall conditions in West Africa, including the rainy seasons of the 1997 El Nino and the 1998 La Nina years. *Journal of Climate* 13 (14): 2628-2640.

Oguntunde PG, Abiodun BJ, Lischeid G. 2011. Rainfall trends in Nigeria, 1901–2000. *Journal of Hydrology* 411: 207-218.

Oguntunde PG, Abiodun BJ, Lischeid G. 2012. Spatial and temporal temperature trends in Nigeria, 1901–2000. *Meteorology and Atmospheric Physics* 118 (1-2): 95-105.

Oliveira VA, de Mello CR, Viola R, Srinivasan R. 2017. Assessment of climate change impacts on streamflow and hydropower potential in the headwater region of the Grande river basin, Southeastern Brazil. *International Journal of Climatology* 37 (15): 5005-5023.

Oloruntade AJ, Mohammed TA, Aimrun W. 2017. Rainfall Trends in the Niger-South Basin, Nigeria. *Pertanika Journal of Science and Technology* 25 (2): 479 - 496.

Ojo O. 1977. The Climates of West Africa. Heineman, London.

Salmi T, Maatta A, Anttila P, Ruoho-Airola T, Amnell T. 2002. *Detecting Trends of Annual Values of Atmospheric Pollutants by the Mann-Kendall Test and Sen's Slope Estimates*. Publications on Air Quality, No. 31. Helsinki, Finland.

Sen PK. 1968. Estimates of the regression coefficient based on Kendall's tau. *Journal American Statistical Association* 63: 1379-1389.

Shahid S. 2010. Rainfall variability and the trends of wet and dry periods in Bangladesh. *International Journal of Climatology* 30 (15): 2299-2313.

Smith M, 2000. The application of climatic data for planning and management of sustainable rainfed and irrigated crop production. *Agriculture and Forest Meteorology* 103: 99–108.

Tarhule A, Woo MK. 1998. Changes in Rainfall Characteristics in Northern Nigeria. *International Journal of Climatology* 18: 1261-1271.

The Punch 2012. *Kogi lost N40bn to floods*. The Punch Newspaper, 28th September, 2012.

Wang D, Hejazi M, Cai X, Valocchi AJ. 2011. Climate change impact on meteorological, agricultural, and hydrological drought in central Illinois. *Water Resources Research* 47: W09527.

Whitehead PG, Wilby RL, Battarbee RW, Kernan M, Wade AJ. 2009. A review of the potential impacts of climate change on surface water quality. *Hydrological Sciences Journal* 54 (1): 101-123.

Wilby RL, Whitehead PG, Wade AJ, Butterfield D, Davis RJ, Watts G. 2006. Integrated modelling of climate change impacts on water resources and quality in a lowland catchment: River Kennet, UK. *Journal of Hydrology* 330 (1): 204-220.

WMO 1975. *Drought and Agriculture*. WMO/ TN 138, Geneva.

WMO 1988. *Analyzing long time series of hydrological data with respect to climate variability*. World Meteorological Organization: WCAP-3, WMO/TD-No: 224, Switzerland, 1–12 pp.

Xu ZX, Li JY, Liu CM. 2007. Long-term trend analysis for major climate variables in the Yellow River basin. *Hydrological Processes* 21: 1935–1948.

Xu Z, Liu Z, Fu G, Chen Y. 2010. Trends of major hydroclimatic variables in the Tarim River basin during the past 50 years. *Journal of Arid Environment* 74: 256–267.

Yavuz H, Erdogan S. 2012. Spatial Analysis of Monthly and Annual Precipitation Trends in Turkey. *Water Resources Management* 26: 609-621.

Zhao FF, Xu ZX, Huang JX, Li JY. 2008. Monotonic trend and abrupt changes for major climate variables in the headwater catchment of the Yellow River basin. *Hydrological Processes* 22 (23): 4587-4599.