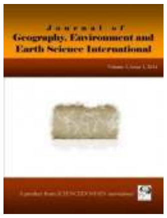

Journal of Geography, Environment and Earth Science International

13(3): 1-12, 2017; Article no.JGEESI.38699
ISSN: 2454-7352

Dimensional Basin Morphometry and Discharge in the Coastal Plains Sands of Ikpa River, Akwa Ibom State, Nigeria

I. S. Umo[1,2*], M. N. Ezemonye[2], M. C. Ike[1] and A. I. Enwereuzor[1]

[1]Department of Geography and Environmental Studies, Alvan Ikoku Federal College of Education, Owerri, Nigeria.
[2]Department of Geography and Regional Planning, University of Benin, Nigeria.

Authors' contributions

This work was carried out in collaboration between all authors. Author ISU designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author MNE designed the study and managed the analyses of the study. Authors MCI and AIE managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JGEESI/2017/38699
Editor(s):
(1) Kaveh Ostad-Ali-Askari, Department of Civil Engineering, Isfahan (Khorasgan) Branch, Islamic Azad University, Iran.
(2) Masum A. Patwary, Geography and Environmental Science, Begum Rokeya University, Bangladesh.
Reviewers:
(1) Lazarus A. Mbaya, Gombe State University, Nigeria.
(2) Suheyla Yerel Kandemir, Bilecik Seyh Edebali University, Turkey.
Complete Peer review History: http://www.sciencedomain.org/review-history/22851

Original Research Article

Received 8th December 2017
Accepted 13th January 2018
Published 24th January 2018

ABSTRACT

This article investigates the relationship between discharge and dimensional morphometry in Ikpa River Basin. Five-dimensional morphometric parameters were generated using topographic maps (sheet 322 NE; sheet 322 SE; sheet 323 SW; and sheet 331 NW) with Geographic Information System of the basin area. Six sub-basins were selected using stratified sampling method, gauged and discharge computed for descriptive and multivariate analyses. The descriptive analysis of discharge characteristics using percentages and ranks revealed remarkable variation between dry season 80.45 cubic meters per second representing 31.3 percent and rainy season 128.21 cubic meters per second representing 68.7 percent of the average seasonal discharge. A Linear Regression Model of the effect of stream frequency, basin intensity, relative perimeter, stream length, and basin area on mean total discharge yielded a coefficient of 0.998 representing 99.8 percent of the influence of dimensional morphometric parameters on discharge in Ikpa River

**Corresponding author: E-mail: umohikpong@yahoo.com;*

Basin. ANOVA was employed for the test of significance at $(0.05)_{5/2}$ confidence level. The computed F value yielded 79.044 and the F Table value of 19.30. This paper established that discharge in Ikpa River Basin is significantly influenced by stream frequency, basin intensity, relative perimeter, stream length, and basin area. This paper concluded that the prevalent seasonal flooding in the estuarine and erosion in the non-estuarine areas of the basin is associated with the nature of dimensional morphometry. Hence there is need for more studies on relief and shape parameter so as to identify appropriate (structural and non-structural) management options for the fluvio-geomorphologic hazards in the basin area.

Keywords: Dimensionality; morphometry; river basin; discharge; geomorphologic hazard.

1. INTRODUCTION

River is one of the most pivotal geo-physical agents of land sculpturing in the Tropics but its vitality on the land modification and discharge characteristics usually relate to the specific morphometric parameters, prevailing climate, nature of vegetation, geology, and landuse. It is usually acknowledged among geographers and geomorphologists in particular that the vitality of any geomorphic unit (especially drainage basin) depends on the interactions between existing landforms and the prevalent processes operating in such unit. According to [1] drainage basin is a structural form of geomorphologic systems which collect the water of precipitation and turnout sediment as a result of runoff processes. It has been viewed as a fundamental geomorphic unit through which precise description of the geometry and processes of landforms could be harnessed because data could be collected, organized and analyzed [2]. Such data usually deepen the idea on appropriate monitoring, predicting and even mitigating geomorphological and hydrological hazards (notably peak-flood discharge, erosion, and mass movement).

Basin morphometry according to [3] represents the measurement and mathematical analysis of the configuration of the earth's surface and of the shape and dimension of its landforms. In some cases, the dimensional morphometric parameters especially basin area, stream length, length of overland flow, mean stream length, perimeter, relative perimeter, relief, stream frequency, basin intensity, and basin texture often exert varying degree of influences on the river discharge that is operational in a river basin over a period of time. Understanding of such statistical relationships between discharge and morphometry of small and medium river basins within the Tropics will enhance the timing and mitigation of the impacts of flood events that have caused considerable losses to life and property in due to climate variability in the area.

In an assessment of monthly stream-flow forecasting using Gaussian process regression [4] observed that the capability to provide accurate and reliable stream-flow forecasts over a flow regime has a direct impact on not only water allocation policies but also sustainable economic development in a given watershed. Although their study yielded strong persistence of stream-flow predictability in the extended period, the low-predictability basins tend to show more variations. Since the 20th century, the needs for a greater awareness and understanding of the analytical techniques employed have been emphasized by [5,6] in both morphometric and discharge studies. Hence, distinct multivariate statistical tools have been employed in researches to evaluate the effects of areal, linear, form, and relief morphometric variables on river discharge at both basin and regional scales.

Ezemonye et al. [7] established the relationships among sixteen geomorphometric parameters of Ikpa River using principal component analysis and analysis of variance. Their study emphasized the need to determine the relationship between basin geomorphometry and discharge in order to predict the fluvio-geomorphologic hazards prevalent in the basin area. Amidst of the observation, attempt to determine the effect of specific geomorphometry on discharge in ungauged river basins of the coastal plain sands deposits are very few [8] or not accessible.

For instance, [9] applied factor analysis and analysis of variance in assessing the relationship between basin area, stream length, relief and others on gully threshold in Ikpa River. [10] carried out correlation analysis of basin density, basin intensity, basin area, stream length and others on discharge and land use in Calabar River while [11] evaluated the relationship of rainfall characteristics, runoff and relief parameters in Iba Oku River with success.

Discounting for the differences in statistical tools, local geomorphology, geologic formations and anthropogenic interferences in the studied basins in Nigeria; each finding tends to affirm strong positive or negative relationship between gully intrusion in Ikpa River Basin [12]; discharge and land use on morphometric parameters in Calabar River [10]; discharge and morphometry [8]. However, one of the issues associated with the outlined studies is that morphometric parameters were often derived from secondary sources (topographic maps, aerial surveys etc) and computed using the manual method which is vulnerable to human errors in representing the topographic features of the basin area.

Within the past two decades, few studies on the relationships of river basin morphometry and/or discharge have been conducted using state of the art technologies such as Geographic Information System (GIS), Remote Sensing and other geospatial software packages in various river basins. Hence, [12] established that the estimation of various morphometric parameters can be handled easily and more accurately with the use of GIS tools to determine their relationships or modelled discharge and storm events using geomorphologic Instantaneous Unit Hydrograph, Soil Conservation Services, Snyder and Triangular models.

In an assessment of correlation between Martian basin morphology and climate, [13] constructed a similarity map of the 43 Andean basins using hypsometric curves and other methods. However, their result failed to reveal any correlation between basin class and its geographical location, elevation, or relief with climate. To them, future work is needed to ascertain whether different classes of Martian basins' morphologies can be tied to their other physical properties.

In a study of variability of hydrological losses with the characteristics of rainfall and antecedent wetness conditions in South Australian Catchment [14] introduced two monographs to determine the IL when a minimum of two independent variables were available. Their results encourage practitioners to utilize multiple data sets to estimate losses, instead of using hypothetical or representative values to generalize real situations.

In Ethiopia, [15] studied the temporal and spatial variations in rainfall and stream flow in the Upper Tekeze–Atbara river sub-basin using 9 stream flow and 21 rainfall stations. Analyses using Mann–Kendall and Pettitt tests revealed a decreasing trend in the dry season, short season (March to May), with increasing trend rainy season and annual totals were dominant in six out of the nine stations.

Litty et al. [16] compared morphometric properties such as river gradient, catchment size and discharge of each drainage basin against measured grain properties of Peruvian coastal River Basins. Although their results yielded better sorted and less spherical material in the South when compared to the North, no correlations were found between the grain size and the morphometric properties of the river basins. The functionality of any drainage basin discharge usually depends on the basin morphometry, climate, geology, vegetation, and land use. In Kerlang River Valley of Malaysia, [17] studied the effect of basin morphometry on minimum low flow discharge. Though each scope was not comprehensive and sample size small, correlation and regression analyses revealed that minimum flow discharge was dependent on basin area, stream length, stream frequency, and maximum relief. Their findings led to the conclusion that changes in any of the dependent variables would affect their role as basin regulator would influence discharge.

But, rainfall amount usually exerts very strong influence on discharge volume across seasons in the Tropics. For instance, base flow often persists during dry season while peak flow is associated with the rainy season. In a scenario where such basin is not gauged, it is difficult to predict their reaction at a unit time. Our interest is on the influence of dimensional morphometric parameters (of basin area, stream length, stream frequency, basin intensity, and relative perimeter) on Ikpa River discharge (which is the quantity of water that passes through a particular location at a given time unit in a drainage basin as emphasized in [18].

1.1 Aim and Objectives of the Study

The aim of this paper is to evaluate the relationship between dimensional morphometric parameters and discharge in Ikpa River. Achieve the aim, the following are specific objectives: (1) To determine the dimensional morphometric variables of Ikpa River basin; (2) To assess the characteristics of discharge in Ikpa River Basin; (3) To analyze the influence of dimensional morphometric parameters on discharge in Ikpa River Basin.

1.2 Hypothesis

This study is built on a null hypothesis that "discharge is not significantly influenced by dimensional morphometric parameters of stream frequency, basin intensity, relative perimeter, stream length, and basin area in Ikpa River Basin".

2. DESCRIPTION OF THE STUDY AREA

2.1 Locations

Ikpa River basin is located in the Northeast of Akwa Ibom State, South-south Nigeria (Fig. 1) and occupies a total area of 512.75 km^2. Absolutely, the Ikpa River Basin is located between longitude 7º46^{1}34.9^{ll} and 8º3^{1}11.9^{11}, East of Greenwich Meridian and latitudes 5º0^{1}3.801^{l1} and 5º16^{1}49.129^{11}, North of the Equator [7]. The basin drains Uyo, the State Capital, Ini, Ikono, Ibiono Ibom, Itu and Uruan and other Local Government Areas within the State.

2.2 Geology and Pedogeomorphology

The Ikpa River Basin has a homogeneous geologic (sedimentary) formation of tertiary and quaternary times. It is basically underlain by coastal plains sands [7,9]. The tertiary sedimentary formations comprise mainly of the coastal plains sands which are the older tertiary rocks (Benin formation) and are more prevalent in the upper and middle parts of the River Basin Obotme, Ibiono Ibom and Itu. The quaternary rocks which formed the River beds and are made of recent deposits of fluvial sediment which are most common in the downstream area of Uyo, Uruan and Ufak Effion areas in Akwa Ibom State.

In terms of pedogeomorphology of the study area, three dominant soil types in the basin area are sandy, clay and loamy. However, [19] stressed that the monohydrate of ferric oxides, goethite, and the anhydrous oxides, hematite are some of the crystallized minerals formed in soils on the coastal plains sands. Thus, most of these minerals exist as the coating on other particles rather than as discrete units [20]. The coastal plains sands are fluvio–lacustrine (tertiary marine deposits) in origin and must have been laid down under conditions which were subject to frequent and rapid changes [9]. There are evidence of recent quaternary deposits of coarse sand and alluvium along the river valleys, Ufiak Effion and the region where Ikpa River enters the Cross River in Edik Ifiayon [8].

2.3 Climate and Vegetation

The Ikpa river basin has a mean annual rainfall of 2443.3 mm with double maxima based on rainfall data of 1977 to 2007. The rainy season lasts between the months of April to October while the dry season usually falls between the

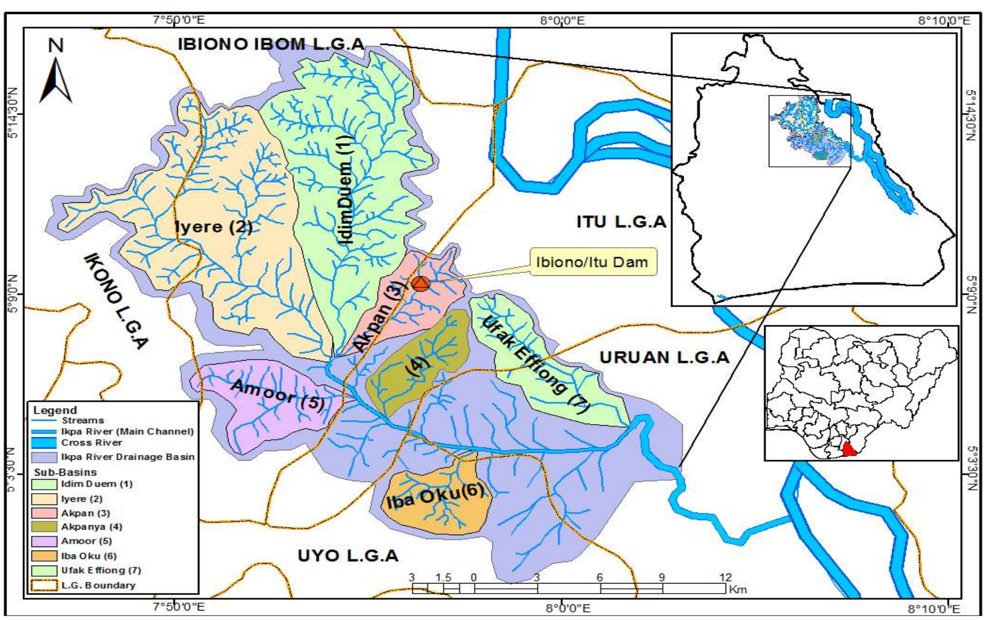

Fig. 1. Relief of Ikpa River Drainage Basin (Extracted from USGS DEM, 2016)

months of November to May annually. The peaks of rain always occur during the months of July and September every year [8,9]. The mean monthly temperature of the area is around 27℃ with a range of about 5℃, but changes do occur based on the season. The average maximum temperature is 31℃ (February) and the coldest month (July) temperature falls below 24℃ [11]. Evaporation in the area is equally high depending on the temperature. The relative humidity within the basin area is often high, ranging from 80 to 100 percent, but decreases with the increase in temperature. Based on the Koppen's climatic classification systems, the study area has a Humid Tropical Climate.

The vegetation comprises of the tropical rainforest belt. Most of the climax vegetation has been altered by widespread human activities like urbanization in the State/Local Government Areas and farming practices around the sub-urban and rural communities of the State. Essentially, the natural forest now exists majorly along the coasts and stream channels as either gallery or riparian vegetation at locations away from human settlements [8]. Dominant species include palm tree, iroko, gmelina, rubber, raffia palm, obeche, shrubs, herbs and others. Over 70% of the palm plantations in the area are made of local varieties.

3. MATERIALS AND METHODS

3.1 Determination of Dimensional Morphometric Parameters

Although there are many operational procedures involved in a quantitative evaluation of fluvial landform properties in geomorphological literature, [21] makes some useful observations when he stated thus:

> *"A conceptual image of the landform must be translated into measurable attributes that represent the concept satisfactorily, and can be quantified with accuracy, precision, and reproducibility. Thus a rigorous operational definition is essential, and this must consider: (a) delimitation of the landform boundary; (b) the quantitative index itself; (c) the sampling scheme required to define a representative subset of the relevant population; (d) the appropriate and available data sources and methods of measurement and; (e) the measurement procedures and practices"* [21].

Drawing from the above viewpoint, Ikpa River Basin was delineated using Strahler [22] ordering scheme. In the [22] scheme, two first-order stream segments join to formed a second-order stream; similarly, two second-order streams join to form a third-order stream and so on [23,24,25]. The basin was classed into six strata using stratified sampling technique for the determination of dimensional morphometric parameters and discharge. However, the morphometric parameters were generated using topographic maps (of Ikot Ekpene sheet 322 NE; Ikot Ekpene sheet 322 SE; Uwet sheet 323 SW; and Calabar sheet 331 NW) each produced on a scale of 1:50,000 by the Federal Survey Department in Nigeria. The topographic maps were rectified and geo-referenced with the help of Arc-GIS 9.0 software assigning Universal Transverse Mercator (UTM), World Geodetic System (WGS dating from 1984 revised in 2004) and 32N Zone Projection System [see 26]. Based on these, the six sampled sub-basins {Idim Duem(1), Iyere Stream(2), Akpan Stream(3), Itam Stream(4), Amoor Stream(5) and Iba Oku Stream(6) were delineated, digitized and the dimensional morphometric parameters computed using the formula presented in Appendix A.

3.2 Determination of the Periodic Discharge and Method of Data Analysis

Discharge observation and recordings in the lkpa River Basin were taken three times a week throughout the sampled sub-basins (see Fig. 1) and their average for each month computed in meter per cubic second to integrate periodic changes. These were done starting from the onset, through the middle and toward the end of each (dry and rainy) season using instruments such as tape/ranging poles, graduated steel band and their velocity over time in cubic meters per second (m^3sec) using a stopwatch.

The procedures adopted include: division of each stream into five segments; followed by the determination of the cross-sectional area (depth multiplied by cross channel bank) for each of the sampled streams at a distant of 12 meters apart, where the stream channel was relatively straight and free from obstruction on meander belt and others on the bank [27]. The velocity was measured by means of the surface float for the five segments, with the measured mean flow velocity taken and multiplied by 0.85 to overcome errors emanating from the effects of wind and cross currents [8,9,28]. The formulas are expressed as follow:

Discharge (Q) = AV. Where A = Cross Sectional Area; V = Velocity

Cross sectional area = [Sum of Stream Segment along transacts {i.e. points a + b + c +d +e}] ÷ Total Stream Segment

Where;

a, b, c, d and e = average depths of the different segments.
XY = Two measurement points at the stream width. Velocity (V) = Flow Distant/Time.

For testing the null hypothesis one that states as follows: Discharge is not significantly influenced by the dimensional morphometric parameters of stream length, basin area, stream frequency, basin intensity and relative perimeter in Ikpa River Basin.

A multiple linear regression model was used to examine the influence of the five morphometric parameters on discharge and test for the significance using ANOVA. The formula for linear regression model is expressed as thus:

$$Y = a + b_1 X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5 X_5 + e$$

Where,

Y = discharge; a = constant value; b_1 to b_5 = beta coefficients; X_1 to X_5 = dimensional morphometric parameters; e = standard error of estimate.

The rationale for the choice of multiple linear regression model in analyzing the influence of the five-dimensional morphometric parameters on discharge is based on the fact that, it is considered an appropriate tool used to account for variations in dependent variable (discharge) on the linear combination of independent variables (morphometric parameters); estimate errors associated with the model; and to generate an equation which provides estimate of one variable on the others [29].

4. PRESENTATION AND DISCUSSION OF RESULTS

4.1 Assessment of Discharge Characteristics in Ikpa River Basin

Detailed monthly and seasonal measurements of discharge within the six sub-basins in Ikpa River are summarized in Tables for comparative and descriptive purposes of the dry season, rainy season and mean seasonal discharge.

The monthly variation in dry season discharge is calculated and presented on Table 1. Result reveals that December records the highest total discharge of 82.29m^3/sec, followed by February 81.39 m^3/sec and March (77.66 m^3/sec). Variations also occur between the individual watersheds. Sub-basin 1 records the highest total discharge of 119.91 m^3 /sec and ranks 1st, followed by sub-basin 2, with a total of 44.49 m^3/sec and ranks 2nd. Others were sub-basins 3, 5 and 6 each records a total of 27.02 m^3/sec, 31.50 m^3/sec, and 16.17 m^3/sec respectively, while sub-basin 4 records 2.24 m^3/sec and rank 6th in the series.

The monthly variation in rainy season discharge is presented on Table 2. The monthly total discharge for rainy season designates that highest amount for the period is associated with September (213.77 m^3 /sec), followed by July (163.89 m^3 /sec) and then June (152.51 m^3 /sec). The monthly contribution of each stream to total discharge indicates that sub-basins 1 and 2 record a total of 269.33 m^3/sec and 106.81 m^3/sec respectively. Other sub-basins 3, 4, 5 and 6 record a total of 47.38 m^3/sec, 4.00 m^3/sec, 72.0 m^3/sec and 30.25 m^3/sec respectively. There is no difference in terms of ranking of discharge for the two seasons and hence sub-basins 1, 2 and 5 ranked 1st, 2nd and 3rd while sub-basins 3, 6 and 4 ranked 4th, 5th and 6th respectively.

Table 1. Dry season discharge within the sampled sub-basins (m^3/sec)

Sub-basin	December	February	March	Total	Rank
1. Idim Duem	38.89	38.89	42.13	119.91	1st
2. Iyere	15.28	17.70	11.49	44.49	2nd
3. Akpan	9.89	9.05	8.11	27.02	4th
4. Itam	1.19	0.50	0.55	2.24	6th
5. Amoor	11.46	9.84	10.20	31.50	3rd
6. Iba Oku	5.58	5.41	5.18	16.17	5th
Total	82.29	81.39	77.66	241.33	

Table 2. Rainy season discharge within the sampled sub-basins (m^3/sec)

Sub-basin	June	July	September	Total	Rank
1. Idim Duem	86.57	79.39	103.37	269.33	1st
2. Iyere	24.31	31.89	50.61	106.81	2nd
3. Akpan	11.42	16.91	19.05	47.38	3rd
4. Itam	1.07	1.41	1.52	4.00	6th
5. Amoor	22.16	24.36	25.37	71.89	4th
6. Iba Oku	6.98	9.93	13.85	30.76	5th
Total	152.51	163.89	213.77	530.17	

The seasonal mean and the percentage of discharge variations are presented on Table 3. The results indicate wide seasonal variations between the sub-basins that make up Ikpa River. Sub-basin1 and 2 records mean total of 129.75 m^3/sec and 80.45 m^3/sec each. Those for sub-basins 3, 4, 5 and 6 are 24.80 m^3/sec, 2.08 m^3/sec, 34.51 m^3/sec and 15.64 m^3/sec respectively. The overall average discharge for the sub-basins 1, 2 and 5 range from 64.88m^3/sec, 25.22 m^3/sec and 17.26 m^3/sec to as low as 1.04 m^3/sec for sub-basin 4 respectively. Similarly, the average discharge for sub-basin 3 and 6 are 12.40 m^3/sec and 7.82m^3/sec. Sub-basin 1 ranks first with 50.4%, sub-basin 2 ranks second with 19.6%, sub-basin 5 ranks third with 13.4%, sub-basin 3 ranks fourth with 9.7% sub-basin 6 and 4 rank fifth and sixth respectively. These results tend to affirmed [15] observation of decreasing trend in the dry season, short season (March to May), with increasing trend rainy season and annual totals in six out of their nine stations.

4.2 Influence of Dimensional Morphometric Parameters on Discharge

The influences of five distinct dimensional morphometric parameters on mean total discharge in Ikpa River Basin were evaluated using multiple linear regression model and the result summarized on Tables 4 and 5. On Table 4, a combined influence of independent variables (stream frequency, basin intensity, relative perimeter, stream length and basin area) on a dependent variable (discharge) in Ikpa River is examined using linear regression model. The result of the model summary reveals that Coefficient of Multiple Determination (R) is 0.999, which suggests a very high positive influence of the five morphometric parameters on discharge. The R square of 0.997 indicates that 99.7% of the proportion of variance in discharge is associated with (accounted for by) stream frequency, basin intensity, relative perimeter, basin area and stream length in Ikpa River Basin. This finding affirms [10,17] observation that low flow discharge was dependent on basin area, stream length, stream frequency, and others in spite of variations in locational, and morphological attributes. Similarly, the adjusted R square of 0.985 suggests 98.5 percent of the influence of selected morphometric parameters. The standard error of estimate of dispersion connected with the model is 2.562.

Analysis of Variance (ANOVA) was employed to test for significance of the combined influence of five morphometric parameters on discharge variation. The result presented on Table 4 yields that sum of squares associated with the regression is 2595.528; those associated with the residual is 6.565, while the total sum of squares associated with the model is 2601.092. Similarly, the computed F-value is 79.044. The F Table value tested at $(0.05)_{5/2}$ confidence level is 19.30. From the computation, the null hypothesis is rejected, while the alternative hypothesis is accepted. It is therefore concluded that “discharge is significantly influenced by stream frequency, basin intensity, relative perimeter, stream length and basin area in Ikpa River Basin”.

Table 6 provides a partial regression coefficient of each morphometric variable on discharge. Unstandardized Coefficients of B reveals 91.264 for a constant value, 35.068 for stream frequency, -58.303 for basin intensity, -3.382 for relative perimeter, 2.059 for stream length and -1.817 for basin area. The Standardized beta Coefficients yield 0.372 for stream frequency, -1.372 for basin intensity, -0.469 for relative perimeter, 4.324 for stream length and -3.425 for basin area. From the standardized beta coefficient, the influence of each of the five-dimensional morphometric parameters on discharge is modelled in equation one using a multiple linear regression. The standard error (e) yielded 2.562.

Table 3. Mean discharge variations in Ikpa River Basin (m^3/sec)

Sub –Basin (stream)	Dry season	Rainy season	Mean total discharge	Average discharge	Percent (%)	Rank
1. Idim Duem	39.97	89.78	129.75	64.88	50.4	1st
2. Iyere	14.83	35.60	50.43	25.22	19.6	2nd
3. Akpan	9.01	15.79	24.80	12.40	9.7	4th
4. Itam	0.75	1.33	2.08	1.04	0.8	6th
5. Amoor	10.50	24.01	34.51	17.26	13.4	3rd
6. Iba Oku	5.39	10.25	15.64	7.82	6.1	5th
Total	80.45	176.76	257.21	128.61	100	

Table 4. Summary of multiple regression model of basin discharge and morphometry

Model	R	R square	Adjusted R square	Std. error of estimate
1	0.999	0.997	0.985	79.044

Table 5. ANOVA model of influence of dimensional basin morphometry on discharge

Model		Sum of squares	df	Mean square	F
1	Regression	2595.528	5	518.906	79.044
	Residual	6.565	2	6.565	
	Total	2601.092	7		

Table 6. Regression and correlation coefficients

Model	Unstandardized coefficients		Standardized Coeff.	T	Sign.	Correlations	
	B	Std. error	Beta			Zero order	Partial
1 Constant	91.264	12.290	……..	7.426	0.085	….	….
Stream frequency	35.068	16.819	0.372	2.085	0.285	0.220	0.902
Basin intensity	-58.303	8.329	-1.372	-7.000	0.090	0.088	-0.990
Relative perimeter	-3.382	0.499	-0.469	-6.781	0.093	0.033	-0.989
Stream length	2.059	0.175	4.324	11.761	0.054	0.849	0.996
Basin area	-1.817	0.189	-3.425	9.639	0.066	0.765	-0.995

$$Y = 91.246 + 0.372x_1 - 1.372x_2 - 0.469x_3 + 4.324x_4 - 3.425x_5 + e.$$

Where;

x_1 is stream frequency; x_2 is basin intensity; x_3 is relative perimeter; x_4 is stream length; and x_5 is relief ratio while e is standard error of estimate.

Table 6 also provides the (zero order) partial correlation coefficient (r) for each of the five morphometric variables and their significance values are as follows: stream frequency (0.220 and 0.285), basin intensity (0.88 and 0.090), relative perimeter (0.033 and 0.093), stream length (0.849 and 0.054) and basin area (0.765 and 0.066) respectively. From the correlation coefficients, it is clear that stream length and basin area exert higher influence on discharge and their regression planes rise above the line of best fit. The positive coefficients suggest that a rise in a given unit of any of the independent variables while holding others constant, will likely attract a corresponding increase in the unit of discharge and vice versa. This finding shows a high level of conformity to that of [10] for Calabar River and [17] for Kerlang River Valley of Malaysia, in spite of the differences in statistical packages, local geomorphology, and area of coverage in each study.

5. SUMMARY OF FINDINGS AND CONCLUSION

5.1 Summary of Findings

In the preceding section, discharge characteristics in Ikpa River Basin have been assessed descriptively. The descriptive analysis of discharge characteristics using percentages revealed remarkable variations between dry season 80.45 cubic meters per second representing 31.3 percent and rainy season 128.21 cubic meters per second representing 68.7 percent of the seasonal discharge which implies that seasonality of climatic (rainfall) events and the basin size played a dominant role in amount and duration of discharge in the basin. Also, wide variations existed among the sampled sub-basins with 64.88 of the average discharge in cubic meters per second (representing 50.4 percent) of the basin originating from Duem Stream; and Iyere stream contributing 25.22 cubic meter per second (19.6%), thus making a total of 70 percent. The remaining 30 percent of the discharge are generated from Amoor (13.4%), Akpan (9.7%), Iba Oku (6.1%) and Itam (0.8%) sub-basins respectively. The implication is that Duem and Iyere streams exert very strong influence on the fluvial processes of the basin.

A multiple linear regression model was used to examine the influence of dimensional morphometric parameters (stream frequency, basin intensity, relative perimeter, stream length and basin area) on discharge. The coefficient of multiple determination (R) indicates a high positive influence of 0.999. The R square of 0.997 implies that 99.7% of the proportion of variance in discharge is associated with the five-dimensional morphometric variables. ANOVA was employed for the test of significance at $(0.05)_{5/2}$ confidence level. The computed F value was 79.044 compared to the F Table value of 19.30. Therefore, the null hypothesis was rejected and alternative hypothesis accepted. It is concluded that “discharge in Ikpa River Basin is significantly influenced by stream frequency, basin intensity, relative perimeter, stream length, and basin area”. The implication is that as catchment size increases; the fluvial discharges become more closely determined by the local geomorphology. For instance, increase in basin size attracts increase in stream length and the corresponding long duration for discharge accumulation. Consequently, rainy season often affects the discharge characteristics by intensifying the magnitude, frequency and duration of flood events in the downstream which is a recurrence geomorphic hazard in the area and have caused various degrees of losses to farm and household property of residents [9] especially in Okpoto, Ididep Usuk, Uruan, Ufak Ofiong, and other communities of the Ikpa River Basin in recent time.

Table 6 offered the influence of individual morphometric parameters on discharge variation in Ikpa River. The linearized equation indicated that stream length and basin area exercise more influences on discharge and were significant at 0.05 confidence level in the series. The partial correlation for zero order of each of the dimensional parameters on discharge yielded positive influence. This positive influence implies that an increase in any of the dimensional variables will lead to a correspondent rise in discharge and vice versa. More succinctly, the positive effect implies that every increase in an independent variable by a given unit while holding others constant, there will be a corresponding rise in the discharge of the basin by a certain unit. Also, the result of the negative partial regression implies that decrease in a morphometric variable by a given unit while other factors remain constant will lead to an increase in discharge by a given unit and vice versa. These findings suggest that fluvial response to watersheds changes in response to variations in the dimensional morphometric variables.

5.2 Conclusion and Recommendations

In consideration of the preceding viewpoints therefore, it is established that periodic discharge characteristics in Ikpa River have strong affinity with the variations in seasons. The minimum-flow discharge prevalent during the dry season with the lowest recorded in February as depicted in Table 1); and peak-flood discharge in the basin area occurs during the rainy season (with the highest recorded in September as shown in Table 2). Similarly, the multiple linear regression and ANOVA models yielded that average discharge and dimensional morphometric parameters of basin area, stream length, basin frequency, basin intensity and relative perimeter in Ikpa River basin are strongly correlated. The implication is that a change in any of the dimensional morphometric parameter attracted a corresponding change in the discharge within the Ikpa River Basin. Furthermore, the findings are indications of the high incidences of upstream erosion and downstream flooding in the Ikpa River Basin. There is urgent need for further studies on dimensionless morphometry parameters so as to determine the influence of relief and shape parameters on discharge in the basin area. Proper knowledge of the dimensional and dimensionless basin morphometric parameter will facilitate the development of appropriate (structural and non-structural) management options for the erosion/flood hazards in the basin area.

ACKNOWLEDGEMENT

We sincerely acknowledged the suggestions from the three reviewers whose comments contributed immensely in improving the quality of this paper, and those from Mrs Agnes Umoren and Mr Obot Ibanga as well as other researchers whose works are referenced in this article.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Jeje LK. Drainage basin development and environment. In G.E.K. Ofomata (ed.) Perspective of Environmental Problems and Management in Nigeria. 2001;53–68.
2. Chorley RJ. Drainage basin as the fundamental geomorphic unit. In RJ Chorley (ed) Water, Earth and Man: A Synthesis of Hydrology, Geomorphology and Socio-economic Geography. London, Methuen. 1969;77– 100.
3. Clarke JI. Morphometry from maps. In GH Dury (ed.) Essays in Geomorphology,. New York, Elsevier. 1966;235–274.
4. Sun AY, Wang D, Xu X. Monthly stream-flow forecasting using Gaussian process regression. Journal of Hydrology. 2014; 511:72–81.
5. Richards KS. Introduction to morphometry. In Gouldie et al. (ed.) geomorphological techniques. Second Edition edited for the British Geomorphological Research Group. 1990;37–38.
6. Strahler AN. Quantitative analysis of watershed geomorphology. Transactions of American Geophysics Union. 1957;38:913–920.
7. Ezemonye MN, Umo IS, Ojinma CC, Ike MC, Enwereuzor AI. Geomorphometric parameters of Ikpa River and its implications for the planning of fluvial hazards in the Northeast of Akwa Ibom State. Journal of Geography, Environment and Earth Science International. 2017; 11(1):1-12.
Available:http://dx.doi.0.9734/JGEESI/2017/34674
8. Umo IS. Drainage basin morphometry and discharge in Ikpa River, Akwa Ibom State, Nigeria. Unpublished MSc. thesis, Department of Geography, University of Benin; 2014.
9. Udosen CE. Gully erosion in Ikpa river basin: A threshold phenomenon. Lagos, Time Communication; 2008.
10. Effiong J. Drainage basin morphometry, land use and discharge in Calabar River basin, Cross River State, Nigeria. Unpublished Ph.D. Thesis, University of Calabar; 2010.
11. Udosen CE. Rainfall pattern in Iba Oku River Basin, Akwa Ibom State and its implication on stream flow regimes. Journal of Scientific Research. 2012; 2(2):31-40.
12. Amry MD, Mohammadi AA. Regional model for peak discharge estimation in ungauged drainage basin using GIUH, Snyder, SCS and triangular Models. International Journal of Water Resources and Environmental Engineering. 2012; 4:86-96.
Available:http://dx.doi.org/10.5897/IJWREE11.153
13. Stepinski TF, Stepinski AP. Morphology of drainage basins as an indicator of climate on early Mars. Journal of Geophysical Research. 2005;110,E12S12.
Available:http://dx.doi/10.1029/2005JE002448
14. Gamage SHPW, Hewa GA, Beecham S. Modelling hydrological losses for varying rainfall and moisture conditions in South Australian catchments. Journal Of Hydrology: Regional Studies. 2015;4:1–21.
Available:http://dx.doi.org/10.1016/j.ejrh.2015.04.005
15. Gebremicael,TG, Mohamed YA, Zaag PV, Hagos EY. Temporal and spatial changes of rainfall and streamflow in the Upper Tekeze–Atbara river basin, Ethiopia. Hydrology and Earth System Science. 2017;21:2127–2142.
Available:http://dx.doi/10.5194/hess-21-2127-2017
16. Litty C, Schlunegger F, Viveen W. Multiple controls on sediment grain properties of Peruvian coastal river basins. Earth Surface Dynamics Discussions; 2017.
Available:http://dx.doi.org/10.5194/esurf-2017-8
17. Yunus AJM, Nakagoshi N, Salleh KO. The effect of drainage basin morphometry on minimum flow discharge: the study of small watershed in Kerlang River Valley in Peninsular Malaysia. Journal of Environmental Sciences. 2003;15(2):249–262.

18. Montgomery CW. Environmental geology (6th ed). Boston, McGraw Hill; 2003.
19. Peters SW, Iwoke AR. Akwa Ibom State: The land of promise. In E.O. Uya (ed.) Lagos, Gabumo Publisher; 1994.
20. Lekwa G. Characteristic and classification of genetic sequence of soils in the coastal plains sands of Eastern Nigeria. Unpublished Ph.D. Thesis, Michigan State University, USA.
21. Richards KS. General problem in morphometry. In Gouldie et al (ed.) geomorphological techniques. Second edition edited for the British Geomorphological Research Group. 1990;39–48.
22. Strahler AN. Hypsometric analysis of erosional topography. Bulletin of the Geological Society of America. 1952;63:1117–1142.
23. Jesuleye IA, Okeke UH, Atijosan AO, Badru RA, Adewoyin JE, Alaga AT. Morphometry assessment of Oba River Basin and its implications for flood. Journal of Geography, Environment and Earth Science International. 2016;8(3):1-10.
24. Zăvoianu I. Morphometry of drainage basins (Developments in Water Science), Amsterdam, Elsevier Science; 1985.
25. Zăvoianu I. Relationships between suspended sediment load discharge and the total number and length of stream segments. Journal of Geography and Regional Planning, 2013;6(2):31-40.
26. Hajam RA, Hamid A, Bhat S. Application of morphometric analysis for geo-hydrological studies using geo-spatial technology –a case study of Vishav drainage basin. Hydrological Current Research. 2013;4: 157.
Available:http://dx.doi.org/10.4172/2157-7587.1000157
27. Agor R. Advanced surveying: A textbook for practicing Engineers and Surveyors. New Delhi, Khanna Publishers. 2008;430-446.
28. Horton RE. Erosional development of streams and their drainage basins: hydrophysical approach to quantitative morphology. Geological Society of America Bulletin, 1945;56:275–370.
29. Gupta SP. Statistical methods. New Delhi, Sultan and Sons; 2009.
30. Horton RE. Drainage basin characteristics. Transaction of America Geophysical Union. 1932;13:350–361.
31. Strahler AN. Quantitative geomorphology of drainage basin and channel networks," in Handbook of Applied Hydrology, V. T. Chow, Ed., McGrawHill, NewYork, NY, USA; 1964.

APPENDIX A

Parameter/Symbol	Formula & interpretation	Reference
Basin order (Sμ)	Hierarchical rank	[22,31]
Basin perimeter (P)	P = Outer boundary of drainage basin measured in (Km)	GIS
Basin area (A)	Area from which water drains to a common stream and boundary determined by opposite ridges.	GIS,
Basin Length (Lμ)	Summation of Length of the streams (kilometers)	GIS
Mean Stream Length	Lsm = Lμ/Nμ Where, Lμ = Total stream length of order 'μ' and Nμ = Number of stream segments of order 'μ'	[6,22,31]
Stream Frequency (Fs)	Fs = Nμ/A; Where, Fs = Drainage frequency. Nμ = No. of streams of all orders; A = Basin area (Km^2).	[30]
Basin density (D_b)	Db = Lμ/A; Where Lμ = Total stream length of all orders; A = Area of the basin (Km^2).	[30]
Length of overland flow (Lf)	Lf =1/2D; Where, D=Drainage density (Km/Km^2)	[29]
Relative Perimeter (Pr)	Pr = P^2/Au; where P^2 = Square of the perimeter; Au = Area of the Basin.	[8,10]

© 2017 Umo et al.; This is an Open Access article distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history/22851