MORPHOMETRY ANALYSIS AND DISCHARGE MEASUREMENT OF RIVER AHUM WATERSHED

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ABSTRACT
This study analysed the Morphometry of River Ahum in an attempt to investigate the likely causes of seasonal flooding as experienced in the past. Extract from the Topographic map of Makurdi was used to define the river basin. Stream channel discharge from the river was measured using the current meter during peak discharge in the month of September. From the study a fern–shaped watershed was developed with a drainage density of 1.257, bifurcation ratio of 8.33 and 3.00 for the three order streams. An area ratio of 0.149 and 3.2 was calculated while a stream length ratio of 0.937:8.615 was developed. Findings also indicated that the stream length of order 1 outnumbered that of orders 2 and 3which culminate in seasonal flooding at the rainfall peak of 69.2mm resulting from the low land overflow. The discharge during the study was between 0.167m^3/s – 4.719m^3/s. It is advisable to carry out more studies on this river for a period of years for purpose forecasting flood events.

KEYWORDS: *Morphometry, Watershed, River Ahum, Flooding*

1.0 INTRODUCTION

One of the consequences of climate change according to Magami *et al*. (2014) is flooding. It is one of the major environmental crises that keep recurring every year in Nigeria from one region to another. It is a natural phenomenon caused by antecedents such as unusual high stage of a river due to runoff from rain flow in quantities too great to be confined in the normal water surface elevations of the river or stream (Djimesah *et al.,* 2018).

The floods have become worst in recent times in Nigeria because thousands of farmers were not only displaced from their homes but food crops were wiped away threatening food security in the nation (IITA, 2012). The majority of Nigeria's states are increasingly suffering from annual flooding during the rainy seasons occasioned by increased precipitation linked to climate change (Aja and Olaore 2014). Farmers all over the country suffered huge economic losses. According to Anugwara and Emakpe (2013), the floods damaged over 1.9 million hectares of lands and reduced food production along flood plains. Rice production in the affected areas was reduced by 22.4%, maize was reduced by 14.6%, and soybean, cassava and cowpea were reduced by 11.2%, 9.3% and 6.3% respectively. A total of 12 million goats, 3 million poultry and 136 cattle were killed in the 2012 floods. The National Emergency Management Agency (NEMA) estimated that a total of N2.29 trillion which represents 2.83% of the rebased Gross Domestic Product of N81 million for 2013 was lost as a result of the floods. The 2015 Global Assessment Report on Disaster Risk Reduction (GAR 15), prepared by United Nations office for Disaster Risk Reduction (UNISDR) states that economic losses from disasters are now reaching an average of US$250 billion to US$300 billion annually (UNISDR, 2015).

Most agricultural activities in Nigeria are performed in the flood plain which includes the full width of narrow stream valleys or broad areas along streams in wide flat valleys. The resulting agricultural runoff from the fields culminates into flow in excess of the carrying capacity of their stream valleys resulting to overflow of the flood plain. The stream valleys (watershed) is described as an area of land that contains a common set of streams and rivers that all drain into a single larger body of water, such as a larger river, a lake or an ocean (Rambabu and Jai 2014). Nigeria has a large number of these rivers well distributed into networks of stream channels which has been classified into four major drainage systems (Idu, 2015) across the country. This network of streams also serves as the natural resource for water supply for domestic activities such as cooking, drinking, washing and many other domestic applications, while for agricultural purposes, they supply water for activities like irrigation, production and processing of agricultural produce which may be plant or animals. Even as these rivers (alluvial streams) serve an important role in human activities, they may also be a threat to human.

There is a need to harness and develop these natural resources, in order to obtain optimal use of its benefits and at the same time be able to prevent and/or control the adversity that accompany the natural resource (river) is paramount. This suggests designing and implementing adequate national Flood Risk Management (FRM) strategy or comprehensive flood risk maps, for Nigeria's flooding problem (Oladokun and Proverbs, 2016). An FRM strategy comprises proper spatial planning and infrastructure to help in controlling the floods which adversely impact Nigeria's sustainable development (Ouikotan *et al*., 2017). Hence, the morphometric analysis of each river can be performed through measurement of linear, aerial, relief, the gradient of channel network and contributing ground slope of the basin (Nautiyal 1994; Nag and Chakraborty 2003; Magesh *et al.,* 2012) is necessary. Most especially to hydrologists, geomorphologists and water engineers, the knowledge of stream morphology can lead to the indirect estimate of its discharge which varies with time and may indicate the occurrence of floods at specific reoccurrence intervals. Morphometric studies can lead to the understanding of drainage basins or watershed characteristics of several rivers (Chaitanva and Kanak, 2017). However, in developed and developing countries, its application is yet to be fully implemented.

In the absence of hydrologic and stream flow records, an understanding of stream morphology can help delineate environmental changes, which through channel instabilities affects land uses directly through fluvial erosions and deposition and also seasonal flooding. In Nigeria specifically Benue State, morphometric studies have been performed on a few rivers, the Morphometry and water balance analysis of River Mu catchment and the morphometry analysis of the River Guma catchment was studied by Agusah (2005) and Ikyoive (2006) respectively. In their report, there is no available data on the morphometry of the River Ahum watershed. Settlements around this watershed comprise mainly of rural dwellers with little or no infrastructure development to curtail the menace of seasonal flooding that occur annually. The agricultural activities which are the main occupation of the rural population within the watershed always suffer a setback due to flooding, In this regard, this study will provide adequate data and information for the development of drainage facilities, watershed management strategy, security of crops and farmlands, prevention of fluvial erosion and deposits.

Materials and Methods

Extracts from Topographical maps of Makurdi sheet 251 NW and 251SW on scale 1:50,000 and sub basin maps of Makurdi developed by Oyetayo *et al* (2018) (Figure 1) were used to delineated the drainage networks of the River Ahum watershed. Tracing paper, pen, line scale, thread, Horton's and Strahler's laws of morphometry analysis were used to develop the drainage basin for the river. The basin or watershed area was calculated using Simpson's method for calculating irregular shapes. Then the length of each stream order was obtained using thread, after which the length equivalent was deduced from the line scale of the topographical map of Makurdi.

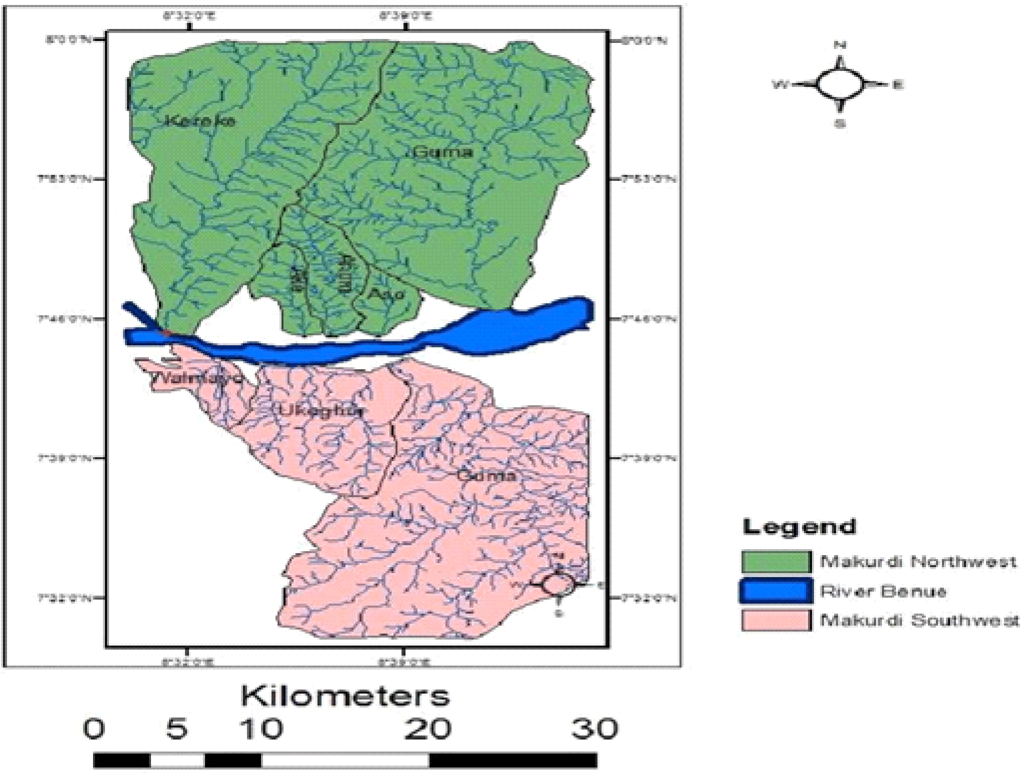

Figure1: Drainage Basin of Makurdi showing river Ahum (Oyetayo et al., 2018)

Discharge measurement was carried out using tape, current meter, pen, paper and a wire strip. The wire strip was tied at one end of the river across the other end in straight line. This enables for the accurate width of the river to be obtained. The total length was then divided into convenient, regular and equal section P_1, P_2, P_3 and P_4. And at each sub-area, the depth was obtained using the current meter rod. Six-tenth of the depth of the sub-area was gotten and the current meter was mounted with weight supporting at the bottom.

The reading in revolution per second (Rev/s) was then deduced from the current meter two-ways switch. The obtained values were used with the rating Equation (1) to deduce the flow velocity in the sub-area according to the international operating instructions for the current meter used. Same procedure was repeated across the stream width to get the velocity at each sub-area and the discharge was evaluated using the continuity Equation (2)

$$V = 0.008 + 0.2667n \quad (1)$$

$$Q = VA. \quad (2)$$

Where;

Q is the stream discharge (m^3/s)

V is the velocity of flow (m^2/s)

A is the crossectional area of the stream (m^2)

n is the stream order

And the area was calculated by considering P_1 and P_4 as triangle while P_2 and P_3 as rectangle.

Data Analysis

According to Horton's law of stream numbers, the watershed was ordered. Beginning with the small tributaries from the stream's headwater, which were designated as order 1 and the streamlets resulting from the joining of two 1st orders was numbered 2. The joining of two 2nd orders was tagged 3 successively. The highest order or the watershed was 3 (Figure 2). The result of the river orders carried out on the watershed indicated: $N_1 = 25$, $N_2 = 3$ and $N_3 = 1$. These orders were used to calculate the bifurcation ratio as stated by Horton's.

$$R_b = \frac{N_i}{N_{i+1}} \quad (3)$$

Whe

R_b is the bifurcation ratio

N_i is the number of streams of order I

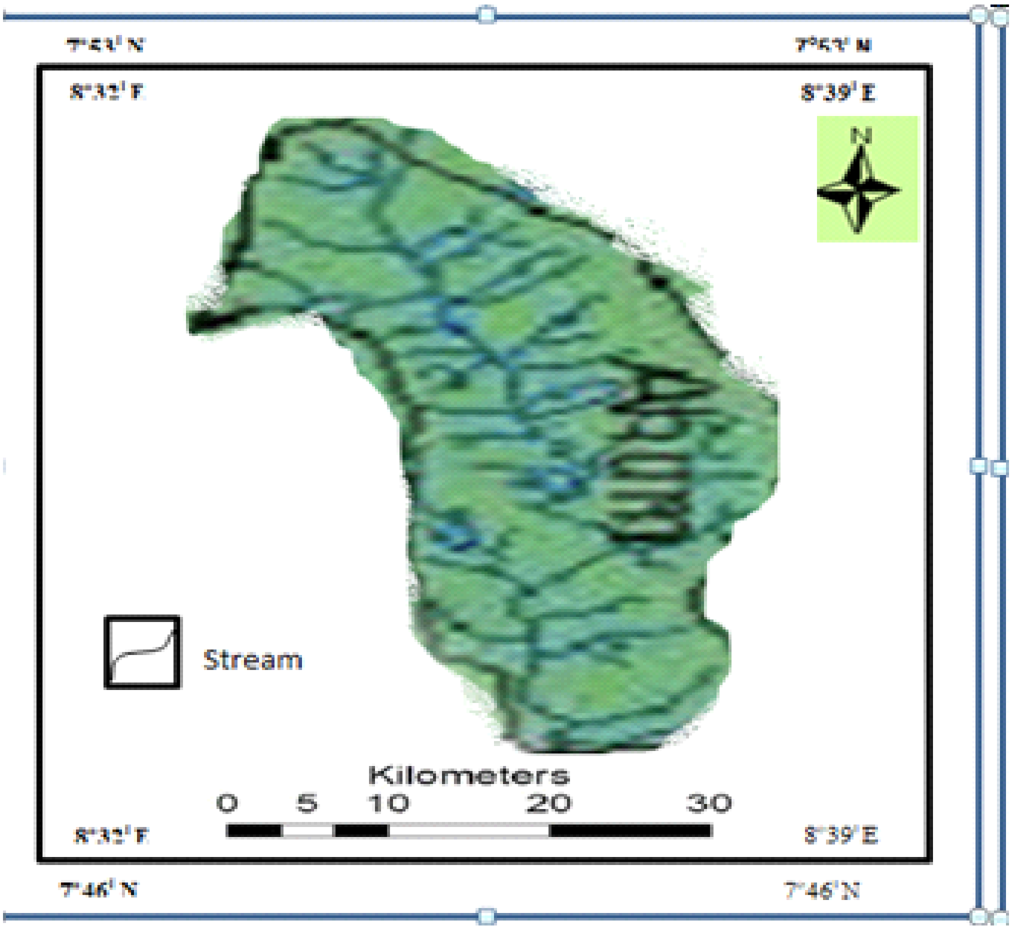

Figure 2: Stream Order for River Ahum.

The length of each streamlet was estimated directly from the topographic map. And with the topographic scale, the length equivalent of the streamlets according to each order was deduced as L the length ratio computed as;

$$R_L \quad \frac{L_{i\ 1}}{L_i} \qquad (4)$$

Where;

R_L is Length ratio

L_i is Length of stream of order i

Therefore, the stream density is

$$D_S = \frac{N_S}{A} \qquad (5)$$

Where;

D_S is the stream density

N_S is the stream number

Drainage density is calculated as;

$$D_d = \frac{L_S}{A} \qquad (6)$$

Where;

L_S is the stream length

D_d is the drainage density

From that drainage density, the average length of overland flow, L_0 was gotten by,

$$L_0 = \frac{1}{2D_d} \qquad (7)$$

Where;

L_0 length of overland flow

Stream area ratio is given as;

$$R_A = \frac{A_i \quad l}{A_i} \qquad (8)$$

Where;

R_A is the stream area ratio

A_i is area of stream of order i

Drainage basin shape was calculated using Form factor as;

$$Ff \quad = \quad \frac{W_b}{L_b} \qquad (9)$$

Where;

Ff is the form factor

W_b is the basin width

L_b is the basin length

Considering a circular area that is equivalent to the area of the basin with W_b and L_b as the width and length of basin from the catchments, the radius of the area is deduced and used to compute the perimeter P_b of the basin which equals the circumference of the equivalent circular area i.e

$$W_b L_b = \quad r^2 \qquad (10)$$

$$P_b \quad 2\ r$$

Where;

Pb is the basin perimeter

Thus, Compactness coefficient is

$$C_C = \frac{P_b}{2\sqrt{\pi A}} = 1.002 \qquad (11)$$

The area ratio R_A was computed according to Horton's law, to estimate the average areas drain by streams of successive orders. The watershed drainage density was also computed from which the average length of overflow L_o for the watershed was deduced. Also with the theories stated earlier, the drainage area and drainage basin shape was computed accordingly.

RESULT AND DISCUSSION

Table 1: Mean Elevation and % area

CE (m)	Ai (km2)	Zi (km)	A1Z1	Ai (%)	Ai LL (%)
<300	17	263.5	4479.5	44.74	100
300-400	16.75	350	5862.5	44.08	55.26
400-500	4.25	450	1912.5	11.18	11.18
	A1 =38		A1Z1 =12254		

C_E= contour elevation Ai= Area between contours; Zi= Mean elevation between contours; A_i{%)= percentage of total area and $A_i(\%)_{LL}$=% of total area given lower limit

Table 2; Stream lengths and order

S/N	Stream length(km)	Stream order
1	1.3	1
2	1.2	1
3	1.6	1
4	1.1	1
5	1.2	1
6	1.1	1
7	1.2	1
8	2.2	1
9	0.7	1
10	1.4	1
11	1.0	1
12	1.3	1
13	1.4	1
14	1.6	1
15	1.6	1
16	1.2	1
17	0.9	1
18	1.4	1
19	1.9	1
20	2.1	1
21	1.4	1
22	1.2	1
23	1.4	1
24	1.8	1
25	1.5	1
26	2.4	2
27	1.0	2
28	0.5	2
29	11.2	3

Table 2: Bifurcation Ratio of the Stream Orders

S_O	N_S	L_A	R_B	R_L
Order 1	25	1.388		
			8.33	0.937
Order 2	3	1.3		
			3.00	8.615
Order 3	1	11.2		

S_O=Stream order; N_S=Number of streams; L_A= Average length; R_B=Bifurcation ratio and R_L=Length ratio

Table 4: Geomorphological parameters of river Ahum

Parameter	Acronyms	Value
bifurcation ratio	$RN_{1,2}$	8.33
bifurcation ratio	$RN_{2,3}$	3.00
Stream length ratio	$RL_{2,1}$	0.937
Stream length ratio	$RL_{3,2}$	8.615
Stream density	D_S	0.631
Drainage density	D_d	1.257
length of overland flow	L_O	0.398
Stream area ratio	$RA_{2,1}$	0.149
Stream area ratio	$RA_{3,2}$	3.20
Form factor	Ff	0.356
Basin radius	R	4.322
Basin perimeter	P_b	27.157
Compactness coefficient	C_C	1.002

Discussion

The mean and median elevation was found to be 322m and 420 with the area-elevation curve taken the typical shape, sloping from the highest elevation down to the lowest elevation. Figure 3 is the graph of the mean elevation of the watershed.

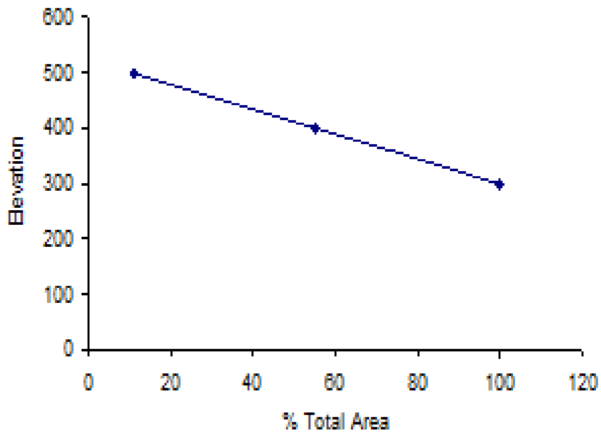

Figure 4: Mean elevation and % Total area relationship

The drainage basin characteristic of the River Ahum is a fern-shaped catchment and it influences the intensity of flood in the watershed. The time of concentration for all tributaries is expected to be more and the discharge distributed over a long period thus should result into low flood intensity. But it is not the case here since the bifurcation ratio of order 2 and 1 is outside the reported range of 2.88-3.0 as proposed by Walkar and Aditya (2014) although that of order 3 and 2 was within range. The high number of first-order streams according to Chitra *et al.* (2011), indicate that there is a possibility of unexpected flash floods after heavy rainfall in the down streams. Also the average lengths of the orders are almost equal except that of order 3 which is 11.2km. The basin also has low drainage density, thus, resulting to low overland flow (L_o). The geomorphology indicated that the stream number (N_i) and drainage area (A_i) correlates negatively with order (i) while the stream lengths (L_i) correlates positively with increasing order (Figure 3)

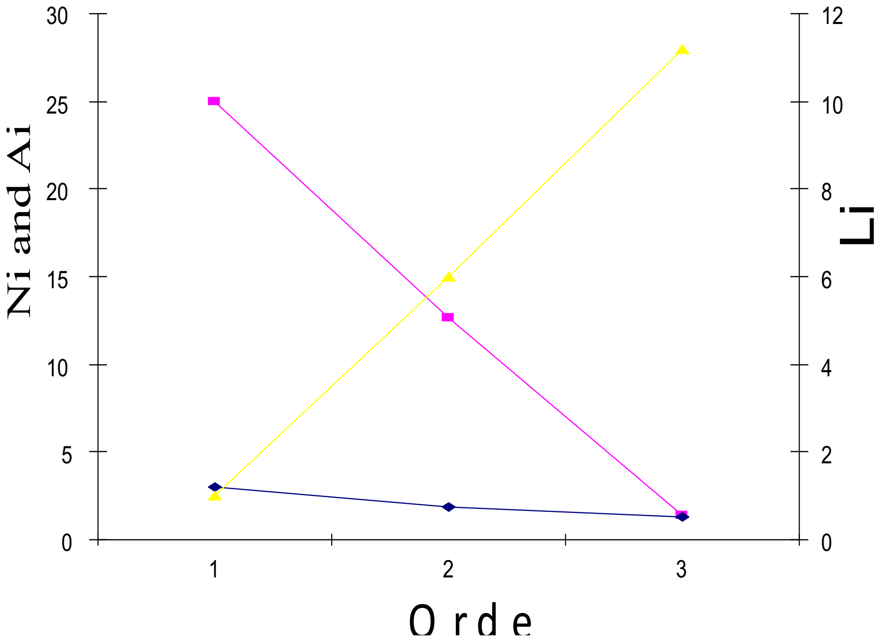

Figure 3: Geomorphology of River Ahum

Comparing the standard daily rainfall data, of the month of September obtained by the Nigeria Meteorological Agency Makurdi with the peak of flooding, the values of September rainfall show that, the discharge of the River is at peak with peak rainfall. This indicates that, the discharge of a River is not only the function of the watershed distribution. But also the function of the rainfall from the study, the discharge obtained ranges from 0.168 - 4.719 m^3/s.

Conclusion

Flooding by River Ahum is a yearly occurrence in Makurdi and is expected to increase due to climate change. Efforts towards mitigating the adverse effects of flood haves mostly bordered on treating the symptoms rather than addressing the root causes. The efforts, though laudable are not enough to protect farmers within the watershed of this river. The government should be proactive and invest massively in flood mitigation methods such as the building of dams, dredging of rivers, clearing of drainages and natural waterways etc. Finally, relevant flood prevention agencies should be well funded and the funds carefully monitored to avoid mismanagement,

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