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Examining the variability of rainfall, temperature and runoff data in the Niger and Benue confluence catchment in Lokoja, Kogi State north central, Nigeria

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Abstract
The study examined the influence of climate (rainfall and temperature) variability on the runoff of Rivers Niger and Benue confluence at Lokoja, Kogi state, Nigeria. Remotely sensed climatic data (rainfall and temperature) for 1979-2014 was obtained from global weather data for soil water assessment tools website (SWAT), water runoff data was generated using Soil Conservation Service Curve Number method (SCS-CN), Multivariate statistical techniques were used to analyze the data. The results revealed that rainfall experienced an average decrease of about 462.7 mm while temperature experienced an average increase of about 3.9 ^{0}C. This increase has effect on runoff, and runoff experienced an average decrease of 31.7 m^3/s. The temperature increases the rate of evaporation which helps in reducing the volume of water in the river. The multiple correlation result shows that rainfall and temperature are significantly associated with runoff. The coefficient of multiple determinations (R^2) indicated that 21.6% of the changes in runoff were accounted for by the combination of rainfall and temperature, while the remaining unexplained variations of 86.4% were accountable by other factors not considered in the present study and the research also shows that, the consistency of the findings in affirming previous studies has shown that remotely sensed climatic data can still be considered reliable as data from conventional stations. The study recommended that effort should be put in place to manage the decrease trend in runoff so that it doesn't affect power generation and other usage and also more open, user-friendly data access especially remotely sensed climatic data.

Keywords: Climate, rainfall, temperature, runoff, Kogi

1. Introduction

The fact that climate varies over space and time is no longer being contested, but the major question being asked is the extent to which such variability affects the many processes that control the functioning of the earth (Beyene, 2016) [10]. According to the Intergovernmental Panel on Climate Change (IPCC, 2007) [23], the average global surface temperature increased by 0.74^{0}C over the last 100 years. One major process that greatly controls life on earth and that is easily affected by climate variability is hydrological cycle mainly through changes in precipitation, temperature, and evaporation, and which subsequently influence the spatio-temporal patterns of transport and distribution of runoff, sediment and stream flow (Tianhong and Yuan, 2015) [38]. A number of research workers have shown that climate change significantly alters regional hydrological cycles, with high prospects for occurrence of frequency and severity of extreme climate events like floods and droughts (Huntington, 2006; Bate *et al*., 2008) [17].

Arnell (2014) [2], Babatolu and Akinnubi (2014) [8] have projected that a significant decrease in runoff in Northern and Southern Africa will result due to climate change, while the runoff in eastern Africa and parts of semi-arid and Sub-Sahara Africa is projected to increase in decades to come. Milly *et al.* (2005) [30], Babatolu and Akinnubi (2014) [8] on the other hand projected decrease in runoff for parts of West Africa. The term runoff incorporates the movement of liquid water above and below the surface of the earth (Davie, 2008) [12].

Surface runoff is part of the rainfall that flows over the surface of the soil to the rivers, lakes, and oceans. Runoff mechanisms that contribute to stream flow can be distinguished as overland flow, through flow/lateral flow, and groundwater flow (Davie, 2008) [12]. Overland flow refers to the water that runs across the surface of the land before reaching the stream while lateral flow refers to the water that runs the subsurface, occurs in the shallow subsurface, predominantly, although not always, in the unsaturated zone. Groundwater flow on the other hand occurs on the deeper saturated zone (Ayoade, 2003) [6]. Some of the factors affecting runoff are factors related to climate, particularly rainfall and characteristics of watershed. The rate and volume of runoff is determined by duration, intensity, and distribution of rainfall while characteristics of watershed are shape, morphometry, topography, geology and land use/land cover (Asdak, 1995; Sterling *et al.*, 2013) [3]. The total annual runoff over the land surface is observed to increase as a result of climate change/variation even though there are regions with significant increase and significant decrease in runoff (IPCC, 2007) [23].

The three main factors influencing hydrological cycle are climate (such as temperature and precipitation), basin physical characteristics (such as topography, soil, and vegetation) and human activities (such as rainfed farming, irrigation, groundwater water extraction, dams' constructions, and soil and water conservation). Evidence from different parts of the world have for long demonstrated that climate variability and human activities have been affecting hydrological cycles (Brutsaert and Parlange, 1998; Chiew and McMahon, 2002; Min, 2002; Yang *et al*., 2004; Brown *et al.,* 2005; Huntington, 2006; Guo *et al.,* 2007; Mu *et al*., 2007; Scanlon *et al*., 2007; Ma *et al*., 2008; Guo *et al*., 2008; Milly *et al*., 2008; Ye *et al*., 2009; Zhao *et al*., 2009;) [17, 30]. For example, Brutsaert and Parlange (1998) have shown that global warming has intensified the global hydrological cycle over the recent years. On the other hand, land cover changes, such as deforestation or afforestation, have been shown to have led to increase or decrease in stream flows in different areas (Richey *et al.,* 1989; Fohrer *et al*., 2001; Brown *et al*., 2005). In general, while climate variability has been causing increase in temperature and changes in precipitation patterns throughout the world, human activities have been altering the spatial–temporal distribution of water resources (Jiang *et al*., 2010; Milly *et al*., 2005; Wang *et al*., 2013a) [30]. These have been resulting into occurrences of a number of disasters such as floods and severe drought.

In Yangtse River of China, Piao *et al*. (2010) showed that climate was the dominant factor controlling runoff; increased withdrawals can explain approximately 35% of the declining runoff observed at the Huayuankou station in the lower reaches of Yellow River over the last half-century. However, Wang *et al.* (2006) found that human activities referring to the construction of dams and reservoirs and increasing water consumption were responsible for the decreased streamflow in the River.

In several arid and semi-arid catchments in north China, a number of studies have shown that increased soil and water conservation and water utilisation have caused reduction in streamflow (Li *et al.,* 2007; Wang and Meng, 2008; Liu *et al.,* 2009a) [41].

Studies in Iowa's rivers have shown that increasing agricultural intensity and water utilisation have increased stream discharge, cause reduction in its variance due to the decreasing surface runoff and increasing baseflow and overall significant change in the water cycle of the basin (Schilling, 2004; Tomer *et al.,* 2005; Du *et al.,* 2012). Moreover, water utilization for agricultural and industrial development can also lead to significant change in the water cycle and affect the variation of surface or sub-surface runoff. In Haihe River catchment of China, human activities were estimated to be responsible for the decline in annual water discharge, which accounts for over 50% of runoff reduction, while the contribution of climate change is relatively small (Wang *et al*., 2012).

1.1 Global climate change and variability on water resources

Climate change is the change in meteorological parameters such as temperature, precipitation, humidity, wind and seasons (Salami, *et al*. 2015). Climate observations over the last century have shown that global mean annual surface temperatures have increased by approximately 0.4 to 0.8°C (IPCC, 2001), while mean temperatures over southern Canada rose by an average of 0.9 °C over the period 1900 – 98. These trends are even more pronounced in the North: some parts of the Canadian Arctic (especially in the northwest) warmed by up to 3.0 °C from 1950 to 1998 Pohl, *et al.* (2006). Climate change increases water resources stresses in some parts of the world where runoff decreases, including around the Mediterranean, in parts of Europe, central and southern America, and southern Africa. In other water-stressed parts of the world particularly in southern and eastern Asia, climate change increases runoff, but this may not be very beneficial in practice because the increases tend to come during the wet season and the extra water may not be available during the dry season (Bangash, 2014). Recent studies such as Lebel and Ali (2009), suggest a recovery of the rain in eastern parts of West Africa, whereas drought conditions endure in western regions.

Climate variability is the variations of the normal state and other statistics of the climate on all temporal and spatial scales beyond that of individual weather events. Variability may result from natural internal processes within the climate system (internal variability) or from anthropogenic external forces (external variability) (IPCC 2001, 2005). According to Roudier *et al.* (2014) several studies have shown that discharge evolutions over the past decades in West Africa have been strongly affected by rainfall variations. After the wet 1950s and 1960s, a strong rainfall deficit has been happening since 1970 in the Sahelian and Sudano-Sahelian areas. Roudier, *et al.* (2014) further stated that rainfall variations have led to strong fluctuations in river discharge with a generally negative trend from 1960 to 2010, especially in Sudanian areas. In Guinean areas the decrease has been more moderate. Mahe, *et al.* (2013) [28] supported by Roudier, *et al.* (2014) underlined the nonlinear effect of this rainfall drop over much of West Africa, with a -20% decrease in rainfall resulting in a decrease of -60% in runoff. Ensemble of rainfall-runoff models was calibrated on stream flow data from 1975 to 2007 from 106 gauged catchments distributed throughout the basins of south-western Australia

The sensitivity of runoff to projected changes in mean annual rainfall is examined using the climate 'elasticity' concept. Averaged across the study area, all 15 GCMs project declines in rainfall under all global warming scenarios with a median decline of 8% resulting in a median decline in runoff of 25%. The study further show Strong regional variations in climate sensitivity are found with the proportional decline in runoff greatest in the northern region and the greatest volumetric declines in the wetter basins in the south (Silberstein, *et al.* 2012) [37].

Based on a geographical information system (GIS), and using gauged hydrological data from 2001 to 2010, digital land-use and soil maps from 2005, Soil and Water Assessment Tool (SWAT) model was applied to the Xichuan Watershed typical hilly-gullied area in the Loess Plateau, China to analyzed runoff and sediment yield variations under different precipitation scenarios. The result shows an increase in runoff and sediment with increased precipitation was greater than their decreases with reduced precipitation, and runoff was more sensitive to the variations of precipitation than was sediment yield (Tianhong and Yuan, 2015) [38].

1.2 Rainfall and temperature impact on runoff

Recent study of Tarim River Basin in China shows that the runoff has fluctuated with changes in temperature and precipitation (Zhang *et al*., 2008) [41]. Annual average temperature and precipitation in the Tarim River Basin have increased significantly (Duan *et al*., 2009) [13]. Fan *et al.*, (2011) studied long-term trend of the hydrological time series including temperature, precipitation and stream flow on runoff in the Tarim River during the past 50 years using correlation analysis and partial correlations analysis. Changes of temperature and precipitation had a significant impact on runoff into the four headstreams of the Tarim River: the precipitation had a positive impact on water flow in the Aksu River, Hotan River and Kaidu River, while the temperature had a positive impact on water flow in the Yarkant River. The results of Holt double exponential smoothing showed that the correlation between the independent variable and dependent variable was relatively close after the model was fitted to the headstreams, of which only the runoff and temperature values of Hotan River showed a significant negative correlation.

The runoff over the source areas didn't change obviously since 1950's in the Tarim River but temperature and precipitation increased over the river basin in the 1990s. The increasing amplitude of temperature increases from the source areas to the lower reaches of the river **(**Qing, 2003), but the result of Hao *et al.* (2007) [16] shows that, the runoff in the headstreams increased but that in the main streams decreased significantly during the past 50 years. The former is a response to climate change, and the latter is due to human activities. The surface runoff in the mainstreams decreased by 41.59, 63.77 and 75.15% in the 1970s, 1980s and 1990s, respectively. According to Natural Resources Conservation Service (NRCS, 2004) [40] all types of runoff do not regularly appear on all watersheds. Climate is one indicator of the probability of the types of runoff that will occur in a given watershed.

In arid regions the flow on smaller water sheds is nearly always surface runoff. Subsurface flow is more likely in humid regions. A long succession of storms, however, may produce subsurface flow or changes in base flow even in arid climates, although the probability of this occurring is less in arid than in humid climates (NRCS, 2004) [40].

Niger River runoff is characterized by marked temporal variability which must have obliterated any trend in the long-term. An increasing trend which is insignificant (0.0226) during the long-term period (1955-2010) but significant (0.6762) in the recent period (1981-2010) has been detected. There is high positive correlation between annual rainfalls (0.653) annual heavy rainfall (0.658) with annual runoff while the correlation between annual temperature and annual runoff is significant but negative (-0.325) (Babatolu and Akinnubi, 2014) [8].

1.3 Rainfall and temperature trend analysis

Trends refer to monotonic increase or decrease in average value between the beginning and end of a time series (Giles and Flocas, 1984) [15]. Modarres and Da Silva (2006) [29] used Time-series of annual rainfall, number of rainy-days per year and monthly rainfall of 20 stations to analyzed and assess climate variability in arid and semi-arid regions of Iran. The result shows that, trends were statistically significant mostly during the winter and spring seasons, suggesting a seasonal movement of rainfall concentration. Results also showed that there is no significant climate variability in the arid and semi-arid environments of Iran.

Beyene (2016) [10] analyzed trends in precipitation and temperature at annual, seasonal and monthly time scales for the periods of 1995-2014 for the Illala station which is located in Mekelle Agricultural research Centre, Tigray region in Northern Ethiopia. From the analysis it was found that, the monthly trend of precipitation which was May, June and July have a decreasing trend. While the both maximum and minimum temperature were found on the months of June, September and December the climate trend results showed that there is no negative or positive statistically significant trend in the study area, despite of slight precipitation decrease in the area.

Obasi and Ikubuwaje (2012) [33] studied rainfall and temperature trend in catchment states and stations of the Benin-Owena River Basin, Nigeria. Climatic data of rainfall and temperature for 35years were collected and subjected to cumulative summation (CU-SUM) and the rank-sum tests. The trend analysis in Benin-Owena River Basin shows that as temperature increases there is a corresponding increase in rainfall. According to Obasi and Ikubuwaje (2012) [33], the trend analysis shows that as temperature increases there is a corresponding increase in rainfall. The trend also indicates that no significant departure of the climatic parameters occurred. The least square regression (r2) and the trend as generated from the Microsoft Excel computations show that the temperature variation ranges from 0.4% in Delta to 3.5% in Edo, an indication that the temperature conditions in states understudy are not uniform even though the trend shows an increase.

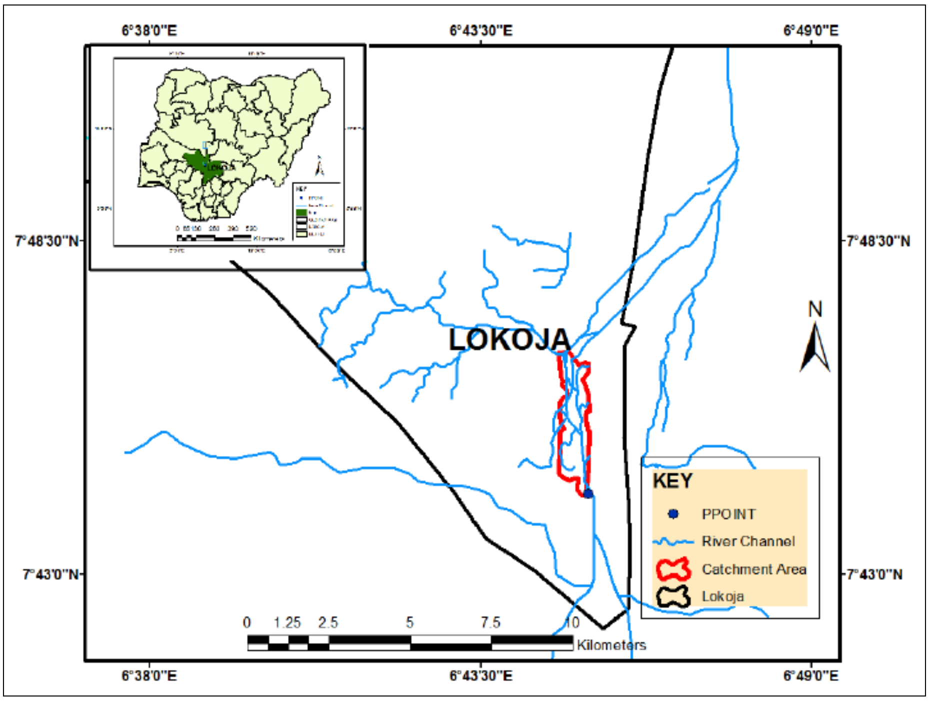
Bose *et al.* (2012) [11] findings revealed that a significant positive increase of 2.16mm in rainfall was recorded in the entire northern Nigeria within the period of 1970 to 2012. It further indicated that majority of the stations revealed an upward trend, with Bauchi, Borno, Kebbi and Sokoto stations showing significant positive trends of 8.13mm, 4.30mm, 4.76mm and 4.42mm respectively and finally concluded that there is high variability in rainfall in the northern Nigeria which signifies a clear evidence of climate change in the region.

With advancement in remotely sensed climatic data, many research works in different parts of the world have assessed the impact of rainfall and temperature on agricultural produce, rivers and run-off. Comparatively, fewer studies are available that analyse rainfall and temperature and also assess the impact of rainfall on surface processes like runoff using an un-gauged station data, remotely sensed climatic data and models. Previous studies on analysis of rainfall variability in Nigeria are mostly on rainfall characteristics and not on runoff. These include the works of (Ayadike (1993) [4]; Olugunorisa and Adejuwon (2003) and Tyubee (2006) [39].

According to (salami, *et al.* 2015) impact of climate change on river Niger is a very crucial issue due to its importance to countries in which it flows through. Olomoda (2011) [36] indicated that since the past five decades, the Niger basin has been affected by series of climatic changes causing extreme low flows along the river. Kingsley *et al.*, (2007) [27] examined the variation of discharge entering the Niger Delta system, 1951–2000. Ayanlade and Odekunle (2009) used satellite images and rainfall data from conventional station, for the periods between 1970 and 2000 to examine and map the spatiotemporal variation in rainfall in Guinea Savannah of Nigeria, Oguntunde *et al.* (2011) studied rainfall trends in Nigeria between 1901–2000, Babatolu and Akinnubi (2014) [8] assess the influence of climate change in Niger River Basin Development Authority Area on Niger Runoff, Salami *et al.*, (2015) assessed the impact of climate change on runoff in the Kainji lake basin of river Niger, they all used data from conventional station in their studies.

2. Study area

River Niger and River Benue confluence lies between latitude 7º 45' 00''N and latitude 8º 12'00''N and longitude 6º 39' 00''E longitude 7º 00' 00''E, in Lokoja (Ijayi *et al.*, 2015). It has an altitude of 45 – 125 meters above sea level (asl) towards the north – west and at the foot of the Patti Ridge, which reaches an altitude of 400m asl. (Ifatimehin, 2009) [19].



Source: Adapted from ASTER (2019)

Fig 1: Map of study area

The area has been inhabited for thousands of years, the present settlement at Lokoja was established in 1857 by the British explorer William Baikie at the site of an earlier model farm constructed during the failed Niger expedition of 1841. Lokoja was the capital of the British Northern Nigeria Protectorate and remained a convenient administrative town for the British colonial government after the amalgamation of Northern and Southern Nigeria in 1914 (Ali, 2008 and Ifatimehin, 2009) [19]. There are extensive flood plains with numerous perennial ponds and marshes on both banks of the rivers before and within the confluence (Ijayi *et al.*, 2015).

Lokoja falls within the tropical savannah climate and the Koppen – Aw climatic group. The averaged total rainfall received over twenty-eight (28) years is 1158.9mm, which the highest concentration of rains is in the month of August and September (Ifatimehin, 2009) [19]. Annual rainfall is between 1016 mm and 1524 with its mean annual temperature not falling below 27^{0}C (Ifatimehin, *et al.* (2009) [19].

Relative humidity is highest through the raining months with a mean value of 822% and 61.1% during the dry season Ogbonna *et al*. (2006) and (Ifatimehin, 2009) [19]. The mean annual humidity is about 70% (Meteorological Department, Federal Ministry of Aviation, 2007). Mean annual temperature oscillates between 26 ºC (July or August) to 35^{oC} in February or March while relative humidity ranges from 50 – 63% (Enokela and Salifu, 2012).

Niger River is 4200 km long from its source in Futa Jalon Plateau to its mouth in the Atlantic ocean; 1200 km of which flows in Nigeria Most of the tributaries of River Niger take their sources from these highlands, The stretch of the river from where it enters Nigeria to Lokoja receives its main supplies of water from rainfall of Upper and Lower Niger Basin Development Authority (U&LNRBDA) area and from such major tributaries as the Kaduna, Kampe, Swashi, Moshi, Awon, Kontagora, Eku, Oshin and Oyun (Babatolu and Akinnubi, 2014) [8]. The river 'loses' nearly two-thirds of its potential flow in the Inner Delta between Ségou and Timbuktu to seepage and evaporation. All the water from the Bani River, which flows into the Delta at Mopti, does not compensate for the 'losses'. The average 'loss' is estimated at about31 km^3/year, but varies considerably between years (FAO, 1997). The river is then joined by various tributaries, but also loses more water to evaporation. The quantity of water entering Nigeria measured in Yola was estimated at 25 km^3/year before the 1980s and at 13.5 km^3/year during the 1980s. The most important tributary of the Niger in Nigeria is the Benue River which merges with the river at Lokoja in Nigeria. The total volume of tributaries in Nigeria is six times higher than the inflow into Nigeria, with a flow near the mouth of the river standing at 177.0 km^3/year before the 1980s and 147.3 km^3/year during the 1980s (FAO, 2015) [14].

Runoff showed dramatic decrease in the period 1971-1993 during which deviation of about 17.9 percent from the long term average was recorded. The low runoff commenced about 1971 and intensified in the 80s. 1994-2010 was another period of high runoff. This high water flow contrasts sharply with the low flow of the 80s. The runoff during this period was 10 percent above the long-term coverage, as shown by Babatolu and Akinnubi (2014) [8].

3. Research methodology

This section presents the sources of material and methods that were used in this study. The major issues presented are data, instruments and software's used for the study, sources of data and data analysis.

3.1 Data, instruments and software used for the study

3.1.1 Data types

Rainfall and temperature for thirty-six years (1979-2014) and Water Runoff for thirty-six years (1979-2014) of the study area.

3.1.2 Sources of data

a. The annual rainfall and temperature for the period of thirty six years (1979-2014) were obtained from Global Weather Data for SWAT (Soil Water Assessment Tools) this is because only thirty six years of rainfall and temperature data were available as at the time of study. The data were collected from two locations around the confluence at Longitude 6.9228 and Latitude 7.9912, Longitude 6.6261 and Latitude 7.5286.
b. The water runoff data was generated using Soil Conservation Service Curve Number method (SCS-CN), this is because the soil conservation service curve number method (SCS-CN) estimates surface runoff from daily rainfall using initial abstractions (surface storage, interception, and infiltration prior to runoff) and a retention parameter which varies with respect to changes in soil, land use management, slope and soil water content (United States Department of Agriculture and Natural Resources Conservation Service, 1999).

This method of estimating direct runoff from rainfall was developed by SCS hydrologists during the early 1950s. The primary uses of such estimate are to establish safe limit for hydrological design and compare the effects of alternative conservation measures in a watershed. Watersheds that Natural Resources Conservation Service (NRCS) are generally concern with a small and unguaged areas (no stream gauge record available or use), thus any runoff procedure should be appropriate for these conditions.

3.2.2. Instrument's and software's used

a. Arc GIS 9.2 for delineating catchment area.
b. Statistical Package for Social Science (SPSS) 23 and Microsoft excel spreadsheet was used to analyze, the mean, standard deviation, correlation analysis.
c. Global Position System (GPS) 60cx for authentication of elevations and locations.

3.3. Data analysis

3.3.1 Preliminary analysis of runoff

3.3.2 Water runoff analysis

The assumption of SCS curve number is that, for a single storm event, potential maximum soil retention is equal to the ratio of direct runoff to available rainfall. This relationship, after algebraic manipulation and inclusion of simplifying assumptions, results in the following expression (USDA-SCS, 1985) and adapted by (De Hamer, *et al.* 2011):

$$Q = \frac{(P-0.2S)^2}{P+0.8S} \qquad \text{…eqn. 1.1}$$

Where;
Q is the direct runoff depth
S is potential maximum retention after runoff beings
P is the total rainfall.
CN is curve number (0.15)
Using the Equation, the depth of runoff for different rainfall is calculated using numerical computation method
The potential maximum soil retention was calculated by using the following formula:

$$S = \frac{1000-10}{CN} \qquad \text{…eqn. 1.2}$$

$$S = \frac{1000-10}{0.1}$$

3.3.3 Multivariate analysis

Multiple correlation coefficient

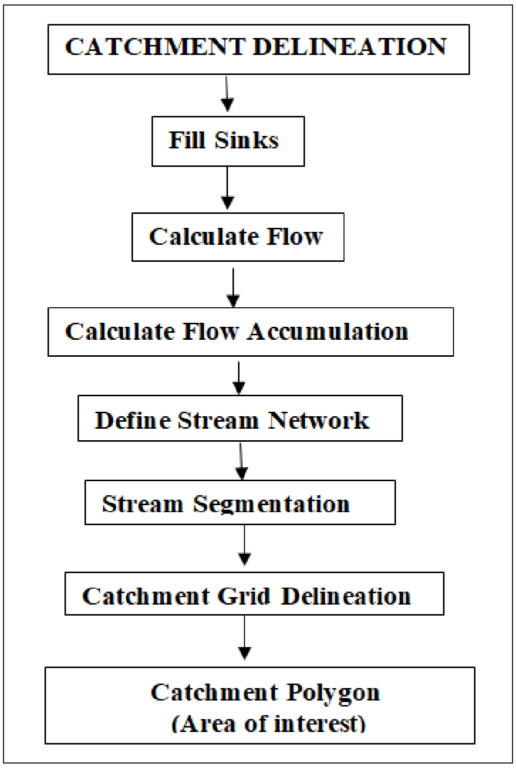
Ayoade (2008) [7] suggested regression analysis and adapted by (Salami *et al.*, 2015), According to Ayoade (2008) [7] it allows us to know the rate of changes of one variable when the other variable is increased or decreased at a given rate. Multiple correlation coefficients were employed in order to determine which of the climatic parameter is more critical to runoff. The climatic parameter is the independent variable whiles the runoff is the dependent variable.
The formular is given by:

$$R = \sqrt{\frac{r^2_{yx_1} + r^2_{yx_2} - 2r_{yx_1}(r_{yx_2})(r_{x_1x_2})}{1 - r^2_{x_1x_2}}} \qquad \text{… eqn. 1.3}$$

Where:
r_{yx1} = correlation coefficient for y and x1
r_{yx2} = correlation coefficient for y and x2
r_{x1x2} = correlation coefficient for x1 and x2

3.3.4 Delineation of drainage networks and catchments

The sequential steps followed in the study for delineation of catchment and stream network using DEM data are presented below Adapted from (Akram *et al.*, 2012):

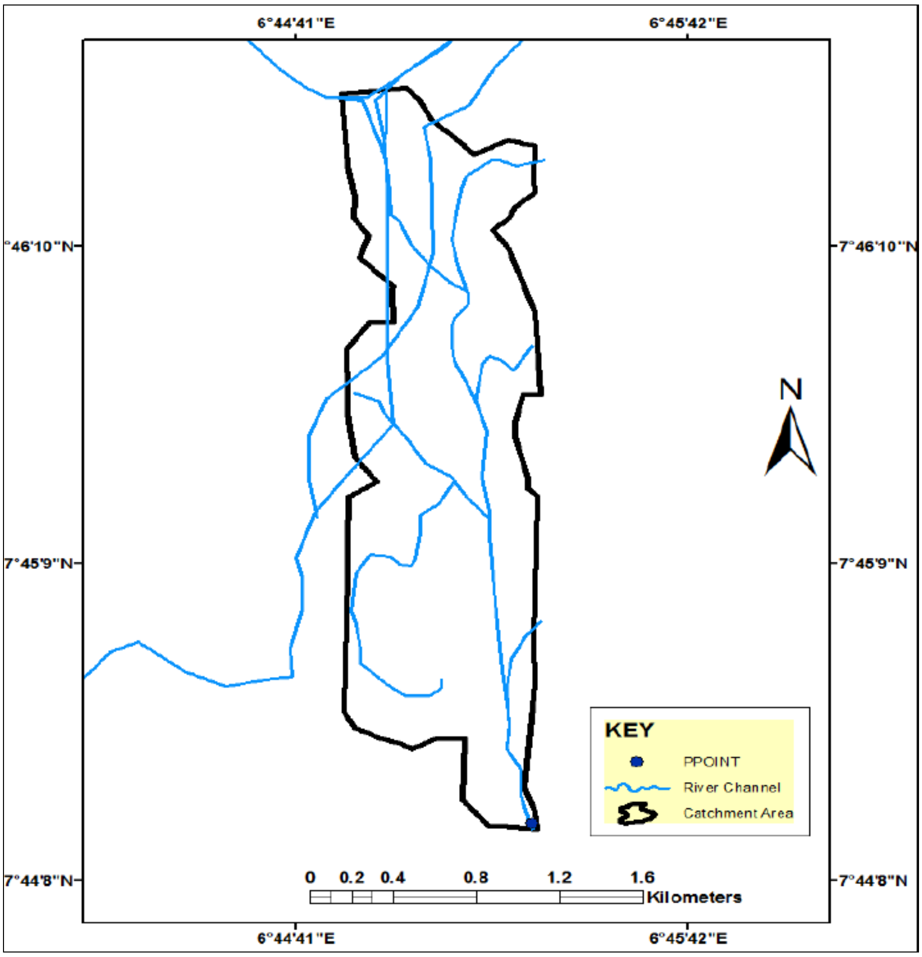


Source: ArcGIS 9.2, 2019

Fig 2: Flow chart of drainage networks and catchments delineation

4. Result presentation and discussion

Discussion results of the findings and interpretation of obtained weather data and runoff in river Niger and Benue confluence in Lokoja.



Source: Adapted from ESRI, 2019

Fig 3: Delineated catchment area of study

Table 1: Annual research data

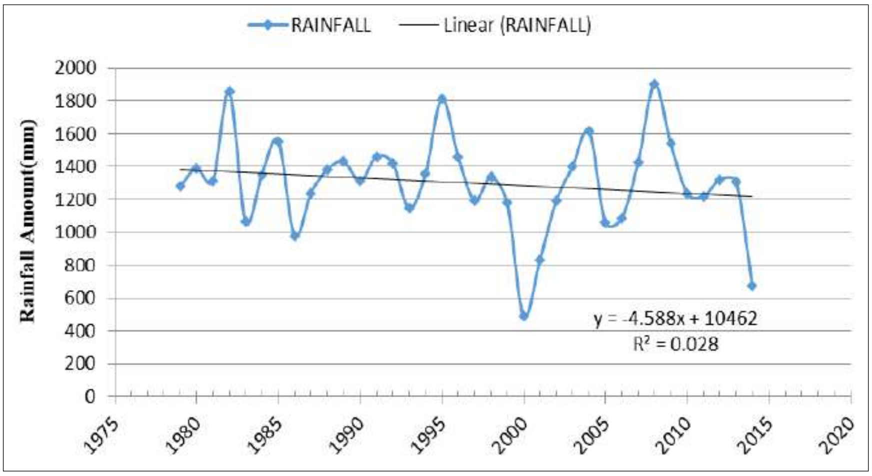
Date	Rainfall (mm)	Temperature (^{0}C)	Runoff (m^3/s)
1979	1282.203172	29	0.1589
1980	1390.011731	29	0.5186
1981	1310.837225	29	0.0613
1982	1859.33172	28	3.8883
1983	1064.495358	29	11.1159
1984	1354.716398	30	0.842
1985	1557.366188	29	7.4454
1986	979.6757955	29	19.5773
1987	1240.516169	30	1.247
1988	1382.342837	29	0.393
1989	1432.29112	28	1.5183
1990	1311.180577	30	0.0581
1991	1462.387598	29	2.5433
1992	1421.939878	28	1.2258
1993	1146.095475	28	5.0674
1994	1355.927485	27	0.073
1995	1816.06422	28	32.9485
1996	1462.229726	27	2.5272
1997	1194.073048	27	2.876
1998	1339.241162	29	0.0102
1999	1178.602131	30	23.5711
2000	489.2705809	31	121.8568
2001	831.612588	30	40.5073
2002	1192.356571	31	5.4602
2003	1400.838465	31	0.0585
2004	1615.931919	32	7.7578
2005	1057.995388	32	16.3453
2006	1083.570439	32	13.8041
2007	1426.828715	31	1.3601
2008	1900.654121	30	44.702
2009	1540.460818	30	6.3905
2010	1239.439793	30	1.2771
2011	1219.029112	30	1.9159
2012	1323.352959	25	0.0088
2013	1306.196189	29	0.0928
2014	673.1391359	30	72.1525

Source: Global weather data for swat 2019

4.1 Trend in rainfall amount

The trend and annual variability in rainfall amount from 1979 to 2014 in Lokoja is shown in Figure 3. It shows that in 1979, the annual amount of rainfall recorded was 1282mm; this amount increased by 7.8% after 10 years to 1382.343mm in 1988 and thereafter decreased to 1194.073mm in 1997, since then it began to show slight decrease by 10.1% in 2006. After this period, the amount of rainfall received in Lokoja decreased steadily and in 2014, a total of 673.1391mm of rain was received, the trend in rainfall amount in Lokoja indicated that rainfall showed yearly variability with 2008 recording the highest amount followed by 1982 and then 1995, while the lowest rainfall amount was recorded in 2000 followed closely by 2014. The study therefore shows that 2008 was the wettest year, while 2000 had the most rainfall deficit year. Furthermore, the information presented in Figure 3 showed that from 1979–2014; rainfall amount in Lokoja showed a decreasing trend due to the yearly variability in rainfall amounts. The straight line equation of the time series yielded= - 4.588x + 10462 for thirty-six (36) years. The trend analysis indicates the rainfall amount over 36 years showed a slight downward trend slight decrease in rainfall in the study area as indicated in Figure 3.

The lowest record was in the year 2000 when it recorded 489mm and 2014 which recorded 673mm, this result affirmed Ayanlade and Odekunle (2009) studies of Shaki, Lokoja, Ogoja and Minna using GIS approach in assessing seasonal rainfall variability in Guinea savannah part of Nigeria, which findings shows that the annual rainfall has been fluctuating overtime at a decreasing trend, rainfall in the guineasavannah also varies both in time and space in the guinea savannah which include the confluence, that shows anomalies (such as decline in annual rainfall, change in the peak and retreat of rainfall and false start of rainfall) can also be detrimental to crop germination and yield, resulting in little or no harvest at the end of the season in the study area (Ayanlade and Odekunle, 2009).

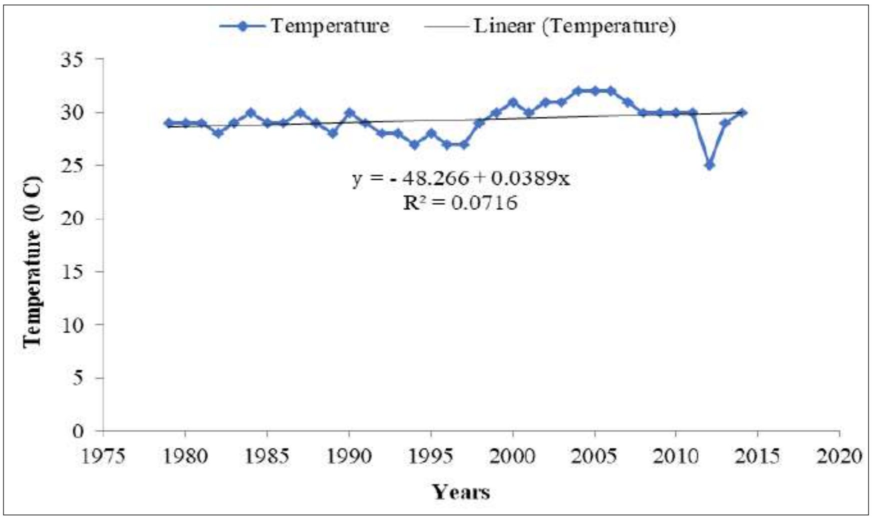


Source: Data analysis (2019)

Fig 4: Trend in rainfall amount from 1979 to 2014

4.2 Trend in temperature

The trend in temperature from 1979 to 2014 in Lokoja showed apparent variability as shown in Figure 4. It shows that from 1979 to 1981, temperature amount in Lokoja remained constant at 29^0C. The value decreased in 1982 to 28^0C and in 1987 and 1990 the value increased to 30^0C. Thereafter, temperature value continued to oscillate from 27 to 29^0C. Increased in temperature values above 30^0C were recorded in 2001 and 2002 with values of 31^0C. From 2000 to 2006, temperature in Lokoja increased from 29^0C to 32^0C being years of highest temperature regimes in the area. After these two years, temperature began to decrease from 31^0C in 2007 to 30^0C in 2011. The lowest temperature amount of 25^0C was recorded in 2012; this value increased to 29^0C in 2014 and thereafter, it increased to 30^0C. The trend in temperature amount in Lokoja indicated showed yearly variability with 2000, 2002, 2003 and 2007 recording the highest amount, while the lowest rainfall amount was recorded in 2012. The study therefore shows that 2000, 2002, 2003 and 2007 were the hottest years, while 2012 had the coldest year. Also, the result in Figure 4 showed that from 1979 – 2014; temperature in Lokoja showed an increasing trend. It therefore showed from 1979 – 2014 temperature increased by 3.4%.

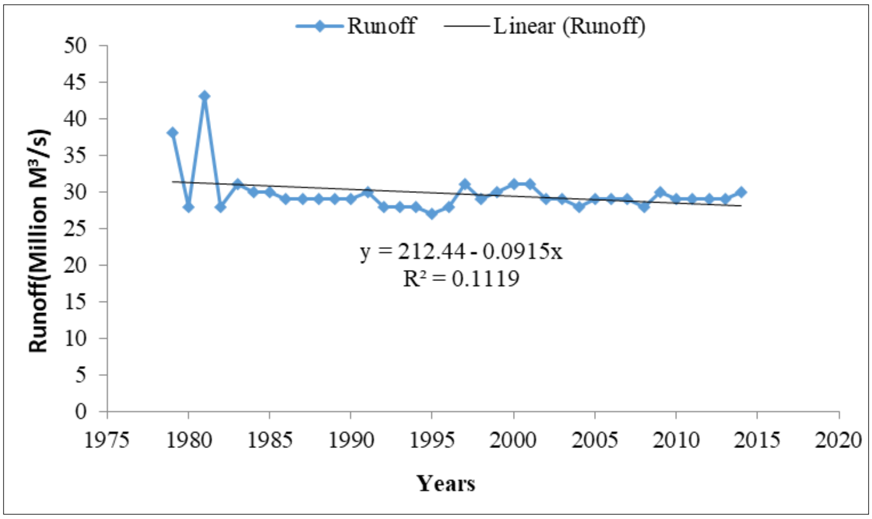


Source: Data analysis (2019)

Fig 5: Trend in temperature from 1979 to 2014

4.3 Trend in runoff in Lokoja

The trend in runoff amount from 1979 to 2014 is presented in Figure 5. It showed that in 1979, the total amount of runoff recorded was $38m^3/s$; this runoff amount decreased to $41m^3/s$ in 1981 and later decreased to 28 m^3/s in 1982. From 1983 to 1996, there was a slight decrease in runoff amount received or recorded in the area ranging from 27 to $31m^3/s$. Thereafter runoff amount continued to oscillate and the values remained between $28m^3/s$ and 31 m^3/s. The trend in runoff amount showed that runoff recorded in the area sharply decreased by 21.1% for 36 years. The trend in runoff amount showed yearly variability with the highest runoff event recorded in 1981 (43 m^3/s), this was closely followed by 1979 with annual runoff value of $38m^3/s$, while the lowest annual runoff event was recorded in 1995 with annual runoff values of 27 m^3/s. Information in Figure 5 showed that from 1979-2014 runoff amount in Lokoja depicted a downward trend implying reduction in runoff event over time. The decrease in runoff amount over time in the area may be attributed to de decline in rainfall amount.



Source: Data analysis (2019)

Fig 6: Total runoff trend from 1979 to 2014

4.4.1 Analysis of significant trend of rainfall

Data on rainfall amount was taken from 1979 to 2014. The linear trend for rainfall is mathematically defined thus:

$RF_t = \beta_0 + \beta_1 t$ …eqn. 4.1

Where
RF_t = linear trend forecast in period t (Rainfall)
β_0 = intercept of the linear trend line
β_1 = slope of the linear trend line (regression coefficient) and
t = time period (1979 to 2014)

The test statistic result in Table 1 showed that the slope of the trend (β_1) is non-zero which implied that there was a linear trend in rainfall, but the trend is not significant (t = 0.977, p>0.05). The linear trend equation of rainfall for 36 years or over time is given as follows:

$RF_t = 1385.37 - 4.627t$ …eqn. 4.2

The slope of -4.627 further indicated that for the past 36 years, rainfall experienced an average decrease amount of about 462.7mm. This decrease has effect on runoff, which was affirmed by (Olaniran, 2002) [35] whom reported the widespread decrease in rainfall of the order of 4.9-14.7% over entire Niger basin during the 1980s which also led to a corresponding decrease of 20.4-35.8% in runoff over the entire basin (Abaje, *et al.*, 2010) shown decline in the annual rainfall yield of Kafanchan, Kaduna state which vegetation of the area is the Guinea Savanna type; and thearea is designated as Koppen's Aw climate of Nigeria (Abaje, *et al.*, 2010) which alsois responsible, in broader terms, for the low levels of water in hydroelectricity power (HEP) generating dams (Kainji, Shiroro and Jebba) which are all located along river Niger (Olaniran, 2002) [35].

Table 2: Summary of linear regression result for rainfall

Variable	Coefficients		
	b	β	t-value
Year	-4.627	-	0.977
Test results			
F- value	0.954		
R	0.165		
R2	0.027		
Constant	1385.37		14.038*
Std Error	288.38		

Source: Data analysis (2019)
*Significant at 5% significance level

Also, the linear trend for temperature is mathematically defined thus:

$T_t = \beta_0 + \beta_1 t$ …eqn. 4.3

Where:
T_t = linear trend forecast in period t (Temperature)
β_0 = intercept of the linear trend line
β_1 = slope of the linear trend line (regression coefficient) and
t = time period (1979 to 2014)

The test statistic result in Table 2 also showed that the slope of the trend (β_1) is non-zero which meant that there was a linear trend in temperature, but the trend is not significant (t = 1.574, p>0.05). The linear trend equation of temperature over time is given as follows:

$T_t = 28.628 + 0.039t$ …eqn 4.4

The slope of 0.039 indicated that for 36 years, temperature experienced an average change increase in amount of about 3.9^0C. This increase also has effect on runoff, but Obasi and Ikubuwaje (2012) [33] results shows that, the trend analysis of temperature and rainfall in nine (9) cities of Nigeria namely Plateau, Delta, Edo, Lagos, Ondo, Kano, Borno, Niger and Zaria for 36 years show that as temperature increases there is a corresponding increase in rainfall in those part of Nigeria.

Table 3: Summary of linear regression result for temperature

Variable	Coefficients		
	b	**β**	**t-value**
Year	0.039	0.261	1.574
Test results			
F- value	2.478		
R	0.261		
R2	0.068		
Constant	28.628		55.795*
Std Error	1.499		

*Significant at 5% significance level i.
Source: Data analysis (2019)

The results in Tables 1 and 2 gives answer to the first research question and shows that there are changes in rainfall and temperature trend, but the trends are not significant in the study area for the past 36 years (1979 – 2014). This is so as the slopes of the trends (β_1) are non-zero.

4.4.2 Influence of rainfall and temperature on runoff ii.

The joint influence of rainfall and temperature on runoff is determined. In order to perform this analysis satisfactorily, the logarithmic conversion method was employed to transform the variables to make them suitable for regression analysis (Rosenberg, 1997). The multiple regression model is mathematically presented as:

$$Y = a + b_iX_1 + b_2X_2 \qquad \text{….eqn 4.7}$$

Where:
Y = LogRunoff
X_1 = Lograinfall
X_2 = Logtemperature
$b_1 – b_2$ = regression coefficients
a = is Y-intercept

The result of the multivariate regression analysis is presented in Table 4. The result showed there was a low multiple correlation (0.464) between rainfall, temperature and runoff. The coefficient of multiple determination (R^2) indicated that 21.6% of the changes in runoff was accounted for by the combination of rainfall and temperature, while the remaining unexplained variation of 78.4% were accountable by other factors not considered in the present study. What this means is that, rainfall and temperature are not the only factors that influence runoff. However, the ANOVA result indicated that rainfall and temperature had significant influence on runoff in the study area ($F = 4.553$, $P<0.05$). This decision is consequent upon the probability value of 0.018 being lower than 5% significance level. The signs of the regression coefficients showed that temperature was negatively related to runoff, while rainfall is positively related to runoff. The negative sign indicated decrease in the runoff in the area with the increase in temperature and vice versa, while the positive sign indicated increase in runoff with the increase in rainfall. Furthermore, information on the significance of the predictor variables indicated that none of the two predictors (rainfall and temperature) exerted significant influence on runoff. The standardized regression coefficient for rainfall shows that a unit increase in rainfall holding temperature constant will result in 26.6% increase in runoff, while a unit increase in temperature holding rainfall constant will be about 31.7m^3/s decrease in runoff. Based on the level of explanations, the result therefore recognized temperature as a significant determinant of runoff in the area followed by rainfall which could lead to water crises (Ye, *et al* 2013). This result is consistent with the findings of Iwara (2014) [25] who identified rainfall as a potent factor responsible for runoff experienced in fallow vegetation, which causes loss in surface nutrient in liquid and solid bound forms.

Table 4: Summary of multiple regression analysis of influence of rainfall and temperature on runoff

Predictor variables	Coefficients		
	b	**β**	**t-value**
Log rainfall	2.529	0.266	1.688
Log temperature	-14.760	-0.317	1.981
Test results			
F- value	4.533*		
R	0.464		
R2	0.216		
Constant Std error	13.524 0.978		1.042

*Significant at 5% significance level
Source: Data Analysis (2018)

4.4.3 Joint influence of rainfall, rainfall frequency and temperature on runoff

Multiple regression analysis was employed after logarithmic conversion was performed on the time series data. The multiple regression model is mathematically presented as:

$$Y = a + b_iX_1 + b_2X_2 + b_3X_3 \qquad \text{…eqn. 4.8}$$

Where:
Y = Runoff
X_1 = Rainfall (mm)
X_2 = Rainfall frequency (numerical)
X_3 = Temperature (^{0} C)
$b_1 – b_3$ = Regression coefficients
a = is Y-intercept

Table 5: Summary of multiple regression analysis on joint influence of rainfall, rainfall frequency and temperature on runoff

Predictor variables	Coefficients		
	b	**B**	**t-value**
Log rainfall	2.514	0.265	1.633
Log Rainfall frequency	0.314	0.037	0.234
Log temperature	-14.762	0.317	1.953
Test results			
F- value	2.954*		
R	0.466		
R2	0.217		
Constant	-14.325		1.053
Std. error	0.993		

*Significant at 5% significance level

Result of multivariate regression analysis is presented in Table 5. It showed that 21.7% ($R^2 = 0.217$) of the variability in runoff amount was accountable by the joint influence of rainfall, rainfall frequency and temperature. The ANOVA result indicated that rainfall, rainfall frequency and temperature have significant influence on runoff amount ($F = 2.954$, $P<0.05$). This result obtained therefore shows that runoff in the study area is principally influenced by rainfall, rainfall frequency and temperature. This implies that these three factors constitute the main challenges affecting runoff in the study location. The signs of the regression coefficients showed that temperature was negatively related to runoff, while rainfall and rainfall frequency were positively related. The negative sign indicated decrease in the runoff in the area with the increase in temperature and vice versa, while the positive sign indicated increase in runoff with the increase in rainfall and rainfall frequency. Information on the significance of the predictor variables indicates that the three predictor variables individually did not exert significant influence on runoff amount (Table 5). However, the strength of each predictor is ranked using the product of standardized regression coefficients (beta). From these results, temperature was observed to exert the most influence on runoff amount; this was followed by relative frequency, while rainfall amount happened to be the least factor that exercised immense influence on runoff amount.

5. Conclusion and recommendations

Conclusively, the research has showed that, the confluence of rivers Niger and Benue for the past 36 years had experienced decrease in amount of about 462.7mm, temperature experienced an average increase of 3.9^0C and also changes in rainfall and temperature trend, but the trends are not significant in the study area while runoff experienced an average decrease of 31.7% downward pattern around the studied rivers for the past 36 years (1979 – 2014). The coefficient of multiple determination (R^2) indicated that 13.6% of the changes in runoff was accounted for by the combination of rainfall and temperature, while the remaining unexplained variation of 86.4% were accountable by other factors not considered in the present study. The consistency of the findings in affirming previous studies has shown that remotely sensed climatic data can still be considered reliable as data from conventional stations. Also in this study, remotely climatic data has made crucial contributions to our understanding of the climate system and its variations. Although the shortness of satellite time series and associated uncertainties (such as undetected drifts in sensor sensitivity have been cited as the main reason for the apparent spectrum of change) expressed by some researchers have so farlimited the detection of robust long-term trends in some climate variables, however, the recent progress made in both instrumentation and retrieval, accompanied by the accumulation of satellite records, can help to remedy this.

The research proffered the following recommendations; That 13.6% of the changes in runoff was accounted for by the combination of rainfall and temperature, further study should be carried out to determine the remaining unexplained variation of 86.4% which were not accounted for and also not considered in the present study, Future studies should assess in detail to high and low flow variations, which are fundamental for agriculture, fisheries and dams, since the rivers are seasonal. There is also need to take into account in future studies, the other factors influencing runoff, especially water and land use changes, in order to be able to guide water managers on better adaptation strategies

As the users of climatic data in the scientific community and the public are rapidly increasing in number, there is need for a new paradigm of more open, user-friendly data access to ensure that society can reduce vulnerability to climate variability and change.

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