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MORPHOMETRIC ANALYSIS OF LOWER ENYONG CREEK BASIN IN SOUTH EASTERN NIGERIA; ITS IMPLICATIONS FOR APPLIED STUDIES.

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ABSTRACT

The drainage basin analysis is important in any hydrological investigation such as study of hydrologic processes, management of wetlands, flood, erosion and landslides susceptibility studies, assessment of groundwater potential and groundwater management. Also, existing theories and models such as the laws of drainage composition can be verified. In the light of the foregoing, the present paper describes the drainage characteristics of the lower Enyong Creek, which is underlain by varying geologic formations. viz; Asu River Formations e.g the Abakiliki Anticlinorium to the recent alluvium in the south It involved detailed map-based quantitative analyses of two 4th order sub-catchments in the study area. The drainage pattern is mainly dendritic type. It is observed that the drainage density value is low which indicates the basin is highly permeable subsoil and thick vegetative cover. The elongation ratio value reveals that the basin is strongly elongated and stream abstraction process constrained by heterogeneous geologic materials. This study would help the local people to utilize the resources for sustainable development of the basin area. .

KEYWORDS: Morphometry, Enyong Creek, elongation ratio, bifurcation ratio Akwa Ibom State.

INTRODUCTION

Drainage basin morphometry is the measurement and mathematical analysis of the configuration of the earth's surface, shape, and dimension of its landforms**.** Ideally, drainage basins should be the framework for better understanding of the hydrologic system. Accordingly, the importance of river basins, particularly in integrated watershed management of water resources has been recognized and greater emphasis is being laid on its interrelatedness, economic use and better management. The basin morphometric characteristics of the various basins have been studied by many scientists using conventional map-based analysis (Horton, 1945; Smith, 1950, Strahler,1957, Ebisemiju, 1976, 1987;Hurtrez et al, 1999, Udosen, 2000, 2004 and 2009 and remote sensing and GIS methods (Srivastava and Mitra, 1995; Agarwal, 1998; Biswas et al., 1999; Nageswara et al, 2010, Somashekar and Ravikumar, 2011, Hajam et al, 2013 and Walker and Nilawar, 2014). Drainage basin morphometry are effective tools in providing the needed data in land and water resources planning and management.

For instance, Somashekar and Ravikumar (2011**),** carried out quantitative morphometric analysis for Hesaraghatta watershed, and the four sub watersheds, Banglore independently by estimating their various aerial, linear, relief aspects, while Ebisemiju (1987) and Udosen (2009) examine the effects of environmental heterogeneity on the interdependence of drainage basin morphometric properties in Eastern, Nigeria. The present study area, lower Enyong Creek, is a tributary of the Cross River and is utilized for cultivation of wetland rice and a variety of other crops (mostly rain-fed agriculture). It is also a major source of water supply to the local communities Hence, the main objective of this study, is to compute basin morphometric characteristics of lower Enyong Creek in relation to sustainable management of one of the most important wetlands in Akwa Ibom State.

PHYSIOGRAPHY OF THE STUDY AREA

The investigated area is enclosed between latitudes 5°11′to 5°28′ N and longitudes 7°51′E (Figure 1) covering an area of 55.63 sq. km falling in Survey of Nigeria toposheet No: Ikot Ekpene 322 NE on 1:50,000

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scale. (appendix a-b). Geologically, the area under study is underlain by a wide range of diverse geological formations ranging from Asu River Formations e.g the Abakiliki Anticlinorium to the recent alluvium in the south. The Asu River Group underlies most areas in the northern part of the study area e.g its intensely fractured outcrops at Uburu. The Asu River Group, which is Albian in age is sub-divided into three formations, comprising essentially of over 200m bluish- grey to olive brown shales and sandy shales, fine-grained micacceous and calcareous sandstones and some limestones (Offordile, 2002). The area is well represented by structurally controlled ridges, denudational hills e.g the 150m high Obotme conical hill, steep-sided valleys, saddle and col at Obot Ito Ikpo, extensive wetlands and alluvial plains forming soil covers of silty clay, sandy and heavily weathered loamy and alluvium. The area enjoys tropical climate and the temperature ranges from 26 to 32º C. The fluctuations in temperature are fairly uniform in character, except during the dry months when the rise in temperature is higher than it is during the long wet period (eight months-March to October) and the level of humidity is high (84%) due to close proximity to the main Cross River Channel. The average annual rainfall in the basin is 2200mm with maximum contribution from southwest tropical maritime air-mass. .

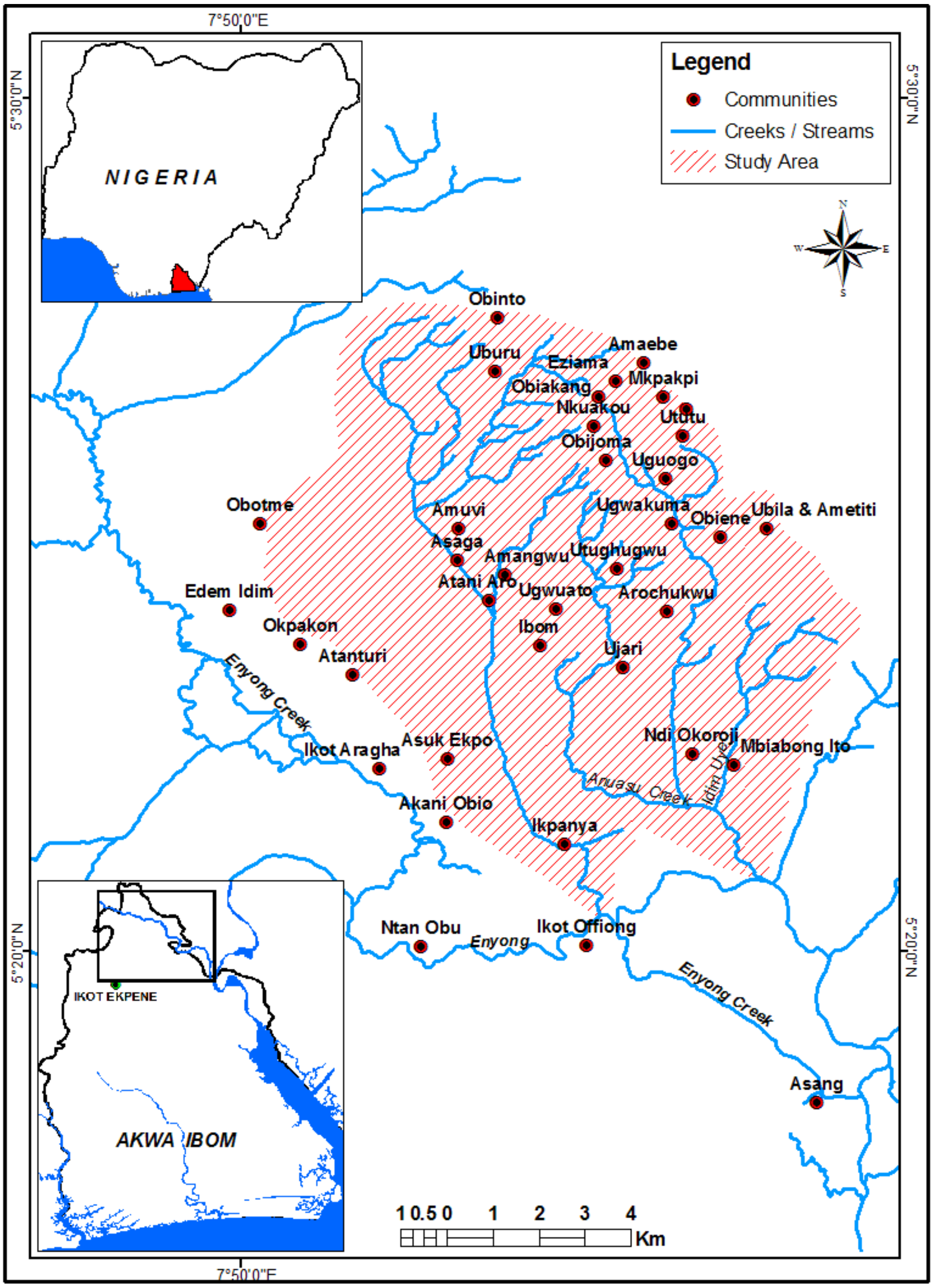


Figure 1: Location map of the study area

MATERIALS AND METHODS

The present study is anchored on detailed map-based analyses of topographic map sheet number 322 Ikot Ekpene NE of 1965 at a scale of 1, 50,000. Topographical map was rectified/referenced geographically and mosaiced and entire study area was delineated in GIS environment with the help of Arc-GIS 9.0 software assigning Universal Transverse Mercator (UTM), World Geodetic System (WGS dating from 1984 and last revised in 2004). Since, morphometric analysis of a drainage basin requires the delineation of all the existing streams, digitization of the drainage basin was carried out for morphometric analysis in GIS environment using Arc GIS 9.0 software. The attributes were assigned to create the digital data base for drainage layer of the basin. Various morphometric parameters such as linear, aerial and relief aspects of the basin were computed. The different morphometric parameters were determined by using the standard methodologies as shown in Table 1.

Table 1: Morphometric parameters with formulae.-Map-based Analysis

Linear aspects	Formulae
Stream Order Sμ	Hierarchical rank [Strahler,1964]
Bifurcation Ratio Rb	Rb = Nμ / Nμ +1 Where, Rb = Bifurcation ratio, Nμ = No. of stream segments of a given order and Nμ +1= No. of stream segments of next higher order.
Mean Bifurcation RatioRbm	Rbm = Average of bifurcation ratios of all orders [Strahler,1964]
Stream Length	Lμ Length of the stream (kilometers) [Horton,1945]
Mean Stream LengthLsm	Lsm = Lμ/NμWhere, Lμ = Total stream length of order 'μ' Nμ = Total no. of stream segments of order 'μ' [Strahler, 1964]
Basin Length Lb	Lb=1.312×A0.568 [Schumm,1956]
Stream Length Ratio RL	RL= Lsm / Lsm-1 Where, Lsm=Mean stream length of a given order and Lsm-1= Mean stream length of next lower order [Horton,1945]
Length of Overland Flow Lg	Lg=1/2D Km Where, D=Drainage density (Km/Km2) [Horton, 1945]
Areal aspects Basin Area A	Area from which water drains to a common stream and boundary determined by opposite ridges. [Strahler, 1964]
1.8 Basin Perimeter P	P=Outer boundary of drainage basin measured in kilometers. [Schumm,1956]
Drainage density Dd	Dd = Lμ/A Where, Dd = Drainage density (Km/Km2) Lμ = Total stream length of all orders and A = Area of the basin (Km^2). [Horton,1945]
Drainage Frequency Fs	Fs = Nμ/A Where, Fs = Drainage frequency Nμ = Total no. of streams of all orders and A = Area of the basin (Km2). [Horton, 1945]
Infiltration Number If	If = Dd × Fs Where, Dd = Drainage density (Km/Km2) and Fs = Drainage frequency [Zavoiance,1985]
Hypsometric Curve	Relates elevation and area using the ratio h/H:;a/A [Strahler, 1952]
Form Factor Rf	Rf = A/Lb 2 Where, A = Area of the basin and Lb = (Maximum) basin length [Horton,1945]
Elongation ratio Re	Re= √A /π / Lb Where, A= Area of the basin (Km2) Lb=(Maximum) Basin length (Km) [Schumn,1956]
Circularity Ratio Rc	Rc = 4πA/ P2 Where, A = Basin area (Km^2) and P= Perimeter of the basin (Km) [Miller,1953]
3.0 Relief Aspects 3.1 Basin Relief H	H = Z – z Where, Z = Maximum elevation of the basin (m) and z = Minimum elevation of the basin (m) [Schumm,1956]
3.2 Relief Ratio Rr	Rr = H / Lb Where, H = basin relief (m) and Lb = Basin length (m) [Schumm,1956]
3.3 Dissection Index DI	DI = H / Ra Where, H = basin relief (m) and Ra = Absolute relief (m) [46]
3.4 Channel Gradient Cg	Cg = H / {(π/2) ×Clp} Where, H = basin relief (m) and Clp= Longest Dimension Parallel to the Principal Drainage Line (Kms) =Lb [Hajam,2013]
Basin slope Sb	Sb = H / Lb Where H and Lb= given above [Miller,1953]

SOURCE: Map -based analysis, 2015

RESULTS AND DISCUSSION

The various morphometric parameters of the lower Enyong Creek basin were determined and are summarized in Tables 2 - 4.

Linear Aspects of the Channel System

The linear aspects of drainage network such as stream order (Nu), bifurcation ratio (Rb), stream length (Lu) results are presented in Table 2.

Stream Order (Nu)

In the drainage basin analysis the first step is to determine the stream orders. In the present study, the channel segment of the drainage basin has been ranked according to Strahler's stream ordering system. According to Strahler (1964), the smallest fingertip tributaries are designated as order 1. Where two first order channels join, a channel segment of order 2 is formed; where two of order- 2 join, a segment of order- 3 is formed; and so forth. The trunk stream through which all discharge of water and sediment passes is therefore the stream segment of highest order. The study area has two 4th order drainage sub-basins, viz; four order-3, nine order-2 and twenty seven order-1 (appendix a-b). The total number of forty two streams were identified, this did not include over four order-2 sub-catchments found in the lower Enyong Creek that contributed runoff directly into the main Enyong Creek (including the anabranching rivers west of Obio Usiere (figure 1). Detailed field work confirmed that the sand-dominated ridge forming anabranching streams are characterized by sub-parallel channels separated by narrow, steep-sided sand ridges stabilized by vegetation with moderate stream powers (Udosen, 2015).

Table 2: Some Morphometric parameters in Lower Enyong Creek

Stream order	Total number of streams (Nu)	Total stream length (Lu)	Log Nu	Log Lu	Mean bifurcation ratio
1	**27**	**25.6**	**1.43**	**1.41**	
2	**9**	**17.25**	**0.95**	**1.24**	**2.58**
3	**4**	**23.05**	**0.60**	**1.36**	
4	**2**	**13.5**	**0.30**	**1.13**	

Source: Map-Based analysis of toposheet Ikot Ekpene 322NE (2016)

Drainage patterns of stream network from the basin have been observed as mainly dendritic type which indicates structural control of Enugu-Okigwe escarpment. The orientation of the order-3 sub-catchments is tangential to Enugu-Okikwe cuesta, with clear evidence of higher bifurcation near source while stream abstraction down-slope is through elongation of order-3 channels It would recalled that this pattern is characterized by a tree like or fernlike pattern with branches that intersect primarily at acute angles. Some parts of the basin represent parallel pattern indicating that the topographical features are dipping and folded around the ridge near the headwaters. A parallel drainage pattern consists of tributaries that flow nearly parallel to one another and all the tributaries join the main channel at approximately the same angle. Parallel drainage suggest that the area has a gentle, uniform slopes and with less resistant bed rock.

Conversely, a radial drainage pattern forms when water flows downward or outward from a hill or dome. The radial drainage pattern of channels can be linked to a wheel consisting of a circular network of parallel channels flowing away from a central high point (Jensen, 2006). The properties of the stream networks are very important to study the landform making process (Strahler and Strahler, 2002).

Relationships between Stream order (Nu) and stream number

Horton,1945) laws of stream numbers states that the number of stream segments of each order form an inverse geometric sequence when plotted against order, most drainage networks show a linear relationship, with small deviation from a straight line. The plotting of logarithm of number of streams against stream order is given in Figure 2, according to the law proposed by Horton gives a straight line. This means that the number of streams usually decreases in geometric progression as the stream order increases.

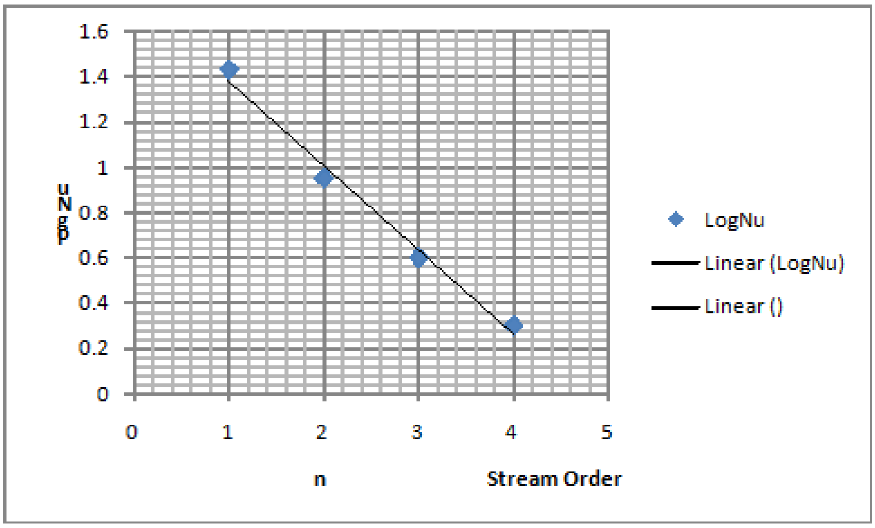


Figure 2.; Regression of logarithm of number of streams versus stream order,

Bifurcation Ratio (Rb)
The term bifurcation ratio (Rb) is a measure of drainage texture and expresses the ratio of the number of streams of any given order to the number of streams in next higher order (Schumn, 1956). Bifurcation ratios characteristically range between 3.0 and 5.0 for basins in which the geologic structures do not distort the drainage pattern (Strahler, 1964). Strahler (1957) demonstrated that bifurcation ratio shows a small range of variation for different regions or for different environment dominates. The mean bifurcation ratio value is 2.58 for the lower Enyong Creek (Table 2) which indicates that the geological structures have less impact on the drainage pattern. This suggests that the study area has low potentials for discharge compared to those of highland areas with bifurcation ratio of 5.0 (Oruonye et al, 2016)

Stream Length (Lu)
Stream length is a major linear parameter and one of the most significant hydrological features of the basin as it reveals surface runoff characteristics (Oruonye et al, 2016). We do know that streams of relatively smaller lengths are characteristics of areas with steeper slopes and finer textures. Longer lengths of streams are generally indicative of flatter gradients. Generally, the total length of stream segments is maximum in first order streams and decreases as the stream order increases. The number of streams of various order in the sub-basin were counted and their lengths from mouth to drainage divide were measured with the help of GIS software. Plot of the logarithm of stream length versus stream order (Figure 3) showed the non-linear pattern which indicates the heterogeneous rock material subjected to differential weathering and erosion characteristics of the basin.

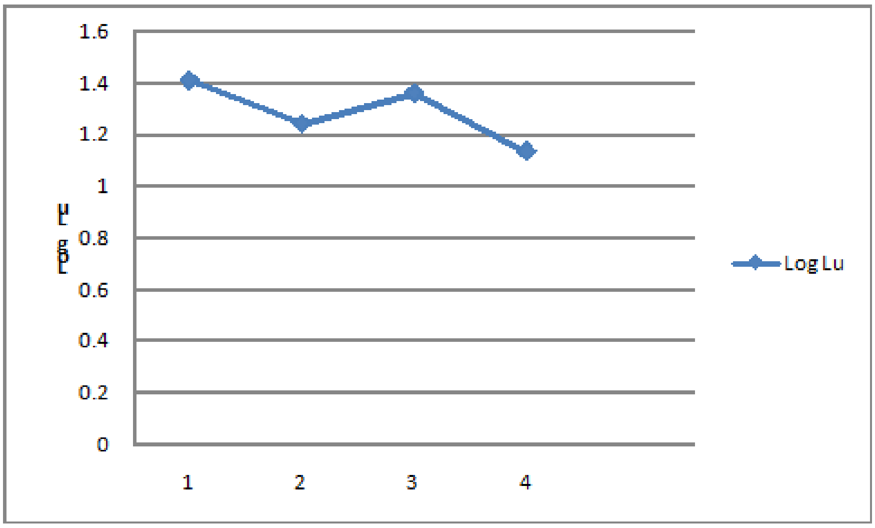


Figure 3: Regression of logarithm of stream lengths versus stream order

This apparent deviation from its general behavior indicates that the order-3 stream segments are long terrain due to marked variation in lithology and topography.

Areal Aspects of the Drainage Basin

Area of a basin (A) is an important parameter in quantitative morphology and previous studies indicate that basin area correlates with virtually all other catchment morphometric parameters Ebisemiju, 1987 and Udosen, 2009).. The area of the basin is defined as the total area projected upon a horizontal plane contributing to cumulate of all order of basins. Perimeter is the length of the boundary of the basin which can be drawn from topographical maps. Basin area is hydrologically important because it directly affects the size of the storm hydrograph and the magnitudes of peak and mean runoff. It is interesting that the maximum flood discharge per unit area is inversely related to size of catchment (Chorley, et al., 1957). The aerial aspects of the drainage basin such as drainage density (D), stream frequency (Fs), texture ratio (T), elongation ratio (Re), circularity ratio (Rc) and form factor ratio (Rf) were calculated and results are presented in Table 3.

Table 3: Areal Aspectsof Lower Enyong Creek

Basin area	Stream frequency	Drainage density	Infiltration number	Mean Length of Overland flow	Basin relief	Stream gradient
18.88	**0.53**	**1.29**	**1.00**	**0.80**	**91.4m**	**1^o**
15.25	**0.72**	**1.06**	**0.76**	**0.97**	**122m**	**4^o**
12.69	**0.87**	**1.21**	**1.05**	**0.91**	**122m**	**4^o**
8.81	**0.91**	**1.12**	**1.02**	**0.47**	**146m**	**5^o**

Source: Map-Based analysis of toposheet Ikot Ekpene 322NE(2016)

Drainage Density (D)

Horton (1932), introduced the drainage density (D) as an important indicator of the linear scale of landform elements in stream eroded topography. It is the ratio of total channel segment lengths cumulated for all orders within a basin to the basin area, which is expressed in terms of km^{-2}. The drainage density indicates the closeness of spacing of channels, thus providing a quantitative measure of the average length of stream channel for the whole basin. It has been observed from drainage density measurements made over a wide range of geologic and climatic types that a low drainage density is more likely to occur in regions of highly resistant and highly permeable subsoil material under dense vegetative cover, and where relief is low as in the Lower Enyong Creek (very coarse drainage densities of 1.06-1.29km/km^2).. Smith (1950), have classified five different drainage textures related to various drainage densities as very coarse (below 2), coarse (2 - 4), moderate (4 - 6), fine (6 - 8) and very fine (8 and above). High drainage density, on the other hand, is the result of weak or impermeable subsurface material, sparse vegetation and mountainous relief. Low drainage density leads to coarse drainage texture while high drainage density leads to fine drainage texture (Strahler, 1964).

Length of Overland Flow

Length of overland flow is simply the length of flow path, projected to the horizontal, non channel flow from point on the drainage divide to a point on the adjacent stream channel (Horton,1945). Horton, for the sake of convenience, had taken it to be roughly equal to half the reciprocal of the drainage density. Overland flow is significantly affected by infiltration and percolation through the soil, both varying in time and space. In this study, the length of overland flow of the Lower Enyong Creek drainage basin ranges from 0.60km to 0.89jkm, which shows moderate surface run

Stream Frequency (Fs)

Stream frequency or channel frequency (Fs) is the total number of stream segments of all orders per unit area (Horton, 1932). The stream frequency values of the sub-basins in the Lower Enyong Creek ranges from 0.53 to 0.91. The value of stream frequency (Fs) for the basin collaborates the lower values of drainage density indicating the decrease in stream population with respect to drainage density. Both values of stream frequency and drainage density show that Lower Enyong Creek basin has a low relief and by implication has a low response to surface runoff

Infiltration Number (IF)

Infiltration number is synonymous with Faniran's index of drainage intensity (Faniran,1969). Infiltration number (If), is an important factor in the drainage morphometric analysis, which is depending on the underlying lithology, infiltration capacity and relief aspect of the terrain. In the present study the infiltration number of the basin ranges from 0.6 to 1.05 and is categorized as moderate to low in nature.

Relief Aspects

The computed values for basin relief and gradient of main channels are indicative of moderate relief and gentle slopes respectively. The basin relief increases from 91m to over140m above mean sea level with corresponding slopes of 1^o to 5^o. it is quite apparent from the hypsometric curve in figure 4 that erosion can still occur in the low to moderate terrains of Idim Uye,(as there is enormous potential energy for erosion on steep sided-valleys.

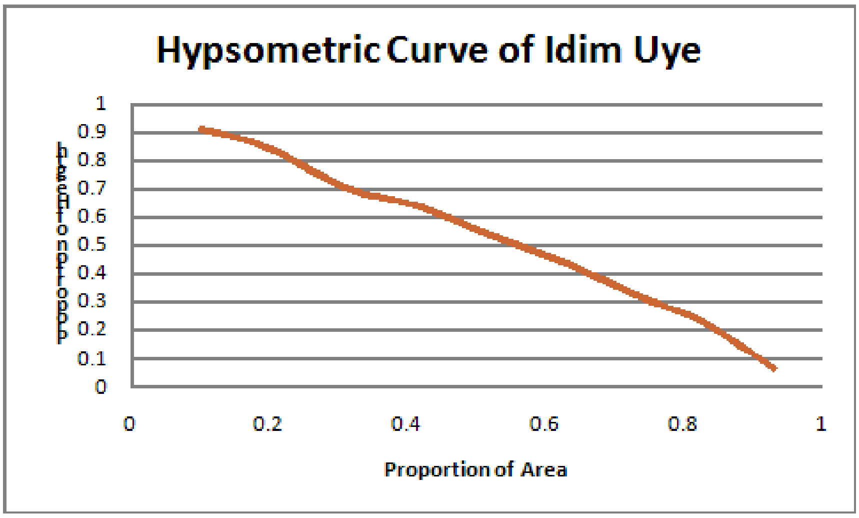


Figure 4: Hypsometric curve of Idim Uye sub-catchment

Elongation Ratio (Re)

Schumm (1956) used an elongation ratio (Re) defined as the ratio of diameter of a circle of the same area as the basin to the maximum basin length. It is a very significant index in the analysis of basin shape which helps to give an idea about the hydrological character of a drainage basin. Elongation ratio determines the shape of the basin and can be classified based on these values as circular (0.9 - 1), oval (0.8 – 0.9), less elongated (0.7 – 0.8), elongated (0.5 – 0.7), more elongated (< 0.5). Values near to 1.0 are typical of regions of very low relief (Strahler, 1964). The Re of the lower Enyong Creek ranges from 0.55 to 0.83 indicating the low relief of the terrain with elongated sub-catchments (appendix a-b) Elongated drainage basins have low side flow for shorter duration and high main flow for longer duration and are less susceptible to flood hazard (Oruonye et al, 2016).

Table 4: Linear aspects of the drainage network of the study area

Serial number	Form factor	Elongation ratio	Circularity ratio	Lemniscate K-factor
1	0.29	0.61	0.57	0.86
2	0.28	0.55	0.19	0.90
3	0.61	0.71	0.27	0.41
4	0.38	0.83	0.25	0.66
mean	0.39	0.68	0.32	0.71

Source: Map-Based analysis of toposheet Ikot Ekpene 322NE(2016)

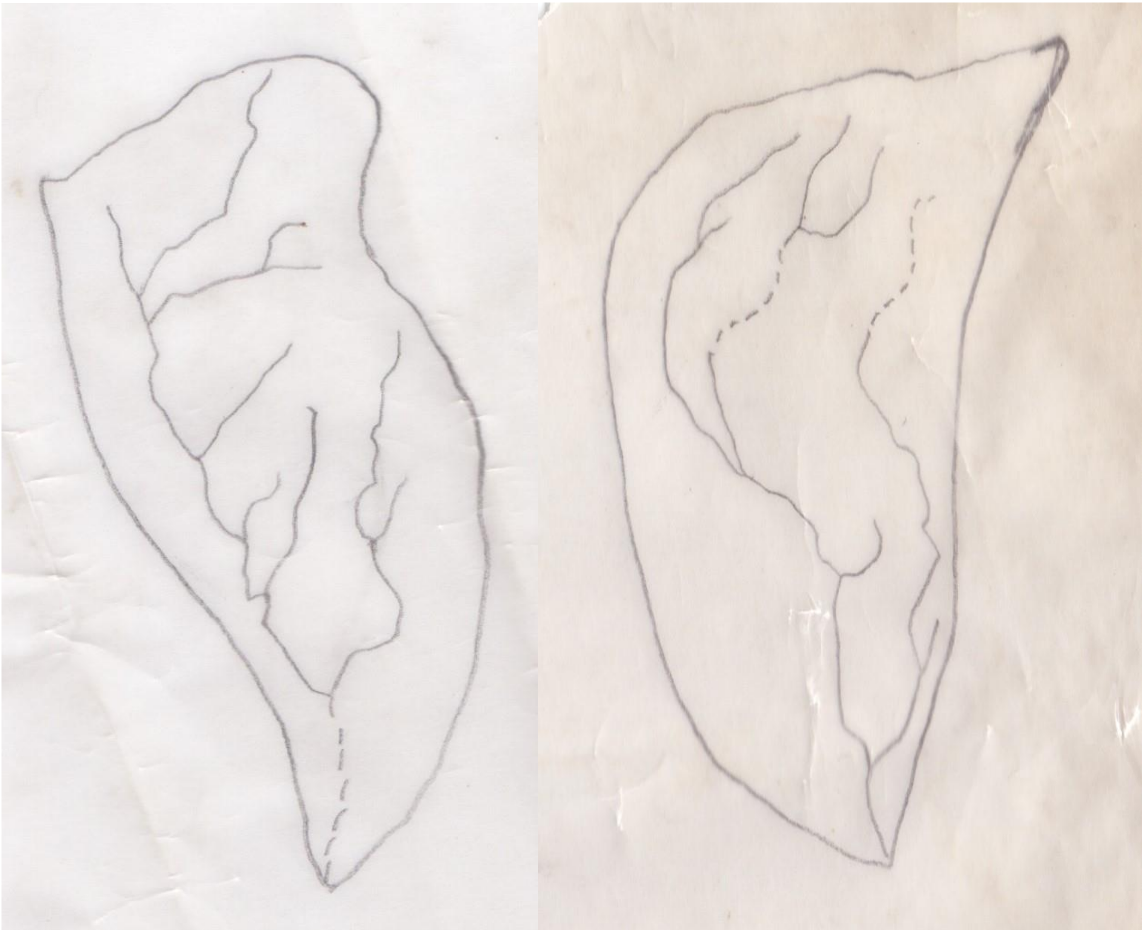
Circularity Ratio (Rc)

Miller (1953) defined a dimensionless circularity ratio (Rc) as the ratio of basin area to the area of circle having the same perimeter as the basin. He noted that the basin circularity ratios range from 0.4 to 0.5 which indicates strongly elongated and highly permeable homogenous geologic materials. The circularity ratio value (0.19-0.57) of the basin corroborates the Miller's range which indicates that the basin is elongated in shape with low discharge of runoff.

Form Factor Ratio (Rf)

Quantitative expression of drainage basin outline form was made by Horton (1932) through a form factor ratio (Rf), which is the dimensionless ratio of basin area to the square of basin length. Basin shape may be indexed by simple dimensionless ratios of the basic measurements of area, perimeter and length (Singh, 1998). The form factor value of the basin varies from 0.2 9 to 0.61 which indicate lower value of form factor and thus represents elongated in shape. The elongated basin with low form factor indicates that the basin will have a flatter peak of flow for longer duration (Plate 1). Flood flows of such elongated basins are easier to manage than of the circular basin.

Plate 1: Flatter peak-flow of longer duration



CONCLUSIONS

The quantitative analysis of morphometric parameters is found to be of immense utility in river basin evaluation, watershed prioritization for soil and water conservation, and natural resources management at micro level. The morphometric analysis carried out in the lower Enyong Creek shows that the basin is having low basin or local relief, very coarse texture, permeable bedrock and elongated in shape. Drainage network of the basin exhibits dendritic pattern but the law of drainage composition relating stream order to total stream length is non-linear, which indicates the heterogeneity in texture and strong structural control in some parts of the basin. Similar studies in conjunction with high resolution satellite data is strongly recommended for the upper Enyong Basin to better understand the evolution of landforms and their processes and drainage pattern demarcations for catchment planning and management.

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3rd order sub-catchment in lower Enyong Creek