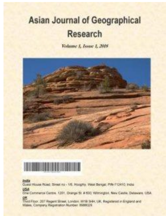

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Dimensionless Geomorphometry and Discharge in the Ikpa River Basin, Nigeria

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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. Authors MCI and IGU managed the analyses of the study. All authors read and approved the final manuscript.

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ABSTRACT

This study evaluates the relationships between dimensionless basin geomorphometry and discharge in the Ikpa River. The basin was stratified into seven sub-units using [1] scheme. Geospatial tools were used in generating data for the digital elevation model, while dimensionless geomorphometric parameters were generated from topographic maps (sheet 322 NE; sheet 322 SE; sheet 323 SW; and sheet 331 NW) of the basin area drawn on a scale of 1.50,000. The sampled sub-basins were gauged and discharge measured by a surface float. Graphical analysis of discharge revealed wide variations between months and in seasons across sub-basins with the rainy season attracting highest volume of discharge and the corresponding fluvial processes. The regression analysis yields a coefficient of multiple determination (R) of 0.937, signifying a very high effect expressed by 87.8 of the proportion of variance in dimensionless geomorphometric parameters on discharge in Ikpa River Basin. Also, the computed F value yields 1.439, while the Table value tested at $(0.05)_{5/2}$ confident level offers 19.30. The result led to the conclusion that variations in relief ratio, average bifurcation ratio, circularity ratio, elongation ratio and form factor have a significant effect on discharge in Ikpa River Basin. This paper recommends for prompt installations of state of the art river gauging and

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monitoring facilities to provide the needed information to the government, researchers, and individuals for the sustainable land and watershed development options (dam and irrigation) in the coastal plain of Ikpa River basin.

Keywords: River basin; geomorphometry; dimensionless parameter; discharge; coastal plain.

1. INTRODUCTION

It is usually argued among contemporary physical geographers and earth scientists that the emergent of landforms in a given geomorphologic unit depended on the prevalent processes that acted on them over a period time and in space. For [2] perspective, the present landscapes have evolved through the Tertiary and Quaternary, and often retain the imprint of previous sub-aerial and marine processes. Hence relicts of depositional surfaces possess the potential for geochronological interpretation through the sedimentary structures. Besides, [3] observes that the definition of landforms of various sorts is an essential part of the geomorphological mapping.

A river basin is an integral part of landform that can be accurately delineated using emerging geospatial technologies {Geographic Information System, Remote Sensing, and Global Positioning System} as applicable in [4,5] with its specific geomorphometric (areal, linear, relief and form) parameters determine base on mathematical and allied equations. In fluvial geomorphology, each parameter plays important role in regulating discharge processes in a given basin [6].

Specific geomorphometry is the measurement and analysis of specific surface features defined by one or more processes and separated from adjacent parts of the land surface according to clear criteria of delimitation [Evans 1974 cited in 7]. The delineation of specific geomorphometry entails drawing a closed boundary at the divide that separates the basin from other basins as discussed in [3,8,9,10]. In the measurements of basin shape, an attempt is made to derive dimensionless indices which consist of compactness coefficient, elongation ratio, wandering ratio, fitness ratio, form factor, relief ratio, circularity ratio etc, and is useful in the prediction of basin form and process relationship [11].

The approaches of drainage basin morphologic division according to [8] are grouped into three categories: The first approach emanated from the geographers' interest in regional delimitation. The second approach was concerned with the identification of the physiographic atoms out of which the matter of regions is built. These atoms were topography forming the characters of the landscape. The third basis resulted from the unitary features of both geometry and process exhibited in the basin over a period of time as recognized by Playfair [8,12] in a quantitative study of specific landform.

The concept of drainage basin has remained a focal point in modern geomorphological inquiries especially with the introduction of fluvio-geomorphological and engineering approaches to quantitative morphology. It is this topographic, hydraulic and hydrologic unity of drainage basin that provided the basis for the morphometric system of [13] as transformed and elaborated by [1,14]. The systematic description of the shape and form of a drainage basin and its sub-basin networks require specific measurements of stream network characteristics and expressing as numerical ratio or linear scale measurements [14].

Geospatial technologies are a convenient method to study the geomorphometric characteristics as the satellite images provide detailed information of earth surface features with its synoptic coverage, high receptivity, cost-effectiveness [4] and have been applied in specific geomorphometric research [11]. But mathematical and statistical models are usually more useful for the analysis and prediction of relationships between dimensionless geomorphometry (landform) and discharge (surface processes) at a basin scale. Such models play a crucial role in understanding and predicting discharge and allied fluvio-geomorphologic hazards (erosion, flooding, and others) that have caused considerable damages to ecosystem, environment, and man in areas within the Humid Tropics [15-18].

However, attempts have been made to established the relationship between river basin discharge and dimensional geomorphometric parameters [16,19] but the influence of dimensionless variables especially relief ratio, circularity ratio, form factor, average bifurcation ratio, on discharge of ungauged basins still require more attention [10,19] in geomorphologic, geographic, and allied science literature because of their effects in regulating the duration and volume flow of surficial processes within a specific landform. Similarly, [7] observed that computer analysis makes the handling of multivariate indices comparatively simple, and new sources of high-quality data are emerging to complement this increased analytical capacity, but progress in research on specific geomorphometry may be dependent on the scholars' willingness to exploit new developments, and gain appropriate insights from it.

Many studies have pointed to the significant influence of basin elevation and morphology on River discharge and sediment fluxes but only a few mathematical relationships are available [20]. For process estimation, shape measurement based upon the distribution of area within the basin is probably more meaningful, and the method of [21] offers considerable potential. Besides, a greater potential may be realized if it becomes possible to recognize fluvio-geomorphologically active contributing area for a particular magnitude of discharge event, rather than employing the basin as defined by its perimeter.

Within this decade, several studies on the relationships of river basin morphometry and discharge have been conducted using state of the art technologies such as Geographic Information System (GIS), Remote Sensing and other geospatial software packages outside the basin area. [22] opines that the estimation of various morphometric parameters can be handled easily and more accurately by using GIS. However, the contributing sub-basin areas often vary based on the local factors such as basin size, surface configuration, land use, lithology, surface runoff, discharge volume, and others; hence infinite form and variety of river basins usually respond to basic geomorphologic laws exists in nature [22].

1.1 Objectives of the Study

The aim of this study is to evaluate the relationship between dimensionless basin geomorphometric parameters and discharge in Ikpa River, Northeast of Akwa Ibom State, Nigeria. To achieve aim, the following are the specific objectives: (1) to compare the discharge characteristic of Ikpa River Basin in Akwa Ibom State; (2) to analyze the association and correlations between dimensionless geomorphometric parameters (relief ratio, average bifurcation ratio, circularity ratio, elongation ratio and form factor) and discharge in Ikpa River Basin of Akwa Ibom State.

1.2 Hypothesis of the Study

This study is built on a null hypothesis that "the dimensionless geomorphometric parameters of relief ratio, average bifurcation ratio, circularity ratio, elongation ratio, and form factor have no significant effect on discharge in Ikpa River Basin, Nigeria".

2. DESCRIPTION OF THE STUDY AREA

2.1 Location and Relief

The Ikpa River is one of the 5th order tributaries of the Cross River. The basin is located in the Northeast of Akwa Ibom State, Eastern Niger Delta of Nigeria (Fig. 1). The Ikpa River Basin is located between longitudes $7^{0}46^{1}34.9^{II}$ and 8^{0} $3^{1}11.9^{I1}$, East of Greenwich Meridian and latitudes $5^{0}0^{1}3.801^{I1}$ and 5^{0} 16^{1} 49.129^{11}, North of the Equator [10,15,16,19]. The basin area covers parts of Ini, Ikono, Ibiono Ibom, Itu, Uruan and Uyo Local Government Areas of the Akwa Ibom State, Nigeria.

Relief of the basin comprises of undulating lowland of the coastal plains which form one of the eco-geomorphologic areas in the State. To [23], the terrain consists of the dissected coastal plains in the middle and Northern sections with an elevation of 100 – 150 meters a.s.l. especially in Duem, the steep slopes of the river valley with the height of 50 – 80 meters a. s. l), and a broad plain sloping gently toward the Cross River channel with elevation less than 50 meters a.s.l. The northern parts are traverse by undulating hills and other landforms of river erosion especially valleys, gorges, ravines, meanders etc; while the downstream areas are characterized by depositional landforms like terraces, floodplains, and ox-bow lakes. The details of Ikpa River Basin location and elevation attributes are summarized in Figs. 1 and Appendix 2).

2.2 Pedo-geomorphology and Climate

The soils in the basin area are loose, friable, unconsolidated ferrallitic in nature and are deficient in weatherable mineral reserves. The soils are mostly deep and possess loamy sand to sandy surface especially at the up and mid-stream areas due to the influence of the basin Geologic formations. The basin geology is

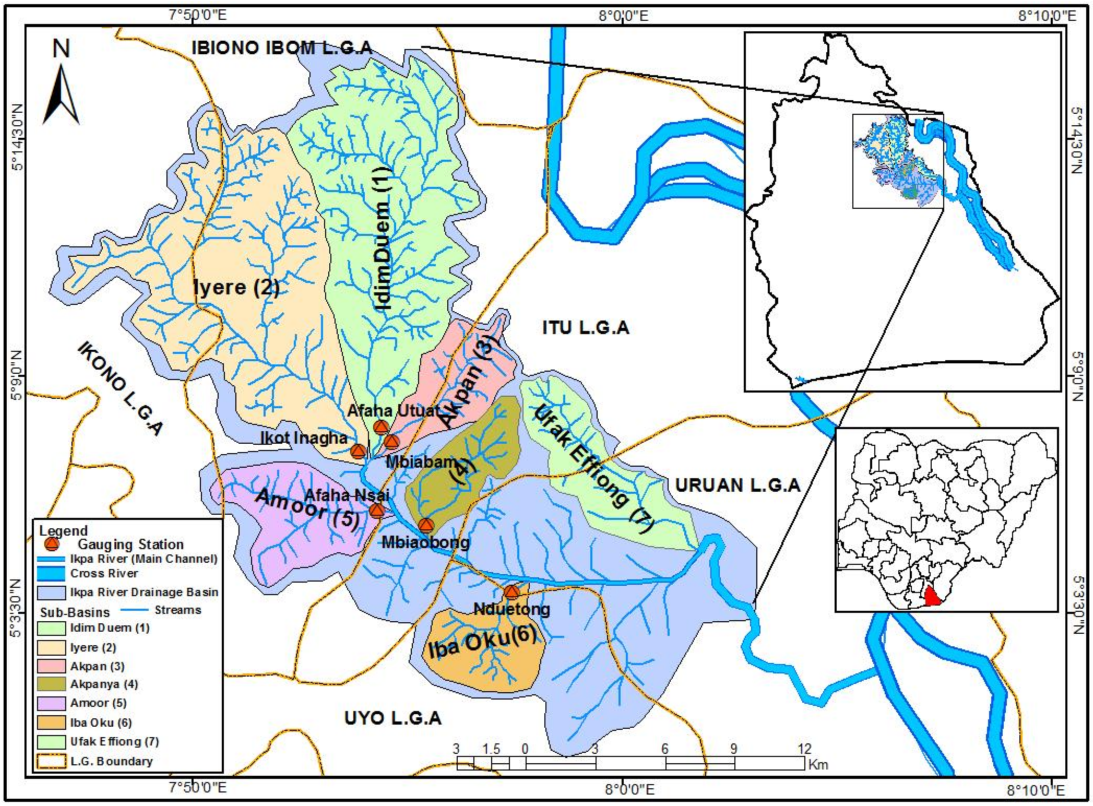

Fig. 1. Location of Ikpa River drainage basin (Extracted from USGS DEM, 2016)

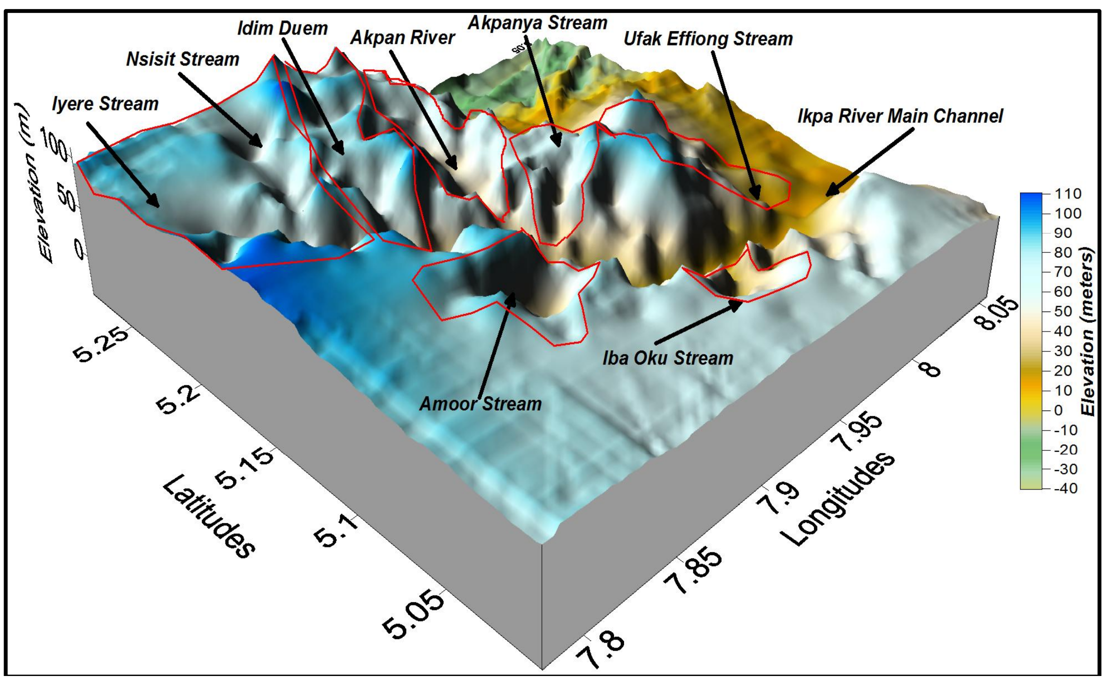

Fig. 2. The digital elevation model of Ikpa River basin
**Projection – perspective; field of view - 30^0; rotation – 45^0; and tilt at angle 35^0.*

underlain by coastal sands plains of Tertiary and Quaternary rocks of sedimentary formations. The Tertiary sedimentary rocks comprise mainly of the coastal plains sands which are the older tertiary rocks (Benin Formation) and are more prevalent at the upper and middle parts of the River Basin. The Quaternary deposits formed the River beds and are made of recent deposits of fluvial sediment/alluvium mostly in the downstream area of Odiok Itam, Ide Uruan, Mbiakpan, Afaha Nsai, and Eman Uruan Communities of Akwa Ibom State.

The climate the Ikpa River Basin is a tropical humid climate (Af) based on the Koppen's classification system. The basin area has a mean annual rainfall of 2443.3mm with double maxima [16,19,23]. The rainy season lasts between the months of April to October while the dry season usually falls between the months of November to March annually. The peaks of rain always occur during the months of July and September every year [23]. The mean monthly temperature of the area is around 27^{o}C with a range of plus/minus 5^{o}C, but changes do occur based on seasons. The average maximum temperature is 31°C (February) and the coldest month (July) temperature falls below 24°C [15,16]. 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 basically, decrease with the increase in temperature.

3. METHODOLOGY AND DATA

3.1 Determination of Dimensionless Geomorphometric Parameters

The Ikpa River Basin was delineated using [1] ordering scheme. The basin was classed into six strata for the generation of dimensionless geomorphometric parameters and measurement of discharge. The five dimensionless geomorphometric 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 sampled sub-basins are Idim Duem (1), Iyere Stream(2), Akpan Stream (3), Itam Stream (4), Amoor Stream (5), Iba Oku Stream (6), and Ufak Efion (7) as depicted in Figs. 1 and 2. The mathematical equations for computing each of the dimensionless geomorphometric parameter are summarized on Table 1.

3.2 Determination of Discharge

In Ikpa River Basin, regular observations and records of discharge were taken weekly and their mean determine for each month making a total of six months (three months each for the dry season and the rainy season) from the sampled sub-basins (see appendix 1). This was done starting from the onset, through the middle and toward the end of each season using instruments such as tape/ranging poles, graduated steel band and their velocity over time in cubic meters per second (m^3sec) using stopwatch (see Agor, 2008; Umo, 2014; Umo et al, 2018).

The procedures adopted for gauging the each sub-basin 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

Table 1. Selected dimensionless specific geomorphometric parameters

Dimensionless parameter	Mathematical formula (Equation)	Reference
Bifurcation Ratio	$Rb = N\mu/N_{\mu+1}$. Where, Rb = Bifurcation ratio; Nμ = No. of stream segments of a given order and $N_{\mu+1}$= No. of stream segments of next higher order.	[1,14]
Mean Bifurcation Ratio	Rba = Average bifurcation ratios of all orders.	[1,26]
Elongation Ratio	$Re= \sqrt{A/\pi}/Lb = 1.128A^{0.5}/Lb$; Where, A= Area of the basin; Lb = (Maximum) Basin length. π = 3.14	[10,24]
Circularity Ratio	$Rc = 4\pi A/P^2$; $= 12.57A/P^2$; Where, A = Basin area (Km^2) and P = Basin Perimeter.	[1,30]
Form Factor	$Rf = A/Lb^2$; Where A = Area of the basin and Lb = (Maximum) basin length.	[13,24,29}
Relief Ratio (Rr)	Rr = H / Lb Where, H = basin relief (m) and Lb = Basin length (m).	[24]

on the bank [16,25]. The velocity was measured by means of surface float using orange, for the three segments while the flow velocity was taken and the mean multiplied by 0.85 to overcome errors emanating from the effects of wind and cross-currents as recently emphasized in [19,26]. The formulas are expressed as follows:

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

Cross-sectional Area =

$$\frac{\text{Total Stream Segment (depth)}\{a + b + c + d + e\}}{\text{Total Stream Segment}}$$

Where; a, b, c, d and e = average depths of the different sub-segments.

XY = Total width of the stream at X beginning of the Cross-section, and Y end of the point of measurement. Velocity (V) = Flow Distant/Time.

3.3 Data Analysis and Hypothesis Testing

Discharge characteristic in the basin area was assessed descriptively using graphs. A multiple linear regression model was used to examine the effect of the five dimensionless geomorphometric parameters on discharge. ANOVA was used to test for significance of the combined effect of the five geomorphometric parameters on discharge variation. Correlation model was employed to assess the influence of individual geomorphometric parameter on discharge in the Ikpa River. The formula for linear regression model is expressed as follows:

$$Y = a + b_1 X_1 + b_2 X_2 + b_3 X_3 + b_4 X_4 + b_5 X_5 + e$$

Where Y = Discharge; a = Constant value; e = Standard Error of the estimate. b_1 to b_5= beta coefficients: X_1 to X_5 = Geomorphometric parameters.

The rationale for the choice of multiple regression model in analyzing the influence of the five dimensionless geomorphometric parameters on discharge is based on the fact that, it is often used to account for variations on dependent variable (discharge) on the linear combination of independent variables (morphometric parameters); estimate errors associated with a model; and to generate an equation which provides estimate of one variable on the others [see 27].

4. RESULTS AND DISCUSSION

4.1 Seasonal Variations of Discharge in Ikpa River

The periodic measurements of discharge within the sampled sub-basins in the Ikpa River are shown in appendix 1. The summaries for mean monthly and seasonal characteristics of discharge are presented as Table 2 and Fig. 3 in this section for comparative purposes. In Fig. 3, the monthly and average discharge reflect high variation in discharge amount between seasons with much proportion of flow occurring during the rainy season due to the intense rainfall events while dry season discharge volume tend to fall due to the influence of high temperature and evaporation in the basin area.

Similarly, variations in discharge characteristics are also observed across the sampled sub-basins in each month and in season. The Duem stream contributes the highest percentage of 50.4, followed by Iyere stream contributing 19.6 percent, thus making a total of 70 percent of the seasonal discharge as reflected in Table 2. The remaining sub-basins (Akpan, Itam,) accounted for only 30 percent of seasonal discharge in the Ikpa River basin. Similar finding has been reached by [15] in his analysis of rainfall pattern and runoff regime of Iba Oku River. However, the differences if that his study focused on longtime trend using time series, variance, and secondary data from the University of Uyo meteorological station.

4.2 Analysis of the Effect of Dimensionless Basin Geomorphometry and Discharge

The regression analysis of the multiple effects of relief ratio, average bifurcation ratio, circularity ratio, elongation ratio and form factor on discharge variation is presented on Table 3. The model result yields a coefficient of multiple determination (R) of 0.937 which is a very strong positive effect of the five geomorphometric variables on discharge in Ikpa River Basin. This is more evident as the R square of 0.878 indicates that 87.8 percent of the proportion of variance in discharge is attributed to the five independent variables while the remaining 11.2 percent could be accounted for by others factors like climate, vegetation, land use, geology and others that were not considered in this present

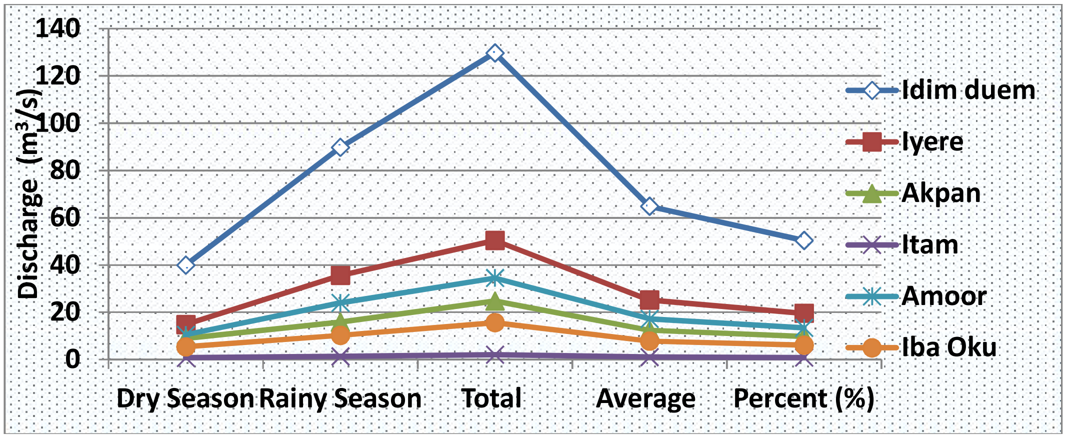

Fig. 3. Summary of seasonal discharge characteristics in Ikpa River basin (m^3/sec)

Table 2. Mean discharge variations in Ikpa River basin (m^3/sec)

Sub –basin (stream)	Mean dry season	Percent	Mean rainy season	Percent	Mean total discharge	Average discharge	Percent (%)
Idim Duem	39.97	49.68	89.78	50.80	129.75	64.88	50.4
Iyere	14.83	18.43	35.60	20.14	50.43	25.22	19.6
Akpan	9.01	11.20	15.79	8.93	24.80	12.40	9.7
Itam	0.75	0.93	1.33	0.75	2.08	1.04	0.8
Amoor	10.50	13.05	24.01	13.58	34.51	17.26	13.4
Iba Oku	5.39	6.70	10.25	5.80	15.64	7.82	6.1
Total	80.45	100	176.76	100	257.21	128.61	100

Table 3. Summary of the regression model

Model	R	R Square	Adjusted R Square	Std. Error of estimate
1	0.937	0.878	0.268	17.813

Predictors: (Constant), Form_Factor, Ave_Bifurc_Ratio, Circularity_Ratio, Elongation_Ratio, Relief_Ratio.

study. Similarly, the adjusted R square of 0.268 suggests that 26.8 percent of the total variation in discharge is influenced by the five independent variables alone. The standard error of estimate associated with the model is 17.813.

The analysis of variance was employed to test for a significant effect of the five dimensionless geomorphometric parameters on discharge in Ikpa River Basin. The result of the model presented on Table 4 reveals that the sum of squares associated with the model is 2283.775; the sum of squares associated with the residual yields 317.317, and the total sum of squares associated with the model offers 2601.092. The computed F value yields 1.439, while the Table value tested at $(0.05)_{5/2}$ confidence level offers 19.30. Therefore, the null hypothesis is accepted and inferred that variations in relief ratio, average bifurcation ratio, circularity ratio, elongation ratio, and form factor have no significant effect on discharge regime in Ikpa River Basin. This finding affirms [19] whose study of the basin dimensional attributes using ANOVA model led to the conclusion that discharge is influenced by Stream frequency, basin intensity, relative perimeter, stream length and basin area in the Ikpa River.

From Table 5, a partial regression coefficient is employed to assess the effect of each geomorphometric variables on discharge in Ikpa River Basin. The unstandardized coefficients of B yields as following: constant value (-60.658), relief ratio (-81.468), average bifurcation ratio (37.565), circularity ratio (8.263), elongation ratio (0.158), and form factor (-8.648). Similarly, the result of standardized coefficients for selected

Table 4. ANOVA model of basin morphometry and discharge

Model		Sum of squares	Df	Mean square	F
1	Regression	2283.775	5	456.755	1.439
	Residual	317.317	2	317.317	
	Total	2601.092	7		

Predictors: (Constant), Form_Factor, Ave_Bifurc_Ratio, Circularity_Ratio, Elongation_Ratio, Relief_Ratio

Table 5. Regression and correlation coefficients

Model	Unstandardized coefficients		Standardized Coeff.	t	Sign.	Correlations	
	B	Std. Error	Beta			Zero order	Partial
1(constant)	-60.658	105.499	…...	-0.575	0.668	….	….
Relief Ratio	-81.486	157.077	-0.463	-0.519	0.695	-0.332	-0.460
Average bifurcation	35.565	19.365	0.857	1.837	0.317	0.850	0.878
Circularity Ratio	8.371	137.936	0.055	0.061	0.961	-0.117	0.061
Elongation Ratio	0.158	8.263	0.010	0.019	0.988	-0.487	0.019
Form Factor	-8.648	25.639	-0.140	-0.337	0.793	0.056	-0.320

variables reveals that relief ratio is -463, average bifurcation ratio is 0.857, circularity ratio is 0.055, elongation ratio is 0.010 and form factor is -0.140. Based on these standardized beta coefficients, the multiple linear regression is modelled in the equation as thus:

$$Y = -60.658-0.453x_1+0.857x_2+0.055x_3+0.010x_4-0.140x_5 +e(17.813)$$

Where x_1 is relief ratio; x_2 is average bifurcation ratio; x_3 is circularity ratio; x_4 is elongation ratio and x_5 is form factor while e is the standard error of the estimate.

Table 5 shows the measurement of the strength of relationship of each geomorphometric parameter on discharge when others are held constant. First, only elongation ratio is significant at 0.05 confidence level. Secondly, the partial correlation coefficients for zero order reveals that average bifurcation ratio (0.850) and form factor (0.056) exercise positive influence while elongation ratio (-0.487) and relief ratio (-0.332) and circularity ratio (-0.117) exercised the negative influence on discharge variation. Therefore, the positive correlation suggest that an increase in a given unit of any of the independent variables while holding others constant will likely attracts a corresponding increase in the unit of discharge and vice versa; while the negative correlation is an indication that an increase in a given independent variable by certain unit will likely lead to a decline in the dependent variable and vice versa.

5. SUMMARY OF FINDINGS

The descriptive analysis of discharge depicted in Fig. 3 and Table 2 reveal remarkable variations in discharge characteristics across the sampled sub-basins in each month and in season. The Duem stream contributes the highest percentage of 50.4, followed by Iyere stream contributing 19.6 percent, thus making a total of 70 percent of the seasonal discharge as reflected in Table 2. The remaining sub-basin accounted for only 30 percent of seasonal discharge in the Ikpa River basin. This result suggests that the flow regime and fluvial processes (flood, sediment yield etc) are most prevalent in the Duem and Iyere streams, and is a crucial research domain for future researchers to explore their relationship.

From hypothesis one, the effects of five dimensionless geomorphometric parameters (relief ratio, average bifurcation ratio, circularity ratio, elongation ratio and form factor) on discharge in Ikpa River Basin was assessed using multiple linear regression model. The model summary reveals a very strong positive multiple coefficient (0.937) which represents 87.8% of the proportion of variance explained by the five dimensionless geomorphometric variables alone. A test of significance using ANOVA gave an F-value of 1.439, which is less than the Table value of 19.30. Surprisingly, the null hypothesis is accepted. It is concluded that variations in relief ratio, average bifurcation ratio, circularity ratio, elongation ratio and form factor have no significant effect on discharge in Ikpa River Basin. Thus, attesting to [19] observations that discharge is mostly control by dimensional parameters or [23] identification of land use, slope, geology, and vegetation in the Ikpa River Basin.

The implication is that other factors such as the geologic formation, vegetation, land use, rainfall, dimensional geomorphometry, and climate act as drivers of Ikpa River discharge. This finding is surprising considering the high combined effect of the regression model; hence it tends to debunk [6] observation at Maros River that basin shapes and relief parameters usually provide a better understanding of the fluvial processes because the ways in which floods are formed depend on it. The contradictory results could relate to the differences in basin size, level of local geomorphology, climate, analytical tools, and ideas. The linear regression equation of the effect of each dimensionless geomorphometric parameter was modelled as follows: $Y = -60.658 -0.463x_1 +0.857x_2 +0.055x_3 +0.010x_4 -0.140x_5$. From the linearized equation, relief ratio is x_1, average bifurcation ratio is x_2, circularity ratio is x_3, elongation ratio is x_4 and form factor is x_5.

The positive effect implies that every increase in an independent variable by a given unit while holding others constant, there will lead to a corresponding rise in the basin discharge by a given unit. Similarly, the result of the negative partial regression implies that decrease in a geomorphometric 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 of watersheds changes in response to spatial variations in the geomorphometric variables.

The elevation models presented as Fig. 2, affirmed [23] observation that the prevalence of gullies, ravines and sheet and other geomorphologic hazards on the upstream areas of Obotme, Ididep, Ikpa, Iba Oku, Nsan and others are due to the interactions between the high relief and discharges over time-scale. Similarly, flash flood events Okpoto-Ididep, Ide-Uruan and Ufak Effion are associated with low relief. Indeed, recent studies on the Ikpa drainage basin morphology conducted by [10,15,16] attested that the Ikpa River Basin is the product of normal erosional and climatic processes.

6. CONCLUSION AND RECOMMENDATIONS

There are clear indications from the regression model that a strong unity exists between dimensionless geomorphometric parameters and mean discharge in Ikpa River Basin with a predicted value of 87.8 percent (see Table 3). However, a test of significance of the relationship using ANOVA model led to the conclusion that periodic discharge in the Ikpa River Basin is not significantly influence by the basin dimensionless geomorphometry (see Table 4). It can be infer from the finding that other factors such as dimensional geomorphometry, rainfall, underlying geology, human interventions especially mining activities, flood plain agriculture may exercise influence on discharge in the basin as previously emphasized in [10,17,19,23]. Assessing from the digital elevation model (Fig. 2), the upstream and middle stream areas tend to possess elevations ranging from high to moderate which suggest that sub-basin discharge volume will also range from high to moderate. The work of erosion (hydraulic action, abrasion, attrition) and transportation are most likely to be dominant in the upstream which together trigger gully, channel migration and sliding activities on the coastal sedimentary deposits [23].

Within the down-stream where the discharge volume is high with low energy to transport loads, deposition is more prevalent and this invariably encourages sediment yield, silting of the channel, creation of ox-bow lakes, and flooding. It is concluded that any alteration on the pre-existing form-process relationships will likely attract a chain of reactions which may manifest in form of geomorphic and hydrologic disasters like erosion, flooding, land sliding and others because of the homogenous climatic and geologic formations in the basin area.

To guide against the prolong negative geomorphic and hydrologic responses as affirmed in various reports [10,15,16,19,23,28] regarding the Ikpa River basin, this paper recommend for prompt installations of state-of-the-art river gauging and monitoring facilities especially at Duem and Iyere streams that control a total of 70 percent of the seasonal discharge and allied activities in the Ikpa River basin area (see Fig. 3). Adequate data on fluvial discharge will provide appropriate information that will be crucial to the government, individual, geomorphologists, hydrologists, engineers, agriculturalists, and other scientists on how to enhance sustainable land and watershed development (e.g. dam/irrigation construction, and erosion control) in the Ikpa River basin. Such capital projects will boost crop productivities of the people in the area.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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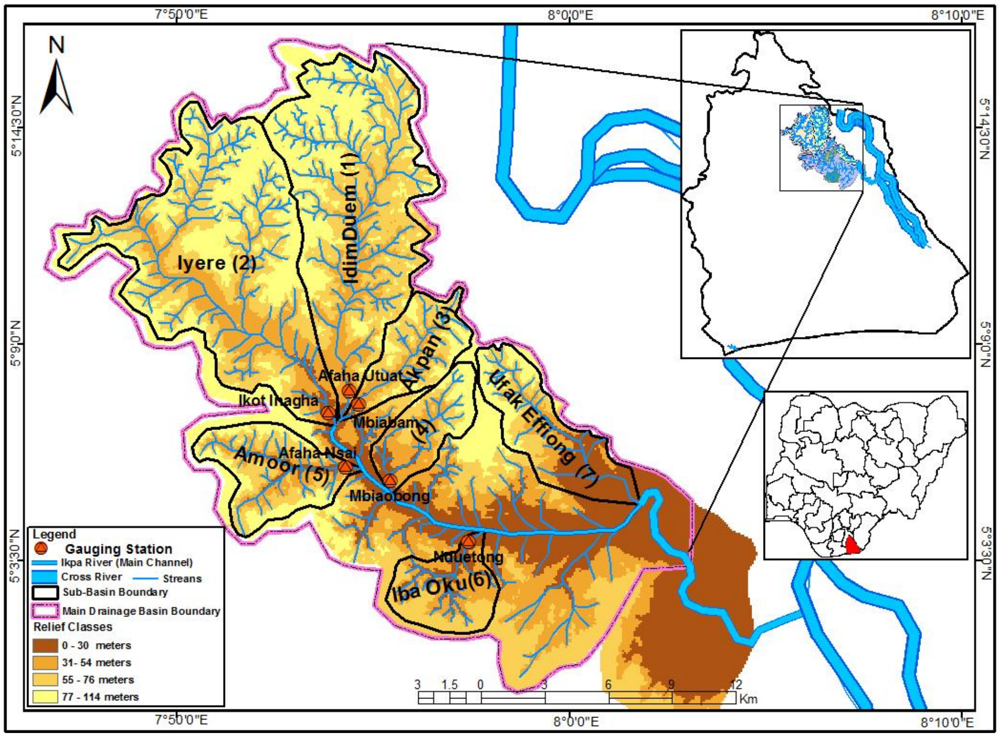
APPENDIX ONE

Summary of Weekly/monthly/Seasonal Basin Discharge (m^3s^{-1})

Sub-basins	December	February	March	June	July	September
1 (week 1)	14.57	10.25	8.90	17.84	21.42	26.50
2	3.50	5.21	2.29	4.99	6.93	12.25
3	2.78	2.48	2.34	3.28	3.86	4.55
4	0.66	0.13	0.12	0.28	0.22	0.50
5	2.83	2.21	1.76	5.06	6.18	5.75
6	1.32	1.33	1.22	1.65	2.21	3.30
1 (Week 2)	15.96	10.29	10.41	19.61	18.87	29.27
2	3.62	4.77	2.75	5.76	8.13	12.21
3	2.81	2.15	2.38	2.17	4.07	4.59
4	0.15	0.14	0.12	0.26	0.34	0.33
5	3.05	2.58	2.46	5.37	5.97	6.71
6	1.41	1.34	1.25	1.60	2.26	3.57
1 (Week 3)	14.63	9.96	12.13	21.40	18.89	23.29
2	4.12	4.39	3.09	6.40	7.36	10.40
3	3.15	2.26	1.60	2.61	4.74	4.94
4	0.18	0.11	0.15	0.26	0.35	0.38
5	2.74	2.45	3.37	6.28	6.18	6.74
6	1.35	1.44	1.43	1.66	2.48	3.77
1 (Week 4)	14.49	8.39	10.69	27.72	20.21	24.31
2	4.04	3.33	3.36	7.16	9.47	15.75
3	1.12	2.16	1.79	3.36	4.22	4.97
4	0.20	0.12	0.16	0.27	0.50	0.31
5	2.84	2.60	2.61	5.45	6.03	6.17
6	1.50	1.30	1.28	2.07	2.98	3.21

APPENDIX TWO



Relief of Ikpa River Drainage Basin (Extracted from 30m x 30m Resolution USGS DEM, 2016)

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