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Morphometric analysis was conducted for the major tributaries of river Benue in Taraba with emphasis on its hydrological response to storm events. The Study Rivers comprises twenty two small watersheds. The drainage networks show that while dendritic pattern dominated river Donga and River Taraba, River Lamurde depicts more of sub-dendritic patterns. Stream orders range from seventh to ninth order. The L_o values range from 0.076 km for River Lamurde to 4.88 km for River Donga denoting gentle slopes and longer paths network on the drainage basins. The mean R_b vary between 2.0 and 6.05 for River Donga basins, and between 3.0 and 5.14 for River Taraba watersheds, while River Lamurde R_b vary between 4.0 and 6.3 indicating transitional zone of geological structure with a remarkable influence of structural disturbances (i.e., warping, alternating high rounded hills and intervening flat topped ridges) .All watersheds have long L_b, ranging from 83.85 km for River Lamurde to 241.62 km for River Taraba. This is indicative of low flooding susceptibility. Catchment characterizations of the study area from basin morphometry do not typify high flooding susceptibility. Environmental degradation through proliferation of haphazard and uncontrolled development within and around the floodplain seem the cause of incessant flooding in major parts of the catchments.

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ABSTRACT

Morphometric analysis was conducted for the major tributaries of river Benue in Taraba with emphasis on its hydrological response to storm events. The Study Rivers comprises twenty two small watersheds. The drainage networks show that while dendritic pattern dominated river Donga and River Taraba, River Lamurde depicts more of sub-dendritic patterns. Stream orders range from seventh to ninth order. The L_o values range from 0.076 km for River Lamurde to 4.88 km for River Donga denoting gentle slopes and longer paths network on the drainage basins. The mean R_b vary between 2.0 and 6.05 for River Donga basins, and between 3.0 and 5.14 for River Taraba watersheds, while River Lamurde R_b vary between 4.0 and 6.3 indicating transitional zone of geological structure with a remarkable influence of structural disturbances (i.e., warping, alternating high rounded hills and intervening flat topped ridges) .All watersheds have long L_b, ranging from 83.85 km for River Lamurde to 241.62 km for River Taraba. This is indicative of low flooding susceptibility. Catchment characterizations of the study area from basin morphometry do not typify high flooding susceptibility. Environmental degradation through proliferation of haphazard and uncontrolled development within and around the floodplain seem the cause of incessant flooding in major parts of the catchments. The study recommends the need to update the database of the River Benue catchment area in Taraba State using GIS and Remote sensing techniques to plan and monitor influx to buffer and exploitation of such in the drainage basins.

Keywords: catchment area; gis; morphometric parameters; river benue; water resources development and flood control.

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I. INTRODUCTION

Continuous assessment of the drainage basin as a fundamental geomorphic unit in water resources development and management cannot be relegated much more as climate change infiltrates and influences every sphere of the globe. Chorley (1971) had long discovered that variations in physical conditions can result in variations of morphometric characteristics of drainage basins and the associated fluvial. This in turn may influence the hydrological response of the basin. Biswas, et al. (2014) affirmed that morphometric properties of a basin influence to a large extent its hydrological responses to flood or drought. The need for continuous comprehensive study of drainage basin characteristics is necessitated by the spatiotemporal variation exhibited by the geometric attributes of basin (Udoka, et.al, 2016). Proper quantification of these basin features has continuously become expedient in the face of many challenges as climate change.

Morphometric analysis addresses statistical correlation of morphometric characteristics of drainage basins and basin hydrology. This type of statistical measure has been developed to describe valley side, channel slopes, area, relief, drainage pattern type and extent of a basin. This analytical description of this physical division of landforms in a watershed is vital to assess flash flooding susceptibility. This information is vital for watershed prioritization for soil and water conservation, and water resources management. It facilitates hydrological prospecting, assessment of the potential of groundwater recharge, and mapping of flood prone areas (Farhan et al, 2016) .When appropriated it aid in planning, development and management of the basin for relevant decision making. However, even with the fast opportunities remote sensing and GIS techniques avail, analytical description of the physical division especially, pertaining to drainage morphometric that influence flood (drainage density, drainage frequency, meandering ratio, stream order and bifurcation) relevant and appropriate for proper planning of a catchment especially on River Benue tributaries in the study area has not been carried out. This present study attempts evaluation of the hydrological response of the basins to morphometric parameters using Geographical Information System (GIS) techniques.

II. STUDY AREA

The study area encompasses major River Benue tributaries in Taraba State. Taraba State is located in the north eastern part of Nigeria. It lies between latitude $6^{o}\ 30^{1}$ and $9^{o}\ 30^{1}$ north of equator and between longitude $9^{o}\ 00^{1}$ and $12^{o}\ 00^{1}$ east of the Greenwich Meridian (Fig. 1). The study river basins 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.

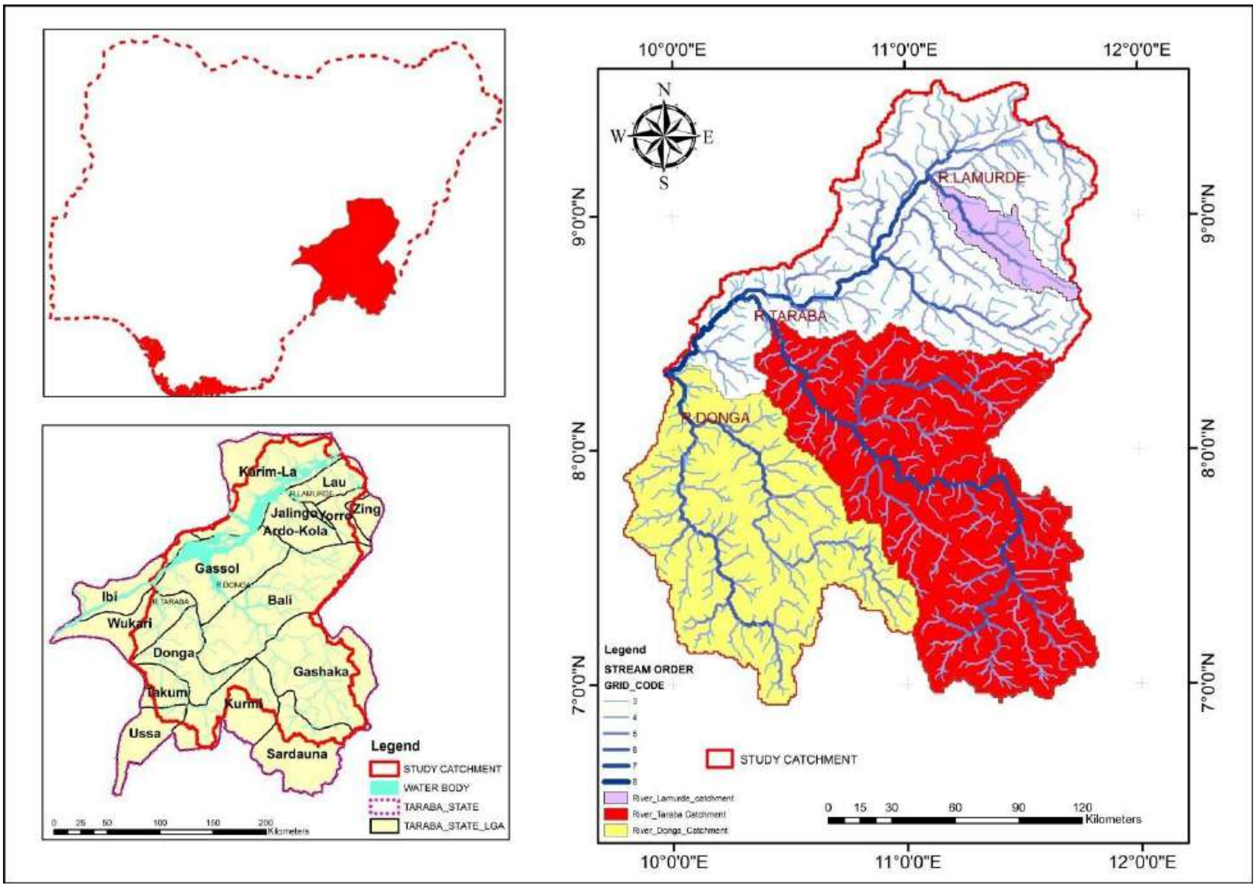

Figure 1: Catchment areas and the Major Tributaries of River Benue in Taraba State

The state has a total land area of about 60,291km² (National Statistic Office, 2015). The land area has three major tributaries to River Benue: River Lamurde, River Taraba and River Donga .There exist twenty-two sub basins in the study area and these sub basins network with these three rivers and drained a total area of about 44,359 km² having perimeter of about 1522km (Fig. 2). River Lamurde which drains the state capital takes its source from Yorro Mountain near Gangoro and flows downhill through Yorro, Tazarang, Alkali Gwa, Bassa and Jalingo. The river flows for over 96km westward before emptying into the River Benue system (Oruonye, 2011) near Tau. It enjoys a total drainage area of about 1265 km² with a perimeter of about 289 km². River Taraba with a perimeter of about 959 km drained about 15,777 km². 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 11355 km². These Sub Basins include among others Ntum, Luggungo, Mbaso, Ngo. River Donga drains five local governments in Southern Taraba before emptying to River Benue in 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.

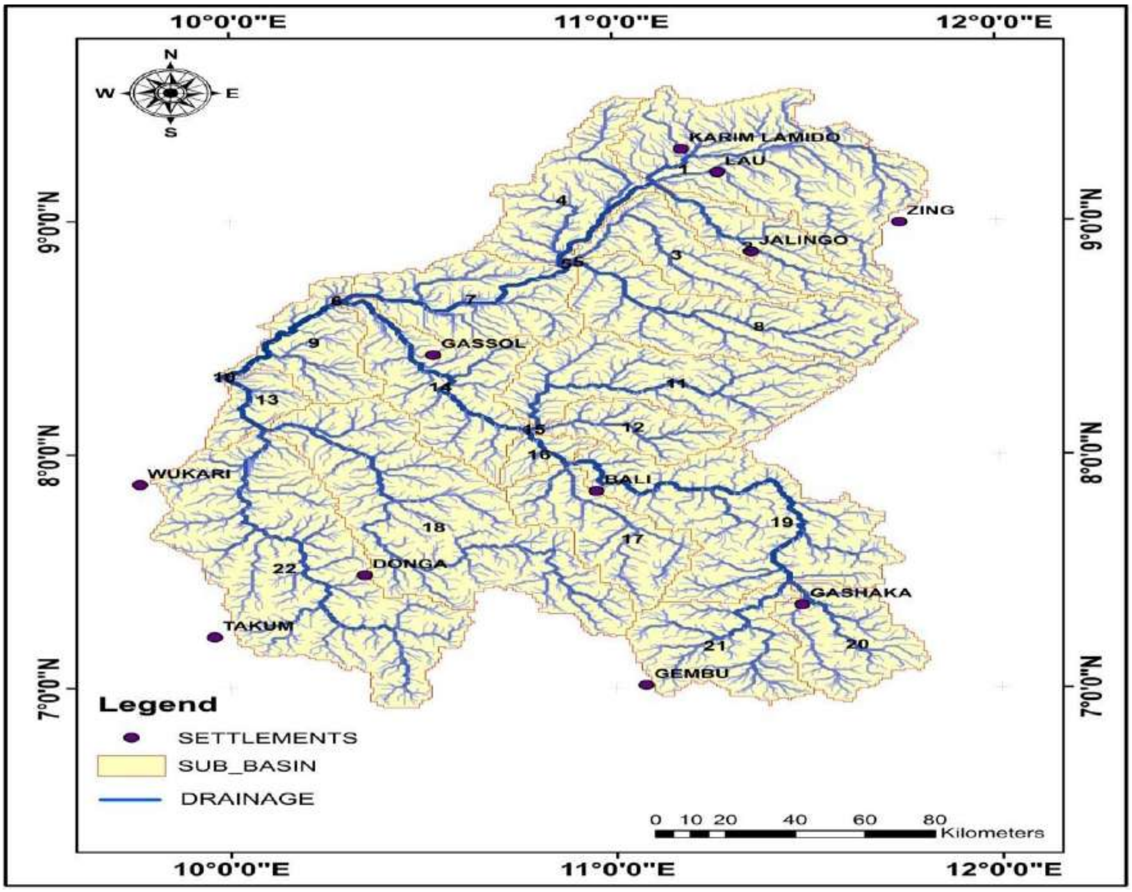

Figure 2: Automated drainage Networks and the sub basins of the Study Area

The soil of the study area can be classified into two major groups following Food and Agriculture Organization (1974) genetic classification system. These are the ferruginous tropical soils and hydromorphic or alluvial soils. The ferruginous tropical soil derived from crystalline acid rocks of the basement complex. Additional information on the soil of the study area based on the textural composition from 0-30 cm depth, using the harmonized world soil database downloaded from the site World map. Havard. edu/data/ geonade: DSMW_RdY depicts nine different soil types (Fig 3). Among these are Numic Nitosols, Lithosols, Fluvisols, Ferric Luvisols and Ferric Acrisols. The soil ranges from deep well drained dark red coarse stony sands and gravel on the higher pediment slopes surrounding the inselbergs and hills, through shallow stony brown sandy fine gravels to deep moderately drained yellowish red concretionary loamy fine sands on the lower slopes (Carter et. al, 1963).

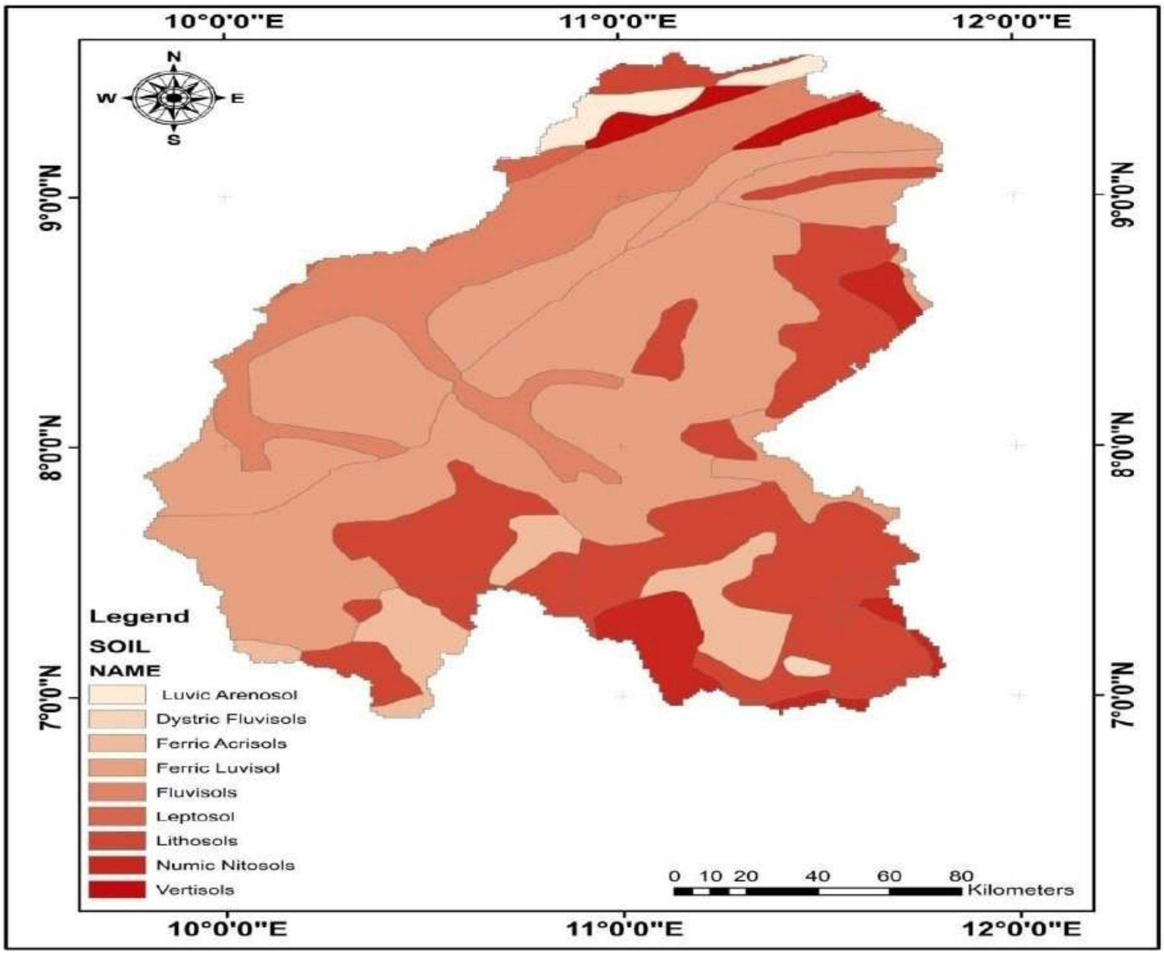

Figure 3: Soil Types of the study area

Table 1: Soil Types and Percentage Area Covered in the Studied Basin

SOIL TYPES	AREA (km²)	PERCENTAGE (%)
FERRIC LUVISOL	7210.6	57.0
FLUVISOLS	776.3	6.0
LITHOSOLS	3889.9	31.0
'HUMIC NITOSOLS'	768.5	6.0
TOTAL	12645.4	100

Sorce: Authors' data analysis

River Taraba catchment area		
SOIL TYPES	AREA (km^2)	PERCENTAGE (%)
Dystric Fluvisols	88.2	0.6
Ferric Acrisols	1168.7	7.4
Ferric luvisol	6750.3	42.8
Fluvisols	1184.9	7.5
Lithosols	5549.4	35.2
Humic Nitosols	1035.6	6.6
Total	15777.0	100

River Donga catchment area		
SOIL TYPE	AREA (km^2)	PERCENTAGE (%)
FERRIC ACRISOLS	1377.7	12.13
FERRIC LUVISOL	6096.9	53.69
FLUVISOLS	671.9	5.92
LITHOSOLS	3023.1	26.62
'HUMIC NITOSOLS'	185.3	1.63
TOTAL	11355.0	100

Source: Authors' data analysis

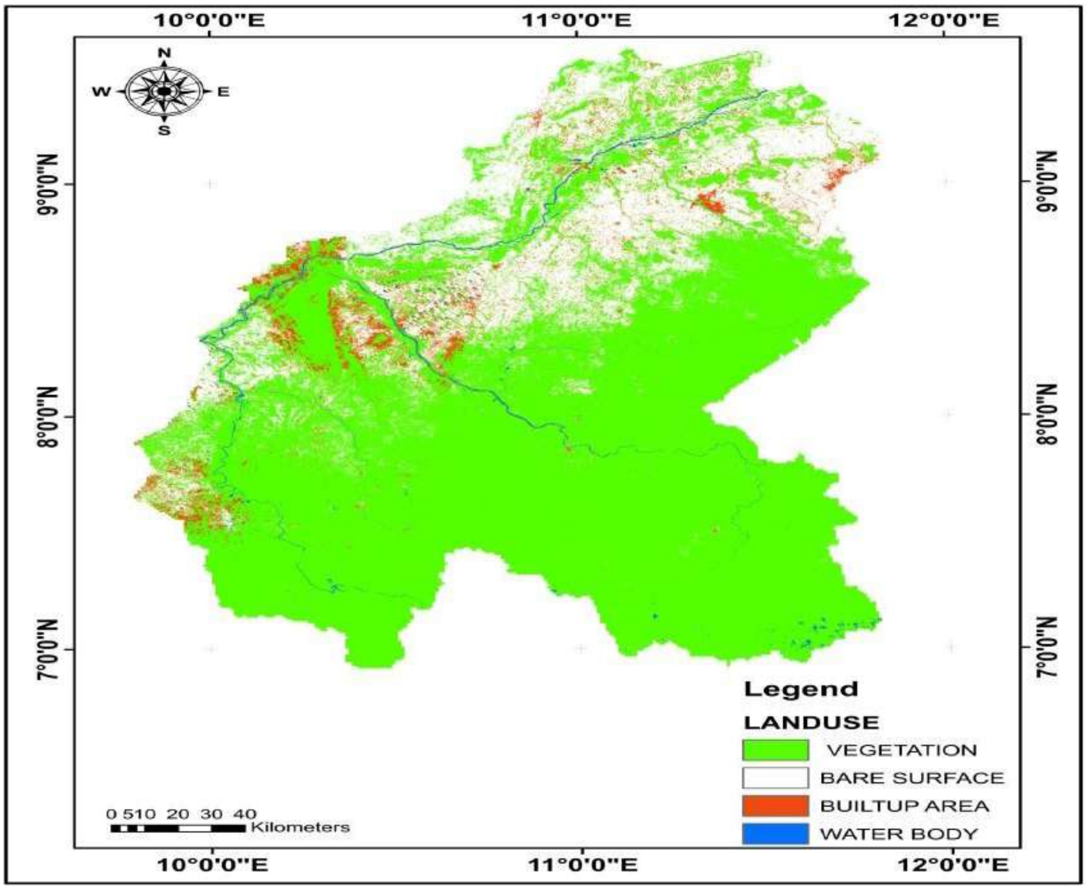

Figure 4: Land use/land cover along the Major tributaries of river Benue in Taraba State

Table 2: Land use Types of the Study Area

River Lamurde Catchments		
Types	Area (km²)	Percentage%
Vegetation	567.4284	44.9
Bare Land	577.5264	45.7
Built Up Area	113.8509	9.0
Water Body	5.6556	0.4
Total	1264.539	100

River Taraba Catchments		
Types	Area (km²)	Percentage %
Vegetation	8330.2824	52.8
Bare Land	6863.01675	43.5
Built Up Area	441.7574	2.8
Water Body	141.99345	0.9
Total	15777.05	100

River Donga Catchments		
Types	Area (km²)	Percentage %
Vegetation	5332.1779	47.0
Bare Land	5705.7236	50.2
Built Up Area	251.3521	2.2
Water Body	65.7443	0.6
Total	11355.03523	100

Source: Authors' data analysis

The result of the land use analysis done for the catchments under study show natural vegetation cover of about 14230 km² which is about 50.1% of the catchment area. Cultivated area and the bare land amount to about 13146 km² about 46.2% of the basin area. Built up area cover of about 807 km², occupy just 2.8%. Owing to the occurrence of good vegetation cover, which is more than half of the basin area, generally one would have expected low occurrence of flooding in the study area. This provides support evidence of low flooding in some areas and high flooding in some areas that are highly denuded. The vulnerability of a place on the globe earth to flood is a function of the region's exposure to the hazard (natural event) and the anthropogenic activities (the extent of built up; transformation on the terrain) which impede the free flow of water (Kelemen and Blist'anova, 2014). However it can be said of the study area that the transformation is concentrated to flood plain as people place themselves in the path of geophysical agents. As the rainfall shorten (Adebayo, 2012) it pushes the farming stakeholders to the plain thereby increases pressure on the watersheds.

III. MATERIALS AND METHOD

3.1 Data Source and Methods

Topo sheets were used initially to demarcate the boundaries of the watersheds, then, the ArcHydro tool was utilized to delineate the final watershed boundaries and stream networks for the three catchments. Topographic maps with a scale 1:50 000 of the area published (1968) was from the archive of the Federal Surveys Department of Nigeria. These topo sheets include: for River Lamurde (SHEET 215); for River Taraba (SHEET 235, 255 and 256); for River Donga (SHEET 254,257, 274 and 275). Other materials explored for the actualization of the objective of this work include: (i) 30 m resolution Digital Elevation Model (DEM) of the catchment areas. This was acquired from the Shuttle Radar Topographic Mission (SRTM) available for the globe and downloaded from http://srtm.usgs.gov/ data/obtaing.html. (ii) Soil image was obtained from Digital soil map of the world (DSMW) from http://Worldmap.havard.edu/data/geonade.html (iii) The digital layer of geological condition of the catchment areas were obtained from harmonization of the works from Federal surveys of 1959 and the Geological Survey of Nigeria in 1985 by digitizing 1: 50,000 topo sheets that capture the basins.

Arc GIS tools were employed to derive, and calculate the morphometric parameters of the watersheds. Different terrain feature/maps for the study area such as drainage map, slope categories, elevation were generated using the Spatial Analyst module. The stream order maps were compiled from the flow direction map for each watershed using the Stream Order tool. Fundamental parameters of the basins such as: area (A), basin length (L_b), perimeter (P), stream order (u), stream number (Nu), stream length (L_u), were measured directly from the DEM using GIS software while the derived parameters such as bifurcation ratio (R_b), drainage density (D_d), stream frequency (F_s), length of overland flow (L_o), circularity ratio (R_c), elongation ratio (R_e), basin relief (B_h), relief ratio (R_r), and form factor (R_f) were calculated based on mathematical relations in Table 3.

Table 3: Morphometric parameters and their mathematical formula

Morphometric Parameters	Methods	Reference
Linear Aspects		
Stream order (U)	Hierarchical rank	Strahler (1964)
Number of Streams (Nu)	Nu=N1+N2.......N_m	Horton (1945)
Stream length in km (Lu)	Lu=L1+L2.........L_m	Horton (1945)
Mean stream Length (L_{um})	L_{um}= Lu/Nu	Strahler (1964)
Bifurcation Ratio (R_b)	R_b=Nu/Nu+1	Schumm (1956)
Stream length Ratio (R_L)	R_L= Lu/Lu-1	Horton (1945)
Areal Aspects		
Area in km² (A)	Area calculation	Schumm (1956)
Perimeter in km (P)	Perimeter calculation	Schumm (1956)
Length of the basin in km(L_b)	Length calculation	Schumm (1956)
Drainage density (D_d)	D_d= Lu/A	Horton (1932)
Stream frequency (F_s)	F_s= Nu/A	Horton (1932)
Circulatory ratio (R_c)	R_c = 12.57*(A/P²)	Miller (1953)
Elongation ratio (R_e)	R_e = 2/ Lb*√(A/λ)	Schumm (1956)
Form factor (F_f)	F_f = A/Lb²	Horton (1932)
Drainage intensity (I_d)	I_d = Fs/Dd	Faniran (1968)
Length of overland flow (L_o)	L_o = 1/Dd*0.5	Horton (1945)
Lemniscate ratio (K)	K = L²/4A	Chorley,et al., (1957)
Relief Aspects		Strahler (1957)
Basin relief in m (H)	H = Z - z	Schumm (1956)
Relief ratio (R_h)	R_h = H/Lb	Melton (1957)
Relative Relief (R_{hp})	R_{hp} = H*100/P	Strahler, (1964)
Ruggedness number (R_n)	Rn = Dd*(Bh/1000)	Strahler, (1964)

IV. RESULTS AND DISCUSSION

4.1 Drainage networks and Stream Order

The drainage networks show that while dendritic pattern dominated river Donga and River Taraba, River Lamurde depicts more of sub-dendritic patterns. Dendritic drainage pattern develops in basins having one rock type with no variation in structure (Waugh, 1995). Dendritic pattern is an indication of a natural drainage basin system underlain with a homogenous rock. Such uniformity of bedrock underlain signifies development of less disturb lithology, morphology and less steepness on drainage network. With this pattern, the times of concentration are long consequently expectedly the runoffs from the catchments are distributed over a long period. Table 5 shows the results of the linear features of morphometric parameters. Based on drainage order using Strahler(1964), all the catchments of

River Lamurde are all of Ninth order while River Taraba and River Donga can be classified as seventh order.

4.2 Number of Streams (Nu) Total and Stream length in km (Lu) Total

The study revealed that in River Lamurde, there were very many streams in the study area compared to its small size. As was shown the total number of streams (N_u) was 225010 within a basin area of about 1264.54 km². River Taraba is 3388 streams in total more than that of River Donga. Stream length (L_u) is a significant physiographic parameter for flood assessment of any drainage sub basins. It is an indicative of runoff characteristics, geomorphic development of stream segments, and tectonic instability (Farhan et al., 2016). Table 5 shows the L_u for the drainage basins with River Lamurde topping the class and Donga sub basins the least.

4.3 Mean stream Length (L_{um}) and Mean Bifurcation Ratio (R_b)

Mean stream length (L_{um}) is calculated by dividing the total stream length of order (u) and number of stream segments of the same order (u). The mean stream length for river Lamurde sub basins varies from 0.12 km for the first order streams to 72.74 km for the ninth-order stream, whereas the mean stream length for river Taraba ranges from 2.09 km for the first order streams to 23.14 km for the seventh-order stream while their overall L_{um} are 0.15 and 2.09 km respectively. Forriver Donga Catchments area, the L_{um} varies from 1.99 km for the first order streams to 29.43 km for the seventh -order stream with overall L_{um} of 2.42 Table 5.

4.4 Mean Bifurcation Ratio (R_b)

Bifurcation ratio is elaborated by Balogun et al., (2013) and Bharadwaj et al., (2014) as an indicator of the complexity and degree of dissection of a drainage basin. In Lamurde Basin, the Bifurcation ratio ranges from 4 to 6.3, while mean R_b was 5.6. Taraba river Basin Bifurcation ratio ranges from 3.0 to 5.14 with R_b 4.31. For river Donga sub basin areas bifurcation ratios ranges from 2 to 6.05 with R_b of 4.3. Iron, (1985) has identified three different Bifurcation ratio categories: Bifurcation ratio <3 indicates flat region, between 3 and 5 is described as geological structure which do not distort the drainage pattern as such and >5 is a drainage network which are lithological and structurally controlled. Lower values of R_b in Donga and Taraba watersheds are representative for homogeneous bedrock (Chorley 1969 and Waugh 1996), structurally less disturbed catchments without any distortion in drainage pattern (Hadley. and Schumm, 1961). By contrast, such high figures registered in Lamurde denote that drainage development of the watersheds is remarkably influenced by structural disturbances. Disturbance such as warping, alternating high rounded hills and intervening flat topped ridges and rejuvenation of the drainage network are noticeable.

Table 5: Linear Features of the River Basins

S/N	Morphometric Parameters	River Lamurde Catchment	River Taraba Catchment	River Donga Catchment
1	Stream order (U)	9	7	7
2	Number of Streams (Nu) Total	225010	9205	5817
3	Stream length in km (Lu) Total	33061.59	19242.86	14099.76
4	Mean stream Length (L_{um})	0.15	2.09	2.42
5	Mean Bifurcation Ratio (R_b)	3.65	4.3	4.3

Source: Authors' data analysis

V. AREA FEATURES OF THE RIVER BASINS

Values of the Area features of the sub basins under study are listed in Table 6. Area features are a measure of the basin geometry. It has important control over the geometry of the stream network thus influencing the shape of the hydrograph (Ayoade, 1988). The shape of the basin determines the lag time and the time of rise among other hydrograph parameters. Several indices were used to describe the watersheds' shape in this study. Such considerations were the circularity ratio (R_c), elongation ratio (R_e), form factor (F_f) and lemniscate ratio (K). Others include a real aspect that relates to the texture of the drainage topography. These indices are drainage density (D_d), stream frequency, drainage intensity (I_d), length of overland flow (L_o)..

5.1 Circularity, Elongation and Lemniscate ratio

The circularity ratio of nearly 0.189 is an indication that the River Lamurde basin is not circular in shape. The elongation ratio of 0.478 is a confirmation of the fact that the basin is not circular. For river Taraba basin circularity and elongation ratio are 0.215 and 0.5794 respectively while Donga Basin are 0.27 and 0.73 in that order. According to Sule and Bilewu (2017), classification index for elongation ratio range from less than 0.5 – 1.0. Chow (1964) had earlier noted that strongly elongated basins have circularity ratios of between 0.40 and 0.50.

It has been concluded that a circular basin is more efficient in runoff than is an elongated one Singh and Singh (1997). R_e values for River Taraba and river Donga which belong to the southern part of the study area are greater than 0.5 (0.58 and 0.73 respectively) (Table 6), while R_e values for the Lamurde Basin is less than 0.5. Such figures indicate that none of the basins under study is circular. They are elongated or less elongated with low relief and mild slopes. This implies that catchments show longer time to peak. It means basins produce a flatter peak of direct runoff for a longer duration. What then brings about the yearly flooding?

Lemniscate ratio (k) describes how closely the actual drainage basin shape approaches the loop of a lemniscates (Ivanova,et.al, 2012). It is considered a useful index to differentiate one morphometric region from another, and to express quantitatively the structural control over basin shape. The k value for river Lamurde catchment area is 1.39 whereas the k values for the watersheds of river Taraba and river Donga catchment areas are 0.93 and 0.59. This indicates that river Lamurde catchments are mostly elongated in shape, and have most delayed time to peak flow. By contrast, river Taraba and river Donga watersheds are less elongated and have a less delayed time to peak flow. However personal observation revealed that there are more cases of flooding in the Northern parts of the study area where we have river Lamurde basin.

5.2 Form factor (F_f) and Stream frequency (F_s)

Morphological characteristics of a watershed like form factor have powerful impacts on watershed hydrology. Form factor (F_f) parameter has been elaborated by Horton (1945) to forecast the Flow intensity of a given river basin. It is the ratio between the area of basin (A) and the square of the basin length (L_b). Catchments with low (F_f) value tend to be elongated, which give low peak flows for longer duration, and thus reduce the chance for the basin to flood. On the other hand, catchments with high (F_f) values experience high peak flow of short duration. This gives a flood of stronger and higher velocities associated with greater erosion capacities. The (F_f) values for the 22 sub-basins range from 0.18 to 0.42 (Table 6). These values indicate that basins under study are more elongated and elongated in shape with low peak flows of longer duration.

(Horton, 1932) define Stream frequency (Fs) as the total number of stream segments of all orders within the basin per unit area. (Fs) is a suggestive of stream network distribution over the river basin. Generally, the value may range from less than 1 to 6 or even more depending on the lithology of the basin (Kale and Gupta, 2001). According to Sreedevi, et.al,(2013), high (Fs) means more percolation with respect to drainage density and thus more groundwater potential.

The observed stream frequency (Fs) values range from 0.51 to 7.94 (Table 6). Except for the river Lamurde Catchments area with high stream frequency, other basins are less than 1. It is obvious that Fs values indicate steep slopes, with low permeability rocks, thus facilitating less infiltration and greater surface flow and high flooding potential (Markose, et. al, 2014). Such Hydrological conditions like this make the catchment more prone to flooding and surface erosion. At the southern part of the study area, river Taraba and river Donga (Fs) indicate a low value. This is an indication that the catchments possess a low relief almost a flat topography (Horton, 1932).

5.3 Drainage density (D_d), and Drainage intensity (I_d)

Horton, (1945) defines drainage density (D_d) as the total length of stream per unit area divided by the area of the watershed. High D_d values denote high runoff and low infiltration rate (Farhan and Atef, 2017). This has been associated with the presence of impermeable underlying materials, spare vegetation, and hilly relief. Conversely, low drainage density implies low runoff, high infiltration and groundwater recharge. D_d values for the 22 sub-basins range from 1.21 to 2.61 see (Table 6).

The achieved value of D_d for river Taraba is 1.22 km / km² for river Donga1.24. km / km². The low D_d obtained in these basins suggest that the catchments have a high percentage of permeable sub soil and vegetable cover (Nageswara et al., 2010) and runoff from the catchment expectedly should be moderate (Raghunath, 2008). Why then is this yearly loss in the study area especially at Fada and Gyata Aure?. In fact at the time of this write up the warning, again have been issued that people at Santride, Natride, Mayoi Dassa should move up hill to avert the impending hazard. D_d value for river Lamurde catchments area is a bit comparatively higher. This implies a higher potential runoff from its large headwater areas especially over the Yorro Mountain near Gangoro, consequently high flooding potential down the tributary along Tazarang, Alkali Gwa, Bassa, Mayoi Dassa , Jalingo and Tau at the pour point.

Table 6: Area Features of the River Basins

S/N	Morphometric Parameters	River Lamurde Catchment	River Taraba Catchment	River Donga Catchment
1	Area in km² (A)	1264.54	15777.05	11355.04
2	Perimeter in km (P)	289.47	959.35	727.40
3	Length of the basin in km(L_b)	83.85	241.62	164.0
4	Drainage density (D_d)	2.61	1.22	1.24
5	Lemniscate ratio (K)	1.39	0.93	0.59
6	Circulatory ratio (R_c)	0.19	0.22	0.27
7	Elongation ratio (R_e)	0.48	0.58	0.73
8	Stream frequency	0.94	0.58	0.51
9	Form factor (F_f)	0.18	0.27	0.42
10	Drainage intensity (I_d)	6.80	0.48	0.41
11	Length of overland flow (L_o)	0.08	1.64	4.88

Source: Authors' data analysis

VI. RELIEF PARAMETERS FOR THE WATERSHEDS

6.1 Basin relief in m (H), Relief ratio (R_h) and Ruggedness Numbers (R_n)

The elevation difference between the highest and the lowest points on the catchment area is the basin relief. Strahler,(1964) posited that relief measures are suggestive of the potential energy of a drainage system present by virtue of elevation above a given datum. Basin relief is pivotal in understanding the denudation properties of any catchment, landforms and drainage networks evolution, overland flow, through flow, and erosional behavior of the terrain (Farhan,et. al.,2016). The total relief of the river Taraba catchments varies from 103 m at Natride to 2244 m around Gembu, while values for the watersheds of Lamurde range from 113 m at Tau to 1440 m around Yorro Mountain near Gangoro . The maximum height of the river Donga Catchment area is 1604 m and the lowest is 96 m. The basin relief of the catchment therefore is 1508 m. The maximum height is found in the South-Eastern part of the basin close to the source by Tsabga hill. The portions where we have the minimum basin relief coincide with the northern part of the basin. Major areas include part of Wukari, part of Takum. It also cuts across Donga, especially GyataAure and Fada town.

According to Schumm (1956), relief ratio (R_h) was defined as the total relief of the catchment (elevation difference between the lowest and the highest points in the catchment) and the longest dimension of the basin parallel to the principal drainage line. The R_h values for the three catchments range from 9.28 to 14.35 (Table 7). Low value of R_h as depicted in river Taraba Basin indicates the predominance of slow erosion processes. However, higher value of R_h in the Lamurde catchment area implies that this Basin is characterized by more intense erosion as compared with river Donga and Taraba watersheds. Among the three watersheds under study, Lamurde has the least drainage area. R_h normally increases with decreasing drainage area and size of a given catchment (Farhan, et al., 2016).

Ruggedness number (Rn) is a dimensionless parameter representing the product of basin relief (Bh) and the drainage density divided by 1000 (Strahler, 1952).The works of Patton and Baker (1976)has elaborated this index's worth to measure the flash flood potential of a drainage basin while Sujatha,et al.,(2013) illustrate the geometric characteristics of drainage basins concern. Accordingly, high value of R_n is obtained when both relief and drainage density are large. Present analysis shows that R_n for river Taraba and Donga catchment area are low 2.74 and 1.87 respectively while that of Lamurde is a bit high 3.46, though lower than 0.5.Watersheds having high R_n values (>0.5) are highly susceptible to an increase in peak discharge, high soil erosion rates, and high sediment load production (Sreedevi et al., 2013).

Table 7: Relief Aspects of the River Basins

S/N	Morphometric Parameters	River Lamurde Catchment	River Taraba Catchment	River Donga Catchment
1	Basin relief in m (H)	1327	2142	1508
2	Relief ratio (R_h)	14.35	9.28	9.78
3	Ruggedness Numbers (R_n)	3.46	2.74	1.87

Source: Authors' data analysis

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VII. CONCLUSION AND RECOMMENDATION

Morphometric analysis carried out for the major tributaries of river Benue in Taraba confirms the presence of twenty-two catchments. Not a pronounced variation exists in the geomorphometric parameters characterizing the three major rivers. Drainage density (Dd), relief ratio (R_h), elongation ratio (Re), circularity ratio (Rc) and ruggedness number (Rn) do not differ considerably. High values of bifurcation ratio in some selected areas especially in Lamurde basin indicate transitional zone of geological structure with a remarkable influence of structural disturbances (*i.e.*, warping, alternating high rounded hills and intervening flat topped ridges). However, the overall mean bifurcation ratio was low. This is an indication that the landforms and geology of the study area do not vary from one catchment to the other. Rainfall to runoff ratio will not be much. Invariably, the difference in the conversion of rainfall into runoff from one catchment to another will depend much on the exposure or exploration of the basins. A dendritic drainage pattern dominated the catchments. The catchments of river Taraba are elongated, Lamurde are more elongated, whereas the watersheds of Donga are less elongated, and approach the oval category. The longer the basin length the little the effect on the extent to which the surface runoff manipulates the basin and is lowered by agents of denudation. Catchment characterizations of the study area from basin morphometry do not typify high flooding susceptibility especially in terms of low mean catchment slope, low drainage density (*Dd*) and stream frequency (F_s). The lack of the basin with a sufficient channeling system will result in a chaotic surface flow regime, which is rather an overland flow than surface runoff. This scenario was indicated by the basin assessment of the bifurcation ratio (R_b). Variations in morphometric and morphological characteristics of these watersheds have not significantly influenced the potential of flash floods occurrence. It has not significantly influenced the hydrological response of the major tributaries of river Benue in Taraba State as we have in other parts of the country. Yearly losses incurred through flood seem self-induced as a result of people placing themselves in the path of geophysical agents through encroachment. Environmental degradation through proliferation of haphazard and uncontrolled development within and around the floodplain seem the cause of incessant flooding in major parts of the catchments.

It is recommended that human activities that could impact negatively on the drainage network should be discouraged. More so, similar study is recommended with a comprehensive assessment targeted to categorize the flooding susceptibility of the area to evaluate precisely the flood vulnerability to unravel the multivariate nature of the problem with the view to finding a holistic solution. Having established in this study that variations in morphometric and morphological characteristics of these watersheds have not significantly influence the hydrological response of the major tributaries of river Benue in Taraba, State, and that the basin is neither prone to floods it is therefore necessary to examine the nature and the general soil characteristics of the basin in order to ascertain the reliability of the findings generated from the assessments of the morphometric characteristics.

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