African Journal of Engineering Research
Vol. 6(3), pp. 55-63, December 2018
DOI: 10.30918/AJER.63.18.028
ISSN: 2354-2144
Full Length Research Paper

Rainfall variation, water resources potential and implication for flooding: A case study of catchment area of major tributaries to River Benue in Taraba State

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Accepted 23 November, 2018

ABSTRACT

Rainfall is one of the most frequently discussed of all climatic variables in the tropics. This is because in conditions of reasonable uniform high temperature, it is rainfall that, by its presence or absence, scarcity or extremity, reliability or variability, determines the seasons, production or failure of crops, vulnerability of a place and directly or indirectly potential of water resources. Below or above normal rainfall, both have implications on agricultural sector and the stakeholders in the state. To fully exploit the potential of the water resources and to checkmate the excess from Lagdo dam in the state, the federal government has embarked on the building of a buffer (Kashimbilla dam). Using rainfall data for Jalingo, Gassol, Donga and Gembu for the period of 1979-2015 an attempt is made to establish the changing rainfall pattern and surface water potential in some selected catchment areas on Upper Benue River Basin in Taraba. The data were subjected to descriptive and trend analyses. The result shows that, except in Gembu, rainfall generally in the study area have been sporadic but with increasing insignificant upward trend. Inter annual variability was low. Annual rainfall coefficient of variation ranges from 2.3% in Donga to 17.5% in Gassol. Low values of coefficients are indicative of higher rainfall reliability and more dependability distribution. However when this resource is not properly managed and coordinated can serve as resistance bringing disaster. It is recommended that even though there may be some individual whom government must have been issued certificate of occupancies but fall within the risk of equal or greater than 50 years recurrence interval flood should be revoked, there properties acquired and they be relocated and resettled. Beyond the embankment should be under restriction for re-allocation strictly for dry season farming (Fadama). This when fully harnessed could bring bumper harvest and the world will see that Taraba is truly nature's gift to Nigeria.

Keywords: Rainfall variation, water resources potentials, flooding, Taraba, catchment area.

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INTRODUCTION

It is no longer news that climate is changing and that its impact know no boundary. No sector of the economy is spared. The influence is seen in many sectors of life. Its effect on water resources potential is of two fold. Water resources are scarce in many regions while some loom in floods. Regions with normal rainfall and thus adequate water resources are now having rainfall deficit (Deve, 2000). While aridity is spreading its tentacle, some areas submergence is the case.

The study area receives continual rainfall reduction in major parts of the zone. In a preliminary study by Adebayo (2012), cessation date of rainfall exhibits downward trend in all stations except Gembu. This downward trend is an indication that rains now end earlier than normal in the state. This also means that the length of raining season is decreasing in all that state but ironically the area is always victim of flood disaster. At the time of writing this report as already declared by NEMA, nine out of the sixteen local government areas of the state are already counting their losses. The communities include among others Lau, Karim-Lamido, Ardo-Kola, Gassol, Wukari and Ibi. The memoir of some respondents of the account of flood event of 2005 and 2011 is still fresh. A family recurs in anguish. The River Basin was affected by heavy rainfall culminating to flash floods on 7^{th} August 2005 and 11^{th} August 2011. These events in the past had gross economic consequence on the people of the state. The former truncated interstate movement and paralyzed economic and social activities. Again this year on 2^{nd} of June 2018, it watched away the Maraban Gassol Bridge disconnecting the state from the rest of the nation rendering thousands of passengers' stranded (Figure 1). It now part of life that after heavy down pour to see houses floating on water for hours (Figure 2). These scenarios of extreme events demonstrated the fragility of our socio-economic systems and the extent to which these systems depend on weather and climate. Although it is difficult to attribute to climate change and variability alone to the devastating impacts of recent natural disasters in many parts of the country Nigeria, natural disaster documented of resent, such as Lagos flood of July 10, 2011, Ibadan flood of August 26, 2011, Sokoto, Kebbi, Kastina and Jigawa floods of September 2010, Ogun flood of October 2010 and recently wide spread of flooding in the country in 2012 have demonstrated that many urban areas are highly vulnerable to climate change and vulnerability (Okoloye et al., 2014).

Converting resistance to resource is expedient in the face of climate change and vulnerability context. Deve (2000) declared that effective management of this resource germane if disaster is to be avoided and this can only be possible if rainfall seasonal prediction is given the attention it deserves. This however calls for continuous assessment of the basin.

Several studies have stressed the necessity of management of water resources in Nigeria (Kowal and Adeoye, 1972; Orkuma, 1997; Deve, 2000; Ojo et al., 2003; Adelalu, 2012). However, much is still required for water availability studies of river basins at local level in arid and semi-arid region especially as aridity is spreading its tentacles and the population soars. Cohen (1985), in his write up on impact of carbon dioxide induced climatic change argued that we must broaden the scope of climatic impact studies so as to include other sectors of the economy, such as water resources. Adewumi (2013) declared that where these changes are not met with complementary planning and management measures, challenges such as water pollution, unstable food production, high risk disaster (flood) are unavoidable, particularly along the river banks.

The present study aimed to investigate the trends of rainfall and surface water potential in some selected catchment areas on Upper Benue River Basin in Taraba.

Figure 1. Bridge collapse at Maraban Gassol in Taraba State.

Figure 2. A cross section of Mayo Dassa on July 31, 2017 after heavy downpour.

METHODOLOGY

Study area

The study area encompasses major River Benue tributaries in Taraba State. Taraba State is located at the north eastern part of Nigeria. It lies between latitude 6°30′ and 9°30′ north of equator and between longitude 9°00′ and 12°00′ east of the Greenwich Meridian (Figure 3). It is bordered on the north by Bauchi and Gombe states, on the east by Adamawa state, on the south by Cameroun, and on the west by Benue, Nassarawa, and Plateau. The area is characterized by a tropical wet and dry climate. While the wet season last for about 7 months the dry season is in the neighbourhood of 5 months with a mean annual rainfall which ranges from 800 mm in the northern part of the state to over 2000 mm in the southern part (Adebayo, 2012). The state depicts nine different soil types (Adelalu, 2018). Among these are Numic Nitosols, Lithosols, Fluvisols, Ferric Luvisols and Ferric Acrisols. More than half of the land areas of the study catchments support Acrisol. Acrisols form an old landscape, as classified by the Food and Agriculture Organization. It is a clay-rich, and is associated with humid, tropical climates. Next to this soil type is Lithosols. This is a shallow soil consisting partially weathered rock (parent material). Just like pave cement, it neither hold runoff nor support serious infiltration (Nicholas et al., 2015), and this type of soil account for about 30% of the catchments terrain in the study area.

The land area has three major tributaries to River Benue: River Lamurde, River Gassol and River Donga. There exist twenty-two sub basins in the study area and these sub basins network with these three rivers drained a total area of about 4,435,921.6 hectares having perimeter of about 945.5 miles (Adelalu, 2018). River Lamurde has extensive flood plain on both sides of the river. The northern bank of the river is heavily encroached by residential settlements irrespective of the devastating effects of recent floods in the area while the southern parts are notable cultivated. The river is characterized by several minor catchments of about 118,121.5 hectares (Adelalu, 2018). Among these are Upper Selbe and Upper Kam (Adebayo and Bashir, 2005). The catchment with perimeter of about 920,379.7 hectares drained about 1,435,938.3 hectares (Adelalu, 2018). The drainage encompasses seven major towns in the middle region of the State before emptying to River Benue at the Western part of the State. The towns include Serti-Baruwa, Sarki Ruwa, Karamti, Jamtari, Gangumi, Gayam and Bali. River Donga is characterized by several minor catchments of about 1,135,497.8 hectares (Adelalu, 2018). These Sub Basins include among others Ntum, Luggungo, Mbaso, Ngo. Its sources are from Tsabga hill, which has an altitude range of 4,500 to 5,000 meters above sea level (Adebayo and Bashir, 2005). It flows southwest to other parts of the State with a volumetric flow remaining considerable even in the low water period (Adebayo and Bashir, 2005). This makes these area water resources potential for socio-economic development. However if not properly harness can boost vulnerability of such area to flooding. River Donga drains five local governments in Southern Taraba before emptying to River Benue at the Western part of the State. The LGA which are drained include Kurmi, Ussa, Takum, Wukari, and Donga. These areas are potential to flooding but could be potent when impaired by encroachment through human activities along the bank. More so, the Donga system according to Adebayo and Bashir (2005), have several minor catchment basins characterized by

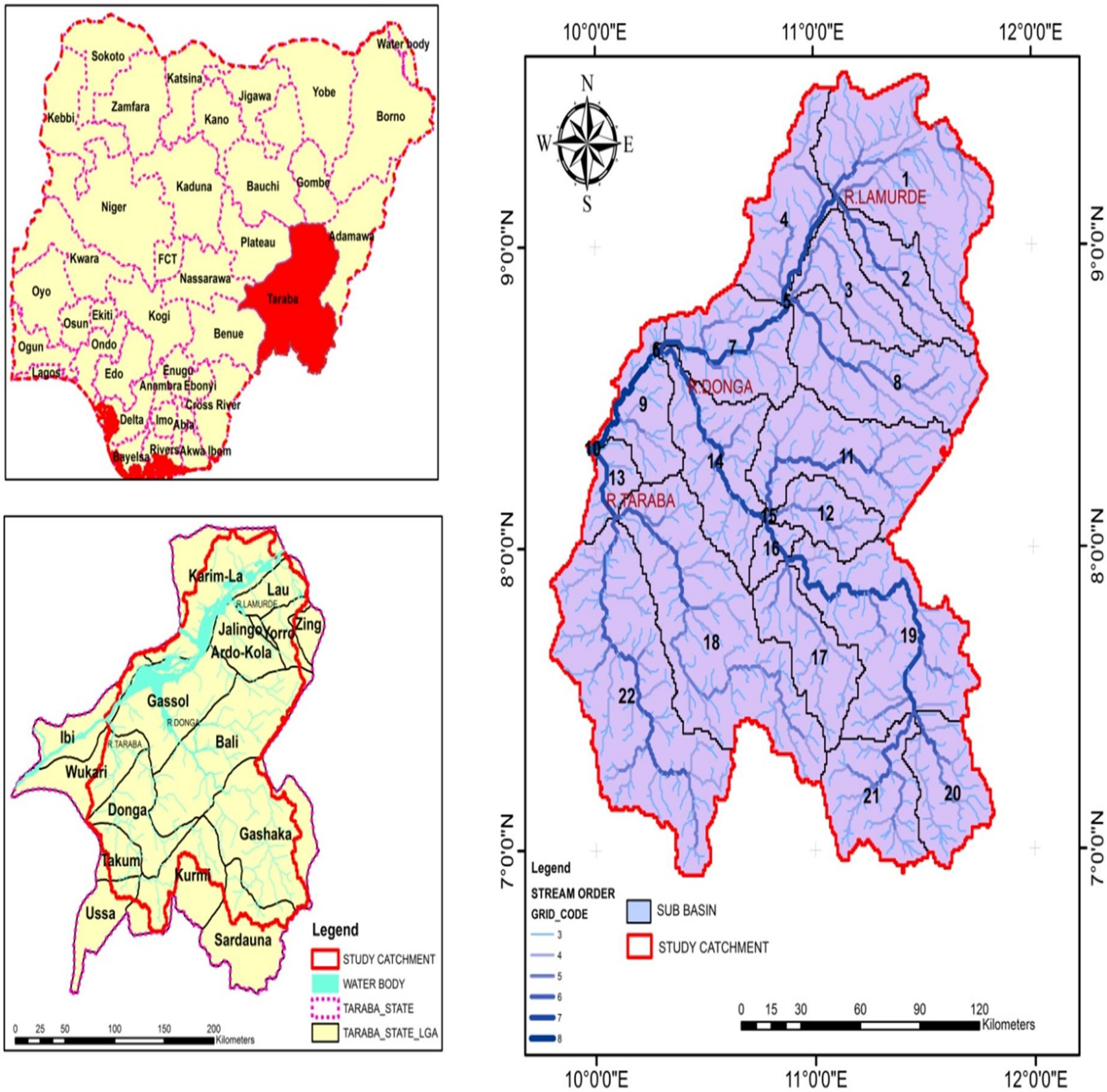

Figure 3. The study area showing catchment and drainage pattern.

rising water volume which can cause back flow and consequently propel flooding of several places in the region.

Data collection and analysis

Monthly rainfall data from 1979 to 2015 was obtained from Upper Benue River Basin (UBRB) for Gassol. For river Lamurde Rainfall data with consideration for the roof (Gembu) and the floor of the study area (Jalingo, Gassol, and Donga) were obtained. For River Donga, with hydrological stations in three places (Tepkwar, Gindin-Doruwa and Donga) but insufficient rainfall data, little adjustment was made. Rainfall for this zone was extracted from rainfall simulation of the area using downloaded surface rainfall data from usgs.worldclim.data base. Lack of sufficient, accurate and consistence data is a major limitation of this study. Missing data in the data sets were filled using linear interpolation and the Ordinary Least Squares methods. In summary the data used and their sources are in table below. Figure 3 shows the location of the catchment areas and the drainage pattern.

To establish extent, distribution and variation from particular year to another in rainfall, rainfall and water level data were subjected to trend analysis and some statistical techniques such as measures of central tendency and dispersion. The monthly rainfall data were used in calculating the mean monthly and annual rainfall for the stations under consideration (Table 1). The overall trend of sequence of the data was carried out by fitting a

Table 1. Data types and sources.

S/N	Type		Format	Date	Source
1	Rainfall	Jalingo (R/Lamurde)	Analogue	1979-2015	COA/TSU
		Gassol (R/Taraba)	Analogue	1979-2015	UBRB
		Donga (R/Donga)	Digital	2015-2016	usgs.worldclim.data
		Gembu	Analogue	1979-2015	UBRB
2	Runoff	Gassol	Analogue	1979-2015	UBRB
		Donga	Analogue	1979-2015	

straight line by least-squares regression to the data points.

RESULTS AND DISCUSSION

Summary of rainfall and runoff variation

In this work, statistical techniques of central tendency and measure of dispersion were used to establish rainfall and discharge distribution and variation from particular year to another. Result shows that the highest annual rainfall event ever recorded over the period under study was in Gembu as expected and the least from Jalingo. The mean annual rainfall values for Donga, Jalingo, Gassol and Gembu are 2102.2, 1060.9, 1010.1 and 1859.0 mm, respectively (Tables 2 and 3). Months of August and September were identified as with heaviest rainfall. The maximum annual rainfall ranges from 2198.0 mm in Donga, 1541.0 in Jalingo, 1286 and 1458.3 mm in Gassol to 2663.0 mm in Gembu.

It can be inferred from the result that the highest annual rainfall event ever recorded over the period under study was in Gembu as expected and the least from Jalingo. Gembu located on the Mambilla plateau recorded the maximum highest total daily and annual rainfall and the minimum at Jalingo which is located at the Northern part of the state. Umar et al. (2015) has noted that in most parts of the Sudano-Sahelian region of Nigeria, months of August still remained the rainiest month and that most seasonal floods in the region are likely to occur in the month of August or September. This is likely also very true in the study area because past record of farm flush, building and bridge collapse had been in Month of August or September. However early this month of June this year, the nation had already registered two federal roads been cut off as a result of flood: One in Moukua LGA, Niger State and one in Taraba, Gassol LGA.

Table 2. Summaries of the results obtained from rainfall data and runoff (1979-2015).

	Stations	Location		Mean	S.D	Minimum	Maximum	CV (%)
		Long	Lat					
Rainfall (mm)	Gassol	10.5° E	8.4° N	1010.1	177.1	674.2	1458.3	17.5
	Gembu	11.2° E	6.7° N	1859.0	285.6	1347.0	2663.0	15.4
	Jalingo	8.5° E	11.1° N	1060.9	135.8	862.0	1541.0	12.8
	Donga	10.0° E	7.7° N	2102.2	50.3	1935.7	2198.0	2.3

Table 3. Summaries of the results obtained from runoff data (1979-2015).

	Stations	Location		Mean	S.D	Minimum	Maximum	CV (%)
		Long	Long					
Run off (M)	Donga	10.0° E	7.7° N	1123.4	3.01	1112.9	1129.3	0.2
	Gassol (Tella)	10.5° E	8.4° N	1331.0	6.38	1311.0	1341.5	0.5

Trend of rainfall events

The rainfall over the study area for the period under study varied from 2663.0 mm over Gembu to 1458.3 mm over Gassol. For Gembu, the highest value of 2663.0 mm was recorded in 2007 and the lowest value of 1347.0 mm was recorded in 1988 (Figure 4). The 1677 mm of rain in 2006 increased to 2663 mm in 2007 with 221.9 mm of the

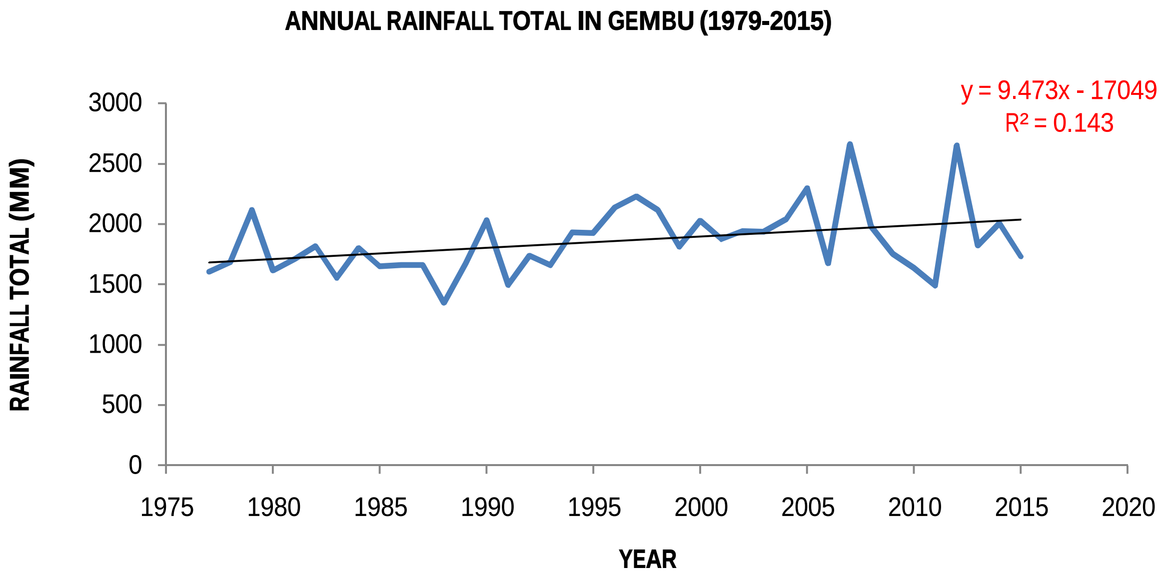

Figure 4. Trend of Gembu rainfall.

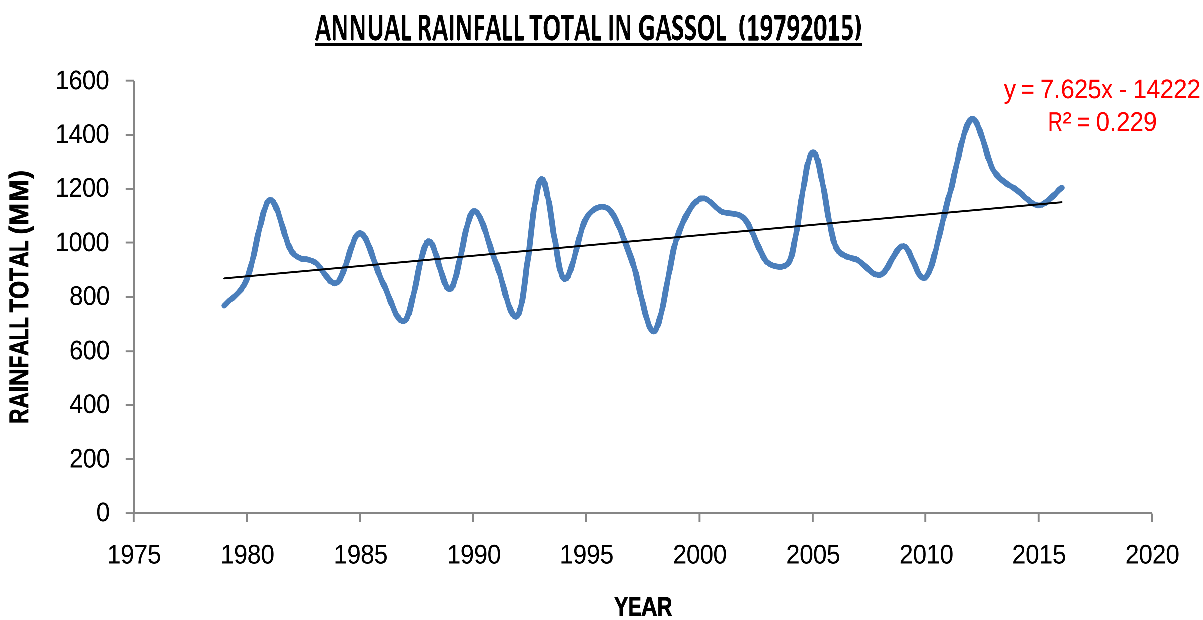

Figure 5. Trend of Gassol rainfall.

amount in September alone. In 2011, 1488.3 mm of rainfall was recorded in this station as against 2650.0 mm in 2012. Over Gassol, the highest rainfall was 1458.3 mm. This was captured in 2012 while the lowest value of 674.2 mm was recorded in 1998. There was also a notable limp from 2010 with 874.2 mm rainfall to 1458.3 mm in 2012 (Figure 5). Jalingo recorded 862.0 mm of rain in 1982 and 1541.0 mm in 2012. For the other years, the rainfall was generally 1060.9 mm (Figure 6).

Every year there is incremental depth of 9.47 mm in Gembu, 7.63 mm in Gassol, 2.36 mm in Jalingo while we have less than 1 mm in Lau. R-Factor in all the stations is very low. R-Factor shows the contribution of other climatic variables to the distribution. This suggests that Sunshine, Wind, Humidity etc contribute 14.3, 22.9, 32.8, 16.6% to the rainfall distribution in Gembu, Gassol Donga, Jalingo respectively (Figure 7). This study has found out that except for Gembu, rainfall, generally in the study area, have been sporadic but with increasing insignificant upward trend. Inter annual variability was low. Annual rainfall coefficient of variation ranges from 2.3% in Donga to 17.5% in Gassol. This finding concurs

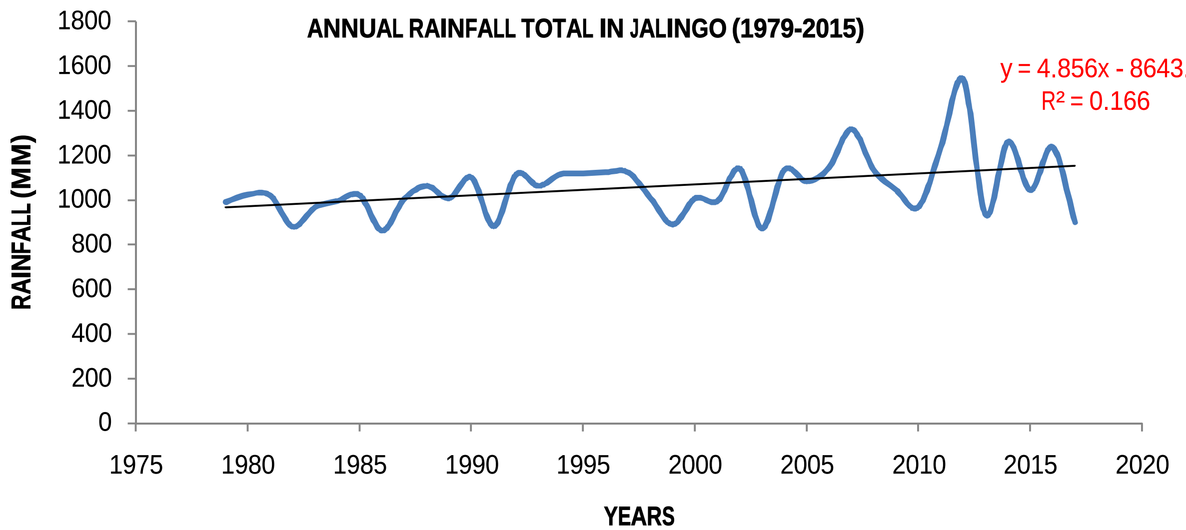

Figure 6. Trend of Jalingo rainfall.

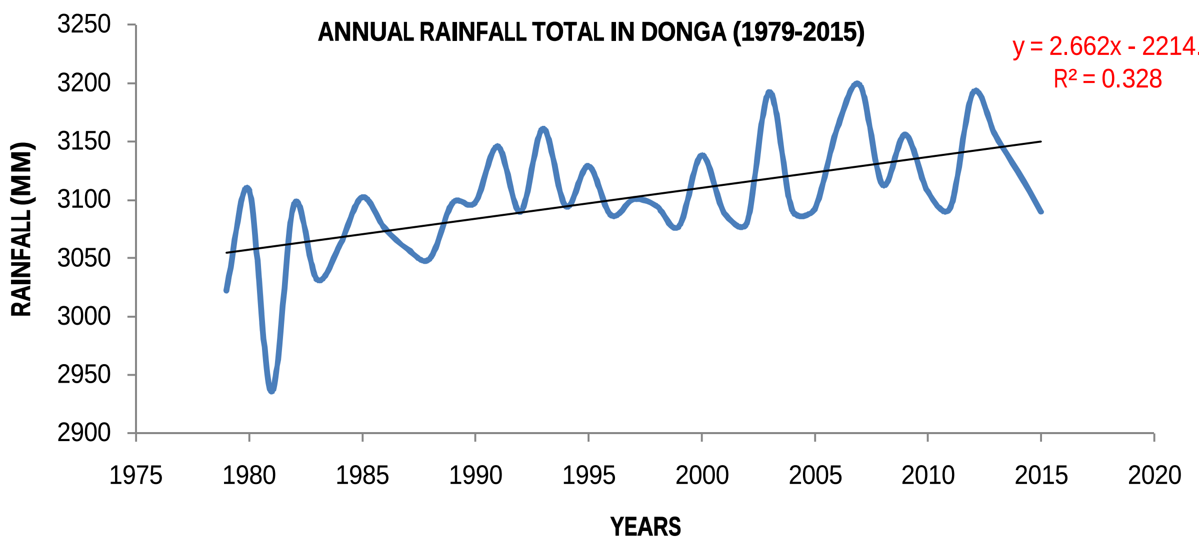

Figure 7. Trend of Donga rainfall.

with the finding of Olubunmi et al. (2015). Low values of coefficients are indicative of higher rainfall reliability and more dependability rainfall distribution (Nsubuga et al., 2013). However when this resource is not properly managed and coordinated can serve as resistance bringing disaster as in the case in many area of the globe.

Rainfall and runoff anomalies in the study areas

This section discusses deviation of extreme rainfall and runoff events from the mean. The graphs highlight the years which are colder/warmer and dryer/wetter (than normal) over the study area, with an obvious linkage to potentially higher flood hazard.

Rainfall anomalies in Gembu, Gassol, Donga, and Jalingo (1979-2015)

Most notable thing and general to all the locations is the erratic pattern of rainfall both in space and time. Except in 1980 and 1990, Gembu received below normal from the 1979 to 1994. For other years except in 2007 and 2011 rainfall was generally some units above normal. Gassol rainfall as shown in fig. 18 was below normal in the late 70s, 80s and early 90s except in 1981 and 1991.The same trend was also observed in Donga and Jalingo. Rainfall over Donga, from 1979 to 2000, except in 1991 and 1993, were deficit. Lau exhibited decadal oscillation from deficit (1979 to 1989) and surplus (1989 to 1999). It seems dry periods are matched by wet ones to give a close to average overall outcome in the region. All stations from 2002 generally have rainfall surplus. Except in Gembu, 2012 remains the wettest year in all the study locations and this period correspond to the year of great disaster in the state.

The result of standardized runoff anomaly seems not to show a drastic change over time in Gassol. It is obvious a below normal runoff precedes a surplus runoff. In this region also, the runoff is not solely affected by the amount of water available from the rain. This is established by the sharp contrast in rainfall excess of 1982, 1991, 1997 and 2000 and the expected turn out from runoff. However from 2006, even though there was no significant increase in rainfall in the region, every extreme event receives more than corresponding rainfall output leading to very wet years (Figure 8). At the lower latitude in Donga, runoff from the early years (1979 to 1999) the region had rainfall below normal (dry years). Other years, though there are intermittent deficit for instance, 1993, 1997-1999, 2001-2003, 2005-2006, 2010-2011 and 2015 recorded runoff excess (wet years) (Figure 9). Olubunmi et al. (2015) have attributed wet years of these regimes to the significant northward incursion of the ITD. This implies that the residential tenure of ITD in a location is a function of the allocation of rainfall total in the place.

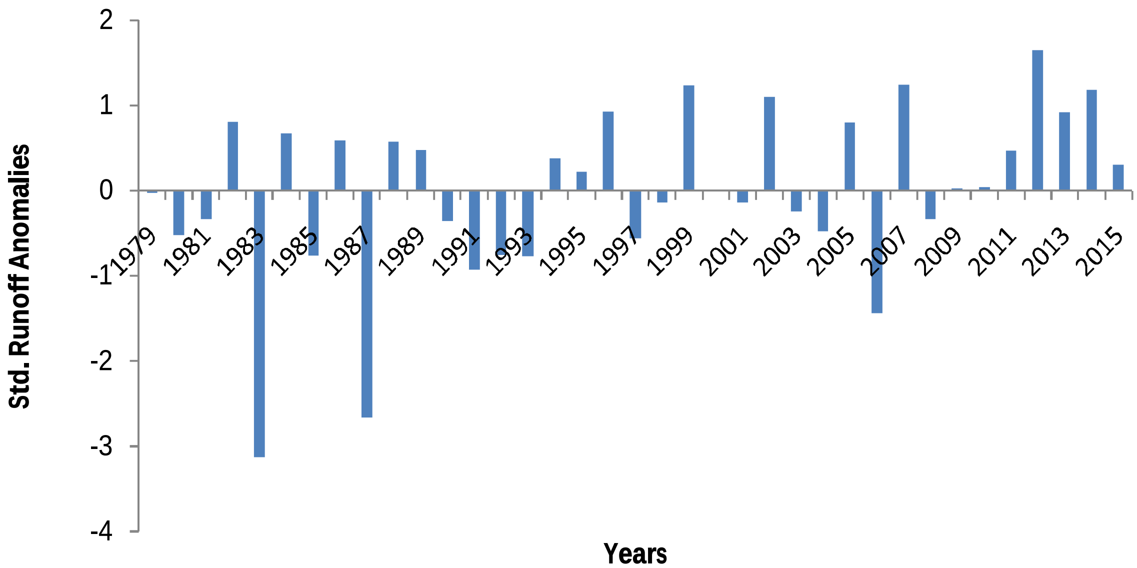

Figure 8. Gassol runoff anomaly.

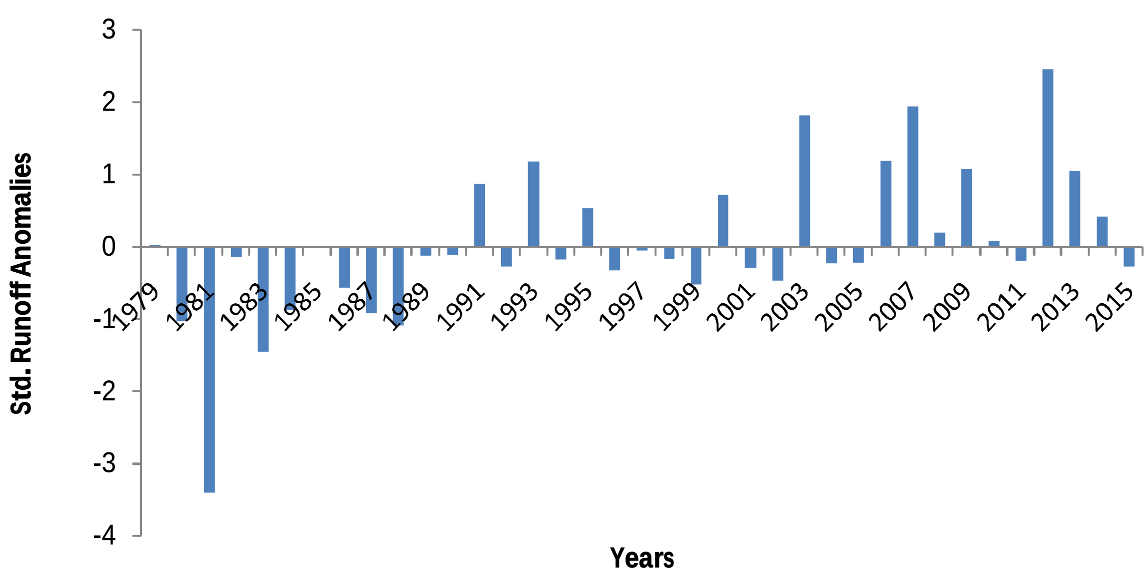

Figure 9. Donga runoff anomaly.

CONCLUSION

The past flood hazards in Taraba were rainfall induced but definitely the catchments received a boost from upstream runoff. The catchments seem also to have quick respond to rainfall. This indicates low storage potential and consequently possibility of large storm runoff giving room to floods. This support the finding of Nicholas et al. (2015) in their work on assessment of rainfall-induced flooding using the Soil Conservation Service Curve Number Method and Geographic Information System in Mararaba, Nasarawa State, posited that catchment with impermeable bedrock are quick to respond to rainfall as they have low storage potential giving large storm peaks, often cause floods and decay rapidly to leave a small base flow generated from soil drainage only. Unfortunately, floodplains of the study area are grossly encroached and density of tree stands is fast disappearing. With evidence of change in climate, these situations increase the time of concentration of storm flow leading to unprecedented rise in water level that overwhelm bridges and water conduits along its paths; submerged properties and washed away farm lands. The government effort to build Kashimbilla dam as a buffer dam will convert this resistance to resource.

RECOMMENDATIONS

1. Redevelopment Authority – First step is to constitute public administrative unit in the state that will partner with Upper Benue River Basin, National Emergency Management Agency, National Water Resources Institute, National Environmental Standards and Regulation Enforcement Agency, to identify and map flood risk areas along the major tributaries (River Taraba, River Donga and River Lamurde). In addition, they will be saddled with responsibility to enact an enforceable floodplain regulation to curb furtherance of land use within the flood plain.
2. Even though there may be some individual whom government must have been issued certificate of occupancies but fall within the risk of equal or greater than 50 years recurrence interval flood should be revoked, there properties acquired and they be relocated and resettled. Beyond the embankment should be under restriction for re-allocation strictly for dry season farming (Fadama). This when fully harnessed could bring bumper harvest and the world will see that Taraba is truly nature's gift to Nigeria.
3. The region's status is vulnerable to climate change. The vulnerability no doubt has alliance with the Land use and land cover change. There is need for farmer to adopt 'farm forest' method of farming system. This will not only checkmate adverse effect of flooding but serve as windbreak and source of additional revenue apart from adding nutrients to the soil.

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Citation: Adelalu TG, Abdullahi I, Alade EJ (2018). Rainfall variation, water resources potential and implication for flooding: A case study of catchment area of major tributaries to River Benue in Taraba State. Afr J Eng Res, 6(3): 55-63.