*International Research Journal of Earth Sciences* E-ISSN 2321–2527
Vol. **4(4),** 17-28, April **(2016)** *Int. Res. J. Earth Sci.*

# Morphometric Diversity on Kuya River Basin

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**Available online at: www.isca.in, www.isca.me**
Received 24th February 2016, revised 28th March 2016, accepted 18th April 2016

## Abstract

*Kuya river (176.4km. length) basin (1555.2sq.km.) is a tributary basin of Mayurakshi river flows from eastern edge of Chottanagpur plateau to gangetic plain of Murshidabad district. This paper mainly focuses on different Morphometric characters of the river basin and how these factors in together brings diversity in river basin. From the study, some remarkable findings are 1) basin is highly asymmetry in terms of area distribution at two sides of the main river (0.39). Basin shape is higly elongated as indicated by circularity ratio (0.30), sinuosity index of the main river is 1.71. Distinct differences in Morphometric characters are exist between upper and lower catchments. Upper catchment is more diversified than lower catchment. River basin is experiencing old stage of the cycle of erosion as indicated by hypsometric integral (0.36). Total number of variable employed for making spatial Morphometric diversity, relief parameters are more regulatory than others as found from principal component analysis.*

**Keywords:** Morphometric aspects, Basin asymmetry, Drainage parameters, Relief parameters, PCA, Weighted morphometric diversity.

## Introduction

Morphometry measuremes and mathematically analyzes the configuration of the earth's surface, shape and dimension of its landforms[1,2] . A major emphasis in geomorphology over the past few decades has been on the development of quantitative physiographic methods to describe the evolution and behaviour of surface drainage networks[2-4].

The quantitative analysis of morphometric parameters is of immense utility in river basin evaluation, watershed prioritization for soil and water conservation, and natural resources management at micro level. Geology, relief, and climate are the key determinants of running water ecosystems functioning at the basin scale[5]. Morphometric descriptors represent relatively simple approaches to describe basin processes and to compare basin characteristics[6] and enable an enhanced understanding of the geological and geomorphic history of a drainage basin[7]. A watershed is an ideal unit for management of Natural resources like land and water and for mitigation of the impact of natural disasters for achieving sustainable development. The morphometric assessment helps to elaborate a primary hydrological diagnosis in order to predict approximate behavior of a watershed if correctly coupled with geomorphology and geology[8]. The hydrological response of a river basin can be interrelated with the physiographic characteristics of the drainage basin, such as size, shape, slope, drainage density and size, and length of the streams[9,10] etc.. Hence, morphometric analysis of a watershed is an essential first step, toward basic understanding of watershed dynamics. Morphometric analysis encompasses a good number of linear, areal and relief parameters which in together describes a complex net of Morphometric diversity. It will help to provide a good number of micro scale landscape unit with unique characteristics and these units do have a unique impact on land use character.

Recently, use of remote sensing and GIS is well recognized tool for delineating variant morphometric segments. SRTM data is used frequently for this purposes with mix responses in connection with its level of accuracy. Spatial resolution is highly responsible for its level of precision. However, it is considered as fast, highly accurate and inexpensive way for calculating morphometric analysis[11-14]. Present work attempts to calculate morphometric pattern emphasizing some of the selected aspects and on the basis of some selected aspects it is tried to segmentize entire river basin into micro level morphometric diversity regions.

**Study Area:** Kuya River is a well known name in the riverine landscape of Eastern India. Taking start from a large pond of Khajuri village, Jharkhand and flowing S-E direction over Birbhum and Murshidabad districts of West Bengal it joins the Babla River near Sabitrinagar of Murshidabad district. Total length of the river is 176.4 km. The basin area can be delimited by 23º26′18″ North to 23º56′30″ North latitude and 87º13′ East to 88º09′30″ East longitudes covering an area of 1555.2sq.km. (Figure-1). Total length of the river is 176.4 km. About 24.64 km. is semi permanent. Total length of its main tributary-Brakeswar (Twin river of Kopai: Kopai and Brakeswar together have made Kuya river) is 82.98 km. out of which 10.57 km. is semi permanent and rest portion is semi permanent. The lower segment has embanked to restrict the over spilling tendency of the river. Agriculture dominates most parts of this basin. Some forest and wastelands are found in upper catchment of the basin.

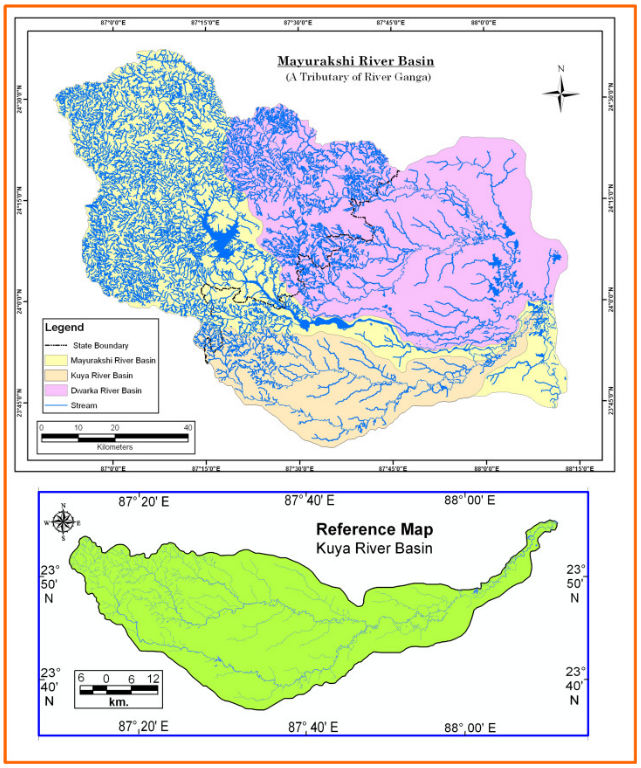



**Figure-1**
**Study area**

## Materials and Methods

Toposheet of Survey of India, google image is used for delineating river basin and following methods is used for measuring individual character of the Morphometric aspects (Table 1).

For weighted compositing of the morphometric variables Principal Component Analysis (PCA) based component matrix is extracted and thereby defined weight of the each parameter is defined. Detail of methodology is described in later analysis part.

**Methods for Asymmetry Analysis:** The major formulas have prepared and used for this basin are basically three types.

Basin Asymmetry: Basin Asymmetry Index (BAI) or Areal Asymetry Index (AAI). Stream Length Asymmetry Index (LAI). Stream Number Asymmetry Index (NAI). Relative Relief Asymmetry Index (RAI). Composite Asymmetry Index (CAI). Weighted Asymmetry Index (WAI). Channel Asymmetry

Basin Asymmetry Index (BAI) or Areal Asymmetry Index: $AaI = \frac{Al}{Am}$ Al = One side of the main stream having less area; Am = One side of the main stream having more area

Length Asymmetry Index: $LAI = \frac{L\mu l}{L\mu m}$ Lμl = One side of the main stream having less total stream length; Lμm = One side of the main stream having more total stream length.

Stream Number Asymmetry Index: $NAI = \frac{N\mu l}{N\mu m}$ Nμl = One side of the main stream having less total number of stream; Nμm = One side of the main stream having more total stream number

Relative Relief Asymmetry Index: $RRAI = \frac{RRl}{RRm}$ RRl = One side of the main stream having less relative relief; RRm = One side of the main stream having more relative relief

Composite Asymmetric Index (CAI): $CAI = \frac{\sum_{i=1}^{n} PAI}{N}$ PAI = Parameter Specific Asymmetry Index; N = Number of parameters

$$\sum_{i=1}^{n} PAI = \frac{Al}{Am} + \frac{N\mu l}{N\mu m} + \frac{SL\mu l}{SL\mu m} + \frac{RRl}{RRm}$$

PAI= Parameter Specific Asymmetry Index

For preparing composite and weighted asymmetry indices four relevant and measurable absolute parameters have selected namely area, stream number, stream length and relative relief from left and right side catchments of the main stream.

$WAI = \sum_{i=1}^{n} Wi * PAI$ WAI= Weighted Asymmetry Index; Wi= Weight of ith parameter

Channel asymmetry index $CAI = \frac{\overline{CW}_{mi}}{\overline{CW}_{ma}}$

$\overline{CW}_{mi} = average\ minimum\ width$

$\overline{CW}_{ma} = average\ maximum\ width$

CAI and WAI values range from 0-1. ‘0’ means highly asymmetry and ‘1’ means symmetry.

PAI value also ranges from 0-1. ‘0’ means highly asymmetry and ‘1’ means symmetry.

SSI and ASI range from 0-1. Value nearer to ‘0’ means less stability; ‘1’ means high stability of the bank. If the minimum value is less than 1m., all widening values shuld be converted into smaller units like meter to cm.

## Results and Discussion

**Linear Morphometric Aspects:** Linear aspects includes stream ordering, bifurcation ratio, length of stream, junction angle, over land flow etc. These aspects help to explain the evolution of drainage basin, hydrological potentialities, chance of hydrological extremities or flood behaviour, shifting course of river etc.

**Entire Basin as a Whole:** Morphometric measurement for entire basin gives a generalize picture at a glance (Table-2).

**Table-1**
**Methods for the Calculation of Different Morphometric Parameters**

| Aspect | Parameter | Formula | Reference |
|---|---|---|---|
| LINEAR | Stream Order | Hierarchical Rank | 7 |
| | Stream Length (Lμ) | Length of the Stream | 2 |
| | Bifurcation Ratio (Rb) | $Rb = \frac{N\mu}{N\mu+1}$ Nμ = Number of stream; Nμ+1 = Number of stream in next higher order | 15 |
| | Law of Stream Length (Lμ) | $L\mu = L1R_L(\mu-1)$ L1 = Length of the 1st Order | 2 |
| | Weighted Bifurcation Ratio (Rbw) | $Rbw = \frac{Rb_1 \times n_1 + Rb_2 \times n_2 + \cdots + Rb_n \times n_n}{n_1 + n_2 \cdots n_n}$ | 16 |
| | Law of Stream Number (Nμ) | $N\mu = Rb(K-\mu)$ k = highest order of the basin; μ = basin order | 2 |
| | Channel Sinuosity Indices (CI) | $CI = \frac{CL}{AL}$ CL = Channel length; AL = Air length | - |
| | Law of Junction Angle (Aμ) | $A\mu = A1R_A(\mu-1)$ RA = Junction ratio; A1 =Angle of the 1st order | 15 |
| | Constant Channel Maintenance (CCM) | CCM = 1/Dd | 15 |
| | Length of Over Land Flow (Lof) | (Lof) = ½ Dd | 2 |
| AREAL | Form Factor (F) | $F = \frac{A}{L^2}$ A= Basin area; L= Basin length | 17 |
| | Compactness Co-efficient (Cc) | $Cc = P_b/\sqrt{2\Pi A}$ $P_b$ = Perimeter of the basin | 17 |
| | Circularity Ratio (C) | $C = \frac{4\Pi A}{\rho^2}$ ρ = basin perimeter | |
| | Elongation Ratio | $F = \frac{\Pi}{4}R^2$ R =Diameter of an equivalent circular area | 15 |
| | Drainage Density (Dd) | $Dd = \frac{\sum L}{A}$ L = Length of the rivers; A= Area | 17 |
| | Stream Frequency (Df) | $Df = \frac{\sum N}{A}$ N = Number of river segments | 17 |
| | Drainage Texture (Dt) | $Dt = N\mu/P$ Nμ = Total number of stream in all segments; P = Basin perimeter | 2 |
| | Areal symmetry (Aa) | $Aa = \frac{Ar}{Al}$ Ar = Area of the low area of the stream<br>Al = Area of the more area of the stream | After Author |

| | | | |
|---|---|---|---|
| **RELIEF** | Hypsometric Integral | $HI = \frac{Ls}{Lus}$ HI = Hipsometric Integral; Ls = Proportion of un eroded part; Lus = Proportion of eroded part | 16 |
| | Erosional Integral | $EI = 1 - \frac{Ls}{Lus}$ EI = Erosional Integral | 16 |
| | Percentage hypsometric curve | h/H/a/A h and a = height and area between two contours; H and A = Total Height and Area of the entire basin | 16 |
| | Relative relief | Rr = (Rma–Rmi) Rma= Relief maximum; Rmi= Relief minimum | |
| | Dissection index | $DI = \frac{Rr}{Hx} \times 100$ Hx =Maximum relief; Rx = Relative relief | |
| | Ruggedness Index | $Rn = \frac{Rr \times Dd}{K}$ K = a conversion constant and is 1000; Rr = Relative relief; Dd= Drainage relief | - |
| | Slope Ratio | Rs = Sµ/Sµ+1 Rs = Slope Ratio, Sµ=Slope of given order, Sµ+1=Slope of next higher order | 2 |

**Table-2**
**Stream Number, Stream Length, Stream Junction Angle**

| **Stream Order** | **No. of Stream** | **Length of Stream** (km) | **Rb** | **Rbw** | **Lb** | **Lbw** | **Junction Angle** |
|---|---|---|---|---|---|---|---|
| 1 | 487 | 504.05 | | 3.36 | | 1.32 | 55.92 |
| 2 | 129 | 322.4 | 3.78 | | 1.56 | | 98.45 |
| 3 | 21 | 129.95 | 6.14 | | 2.48 | | 89.30 |
| 4 | 3 | 173.35 | 7 | | 0.74 | | 70 |
| 5 | 1 | 95.1 | 3 | | 1.83 | | 50 |

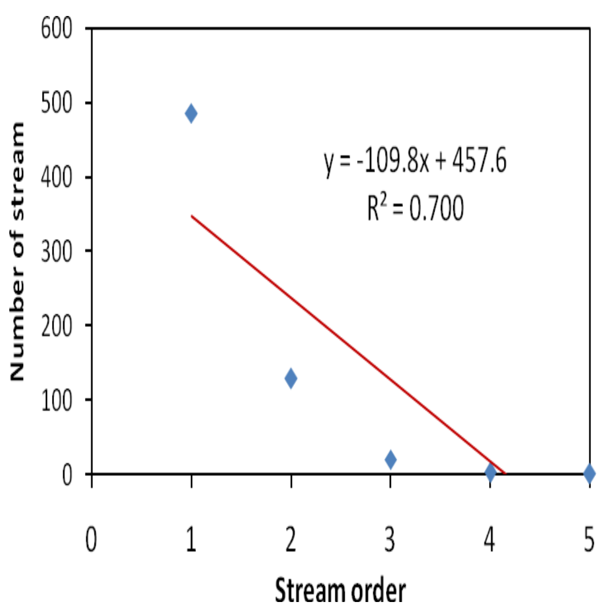



**Figure-2**
**Law of stream number**

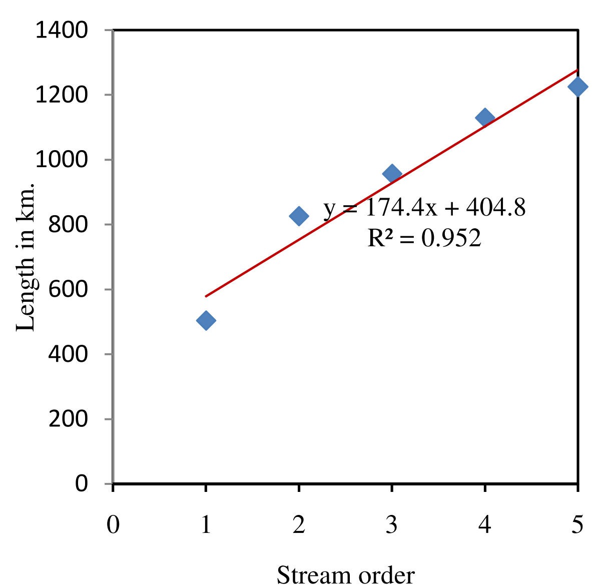



**Figure-3**
**Law of stream length**

**Table-3**
**Some Other Morphometric Aspects**

| Length of Over Land Flow (Lof) | Constant of Channel Maintenance (CCM) | Channel Sinuosity Indices (CI) | Length of Trunk river |
|---|---|---|---|
| 1.88 | 6.32 | 1.71 | 176.4km. |

The total number of the stream in Kuya River basin is 641 and total length of all segments of stream is 1224.85 km. The bifurcation ratio (3.36) for entire basin indicates high rate of stream integration. Bifurcation ratio is 3.36 means more than three smaller stream segments have merged to form one larger segment. High channel sinuosity index (1.71) refers relatively less resistance of the rocks and structures, greater chance of flood (Table-3). As per the normal behaviour of a river basin is concerned, the junction angle gradually increases with increasing order. But in Kuya river the junction angle in successive orders are not regular. In second order stream the significant increase of junction angle tells about the structural and rigid morphological control over stream trajectory.

**Spatial Pattern of Basin Morphometry: Bifurcation Ratio:** The spatial variation of morphometric behaviour is very high all over the basin area. Bifurcation ratio is very high along 80 m. contour which indicates sudden breaks of slope. As large number of stream segments suddenly coalesce to each other, the formation of wider river channel, formation of micro fluvial deposits along topographical bent (80 m. contour), raising of hydrological potentialities of the down slope rivers, increasing rate of river bed deposition etc. have happened.

Law of stream number indicates that with increasing stream order number of stream is decreasing with notable rate ($R^2$ = 0.700). The near geometric growth rate of stream is maintained from $2^{nd}$ to $5^{th}$ order stream.

Very high degree of positive relationship between stream number and stream length indicates a fair degree of allometric growth of these two morphometric items.

**Constant of Channel Maintenance:** Schumm15 has used this as inverse of drainage density as a property termed as the constant of channel maintenance. It says that the number of sq. foot of watershed surface is required to sustain one linear foot of channel or it may be in metric measurement. In the present work 3.36 sq.km of basin area is needed to support 1 km. of channel.

**Length of Overland Flow:** It is the length of water over the ground before it gets concentrated into a definite stream channel[19]. This factor is related inversely to the average slope of the channel and it is quite synonymous with the length of sheet flow to a large degree. It approximately equals to half of reciprocal of drainage density. For Kuya river basin Lof is about 1.88 which indicates relatively finer pattern of stream.

**Law of Stream Length:** It says highly positive relationship between stream order and stream length. Straight line regression trend shows this high degree of positivity (Figure-3).

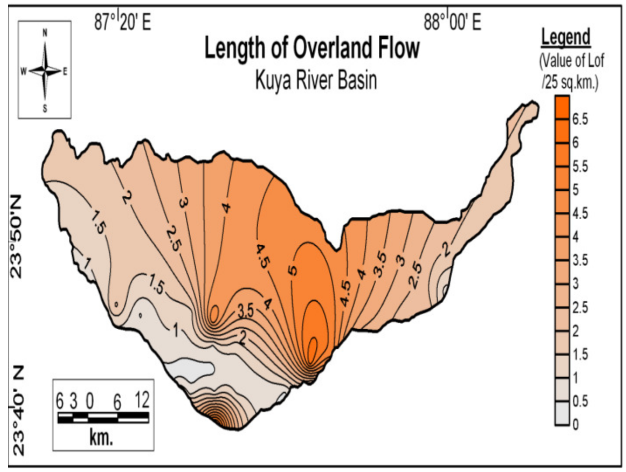



**Figure-4**
**Length of overland flow**

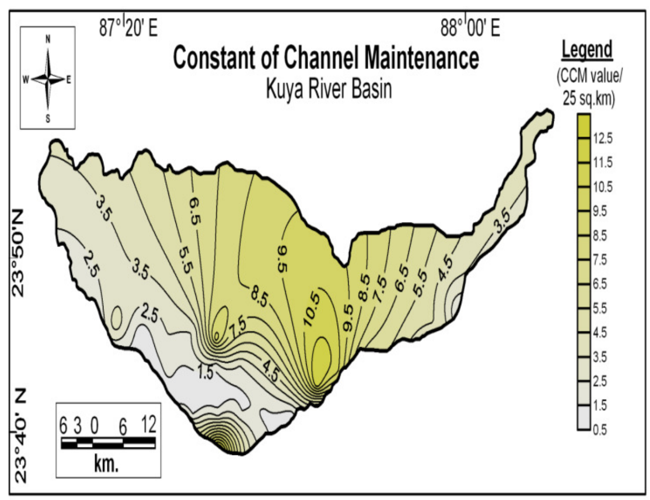



**Figure-5**
**Constant of channel maintenance**

**Sinuosity Indices:** It is the ratio between straight length and actual length of the channel. Over all sinuosity of the main channel is 1.71. Order wise increase of sinuosity is noticeable in this basin. The degree of sinuosity of main river is quite greater than main tributary. Sinuosity of the main river has increased at the down stretch of Kultore barrage. The barrage may have extered any impact to form heavily sinuous river channel. In case of Brakeswar river, the sinuosity has also increased toward downstream segments (Table 4). Over Brakeswar, there is another dam as Nil Nirjan which may also control the nature of river curvature downstream.

**Areal Morphometric Aspects: Basin as a Whole:** Basin Shape Analysis: Indices of basin shape analysis calculated from different methods ranges from 0 - 1; if the value is toward 1, it means basin is circular and 0 indicates absolutely elongated basin. F= 1 also signifies that the basin is characterized by nearly concurrent structural pattern, morphogenetic characteristics and morphological process as should be as per law. But highly elongated basin signifies greater structure-topographical control over the river pattern. In Kuya river basin the Circularity ratio (one of the method of form factor analysis) is only 0.30 which indicates fairly elongated river basin. In general principle there is positive relation between form factor value and flood propensity. In Kuya basin although the basin is elongated and form factor value is small but flood condition is grave some as so many other encouraging factors are concerned.

**Spatial Pattern of Basin Morphometry: Drainage Density:** Drainage density is the length of river per unit area. It is affected by the factors which control the characteristic length like resistance of weathering, permeability of rock formation, climate, vegetation etc. In general low value of Dd is observed in the region underlined by highly resistance permeable material with vegetative cover and low relief. High drainage density is noticed in the regions of weak and impermeable surface material and sparse vegetation and mountain relief. The mean value of Dd in Kuya river basin is 0. 4122km. /sq.km. which indicates the resistance permeable material with fairly vegetative cover and low relief.

But as the spatial variation is concerned, the upper Kuya basin indicates very high Dd value (1.1 to 1.35 km. per sq. km.). Therefore, the basin has probably weak and impermeable surface material and relatively greater topographical relief. But in the Lower Kuya river the condition is completely opposite to the Upper Kuya river basin.

**Drainage Frequency:** The average Drainage frequency is 0. 7876/sq.km. (Table-5). The frequency is very high (1.2-1.4/sq.km.) in the Upper Kuya river basin while it is low (<1/sq.km.) in the lower basin. Greater stream frequency in the Upper basin indicates relatively steeper slope, greater relief variation and multifaceted slope directions. Very low stream frequency in the Lower segment of the basin says the monotonous flat slope with marginal relief variations.

**Drainage Texture:** It is the total number of stream segment of all orders per perimeter of that area[19]. Horton considered that infiltration factor is the single important factor which influences drainage texture and considered drainage texture to include drainage density and drainage frequency. Like drainage density and frequency, drainage texture is also high (fine) in the Upper catchment and low (coarse) in the lower segment of the basin. Textural fineness in the Upper catchment and coarseness in lower is related with diversity in landscape.

**Table-4**
**Meandering Status in Different Parts of Kuya and Brakeswar**

| Name of the River | Site References | Actual Distance(Km.) | Straight Distance (Km.) | Sinuosity Index |
|---|---|---|---|---|
| Kuya | Source to Kultore | 52.66 | 36.64 | 1.63 |
| | Kultore to Milanpur1 | 53.64 | 29.34 | 1.83 |
| | Milanpur 1 to Confluence | 70.1 | 42.57 | 1.65 |
| Brakeswar | Source to Nilnirjan | 22.81 | 17.60 | 1.29 |
| | Nilnirjan to Confluence | 60.17 | 37.66 | 1.60 |
| | Tekadda to Confluence | 16.43 | 9.59 | 1.71 |
| | Beharia to Confluence | 34.35 | 20.32 | 1.69 |

**Table-5**
**Areal Morphometric Parameters for the Whole Basin**

| Parameters | Circularity Ratio | Form Factor | Compactness Coefficient | Area Asymmetry | Drainage Frequency | Drainage Density | Drainage Texture |
|---|---|---|---|---|---|---|---|
| **Value** | 0.30 | 2.00 | 0.04 | 0.395 | 0.7876 / sq.km. | 0.4122/ sq.km. | 2.37/sq.km. |

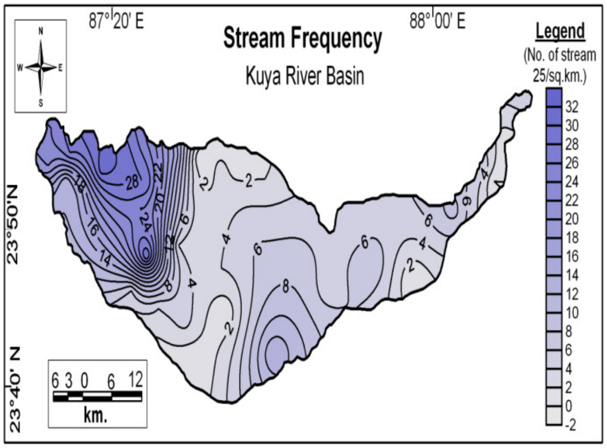



**Figure-6**
**Stream frequency**

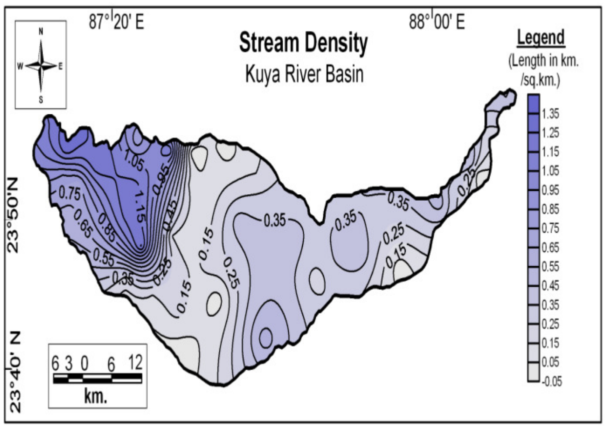



**Figure-7**
**Stream density**

**Relief Morphometric Aspects:** It includes hypsometric analysis, clinographic analysis, altimetric analysis, profile analysis, ruggedness index, dissection index etc.

**Hypsometric Analysis:** Hypsometry describes the area height relation of the basin and thereby its stage of evolution, erosion potentiality etc. can be assessed. Hypsometric integral (HI) shows the how much portion of the total basin area is to be eroded. It is said that HI >0.6 or >60% = Youthful stage, HI = 0.6-0.35 or 60%-35% = Mature stage, HI = <0.35 or <35% = old stage. In Kuya river basin it is only 0.36 which means 36% area of the total land still to be eroded. So river basin is in late mature stage.

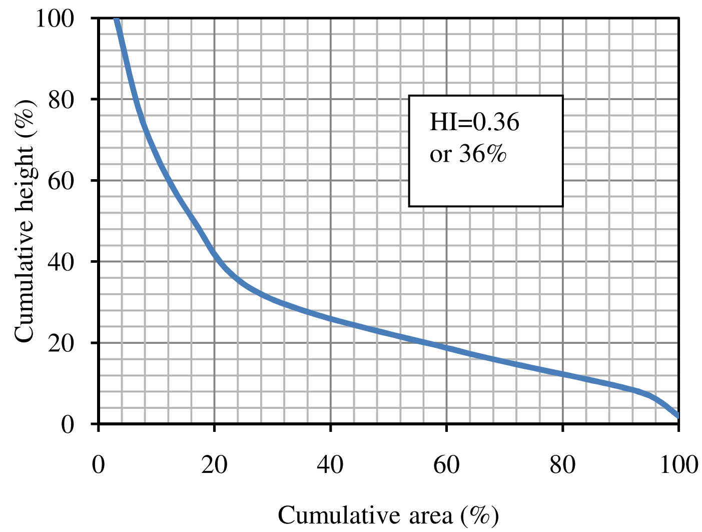



**Figure-8**
**Hypsometric Analysis**

**Table-6**
**Area Height Parameters for Kuya River Basin**

| Height (m.) | Area | h | h/H | a/A | Cumulative % of Height | Cumulative % of Area |
|---|---|---|---|---|---|---|
| <20 | 112.5 | 10 | 2 | 7 | 2 | 100 |
| 20-40 | 525 | 30 | 6 | 31 | 8 | 93 |
| 40-60 | 593 | 50 | 10 | 34 | 18 | 62 |
| 60-80 | 212 | 70 | 14 | 12 | 32 | 28 |
| 80-100 | 137 | 90 | 19 | 8 | 51 | 16 |
| 100-120 | 78 | 110 | 22 | 5 | 73 | 8 |
| >120 | 55 | 130 | 27 | 3 | 100 | 3 |
| | 1712.5 | 490 | 1 | | | |

**Hypsometric curve and hypsometric integral: Clinographic Analysis:** Linear and spatial slope analysis one of the important task to describe the flow pattern, runoff concentration etc. Linear slope direction of the main river is toward east and gradient is 1: 1257. At the upper segment (above 80m. contour) gradient value is 1:300 but it too low at the downstream. Spatial character of slope shows that the degree of slope is more in upper catchment of the basin.

**Relief Analysis:** It includes relative relief, dissection index, ruggedness index etc. Diversity of intra basin parameters are high in the upper catchment and low in the lower catchment.

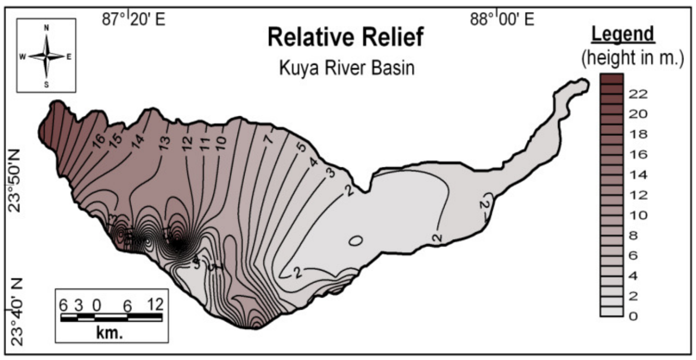



**Figure-9**
**Relative relief**

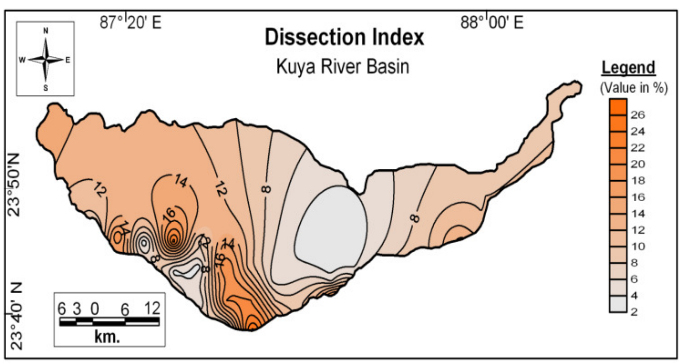



**Figure-10**
**Dissestion index**

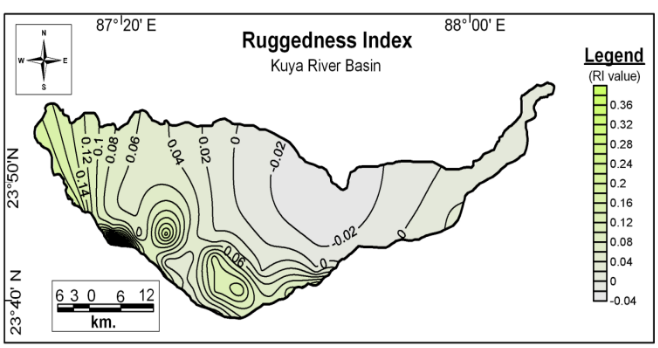



**Figure-11**
**Ruggedness index**

**Long Profile of the Kuya and Brakeswar Rivers:** The term ***graded*** stream was first used by G. K. Gilbert in 1876. According to him the grade is such condition where "the load of a given degree of commission is as great as the stream is capable of carrying; the entire energy of the descending water is consumed by the translation of water and its load, and therefore non-applied to corrasion".

Kessali[18] defined a graded river as one where there is a balance of energy and load. He postulated that a graded stream is characterized by the absence of rapids and waterfalls.

Discharge, sediment load and ultimate base level are the three independent variables in the graded state. Channel width, channel depth, bed roughness, grain size of the sediment load, the channel pattern (meander/braided) and the velocity are the semi dependent variables. Only one variable, the slope of the fluvial system, is regarded as being dependent on all other variables.

Figure-12 and 13 respectively show the long profile character along river Kuya and its major tributary Brakeswar.

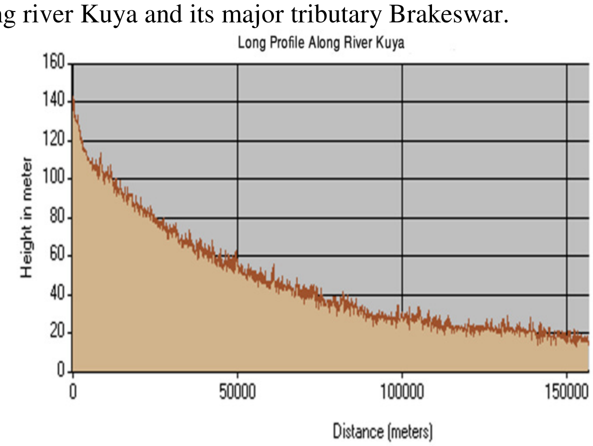
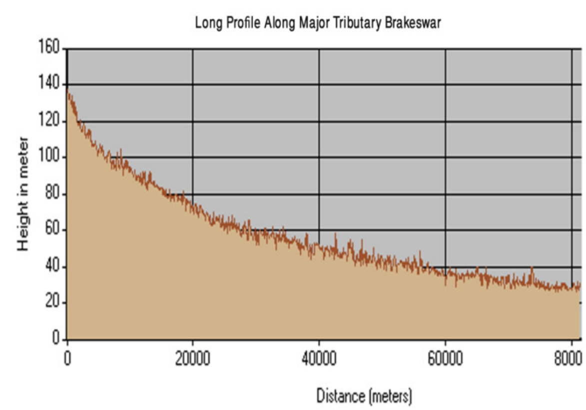



**Figure-12**
**Long profile of Kuya**




Source: Based on SRTM data
**Figure-13**
**Long profile of Bakreshwar river**

**Relation and Priority Analysis among Morphometric Parameters:** Different morphometric parameters have very good relation with one another. Table 7 shows the pattern of relationships among different parameters. Areal morphometric parameters like drainage density, drainage frequency, texture etc. are positively related with some of the relief parameters like relative relief, dissection index, ruggedness index etc. Each of the relief parameters and areal parameters are more strongly correlated among themselves.

MiR=Minimum Relief; MaR= Maximum Relief; RR= Relative Relief; SF = Stream Frequency; DD= Drainage Density; CCM= Constant Chnnel Maintenance; Lof= Length of Over Length Flow; DI= Dissection Index; RI= Ruggedness Index

Results of Principal Component Analysis (PCA) reflect that out of total components, up to components 3 explains 87.537% morphometric variability (Table 8). As per component, relief parameters are more prominent to determine other parameters. The scree plot also confirms the explanation capability of different components.

**Table-7**
**Inter Relationship Between Morphometric Parameters**

| | **MiR** | **MaR** | **RR** | **SF** | **DD** | **CCM** | **Lof** | **DI** | **RI** |
|---|---|---|---|---|---|---|---|---|---|
| MiR | 1 | | | | | | | | |
| MaR | .980(**) | 1 | | | | | | | |
| RR | .576(**) | .727(**) | 1 | | | | | | |
| SF | .436(**) | .405(**) | .159 | 1 | | | | | |
| DD | .296(*) | .267(*) | .078 | .800(**) | 1 | | | | |
| CCM | -.009 | -.034 | -.109 | -.353(**) | -.487(**) | 1 | | | |
| Lof | -.019 | -.045 | -.116 | -.369(**) | -.512(**) | 1.000(**) | 1 | | |
| DI | .013 | .202 | .783(**) | -.008 | -.036 | -.149 | -.153 | 1 | |
| RI | .563(**) | .663(**) | .780(**) | .519(**) | .530(**) | -.253(*) | -.262(*) | .551(**) | 1 |

** Correlation is significant at the 0.01 level (2-tailed).* Correlation is significant at the 0.05 level (2-tailed).

**Table-8**
**Total Variance Explained**

| **Component** | **Initial Eigenvalues** | | | **Extraction Sums of Squared Loadings** | | |
|---|---|---|---|---|---|---|
| | **Total** | **% of Variance** | **Cumulative %** | **Total** | **% of Variance** | **Cumulative %** |
| 1 | 4.026 | 44.729 | 44.729 | 4.026 | 44.729 | 44.729 |
| 2 | 2.310 | 25.671 | 70.400 | 2.310 | 25.671 | 70.400 |
| 3 | 1.542 | 17.137 | 87.537 | | | |
| 4 | .761 | 8.460 | 95.997 | | | |
| 5 | .227 | 2.518 | 98.514 | | | |
| 6 | .110 | 1.219 | 99.733 | | | |
| 7 | .024 | .267 | 100.000 | | | |
| 8 | 6.20E-007 | 6.88E-006 | 100.000 | | | |
| 9 | -6.17E-016 | -6.85E-015 | 100.000 | | | |

Extraction Method: Principal Component Analysis.

Table-9 shows that in component 1 relief parameters are dominant but in component 2 drainage parameters are dominant. From this account again it can be stressed that relief parameters are more prominent explanatory factors of morphometric diversity than drainage parameters. Figure-14 also depicts the same fact as stated above.

**Table-9**
**Component Matrix(a)**

| | Component | |
|---|---|---|
| | 1 | 2 |
| MiR | .717 | .396 |
| MaR | .786 | .460 |
| RR | .749 | .522 |
| SF | .673 | -.362 |
| DD | .635 | -.548 |
| CCM | -.498 | .745 |
| Lof | -.498 | .745 |
| DI | .444 | .310 |
| RI | .886 | .181 |

Extraction Method: Principal Component Analysis. a 2 components extracted.

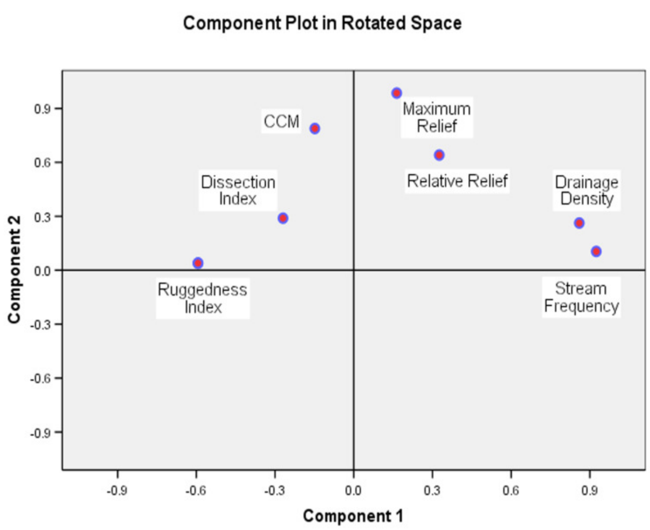



**Figure-14**
**Component 1 and component 2 plot of different morphometric variables**

Weighted morphometric score using PCA methods has plotted as factor 1 and factor 2 in figures 15 and 16 respectively. Weighted score in factor 1 shows that morphometric weight is maximum in the upper catchment and gradually declined downstream. High diversity of all the individual parameters in the upper catchment explain traceable weighted score.

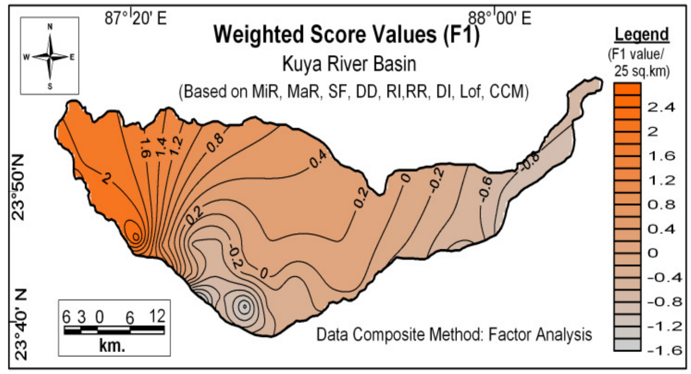



**Figure-15**
**Weighted morphometric score (factor 1)**

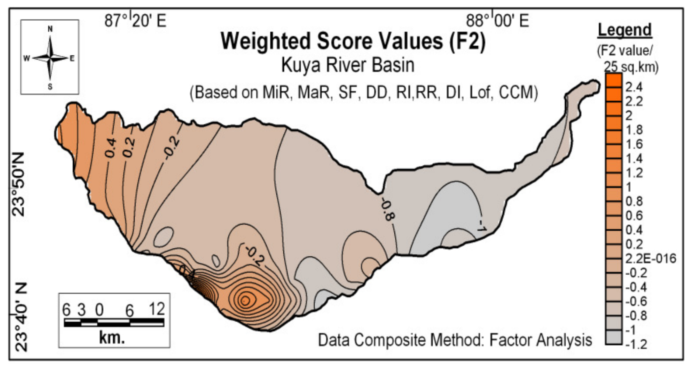



**Figure-16**
**Weighted morphometric score (Factor 2)**

**Basin and Chanel Asymmetry:** Basin asymmetry is defined as the proportion of area in two sides of the main river and thalweg asymmetry is defined as the distribution of width in two sides of the thalweg. These indicators clearly reveal the tilting tendency of the basin and channel. Weighted asymmetry index means after measuring asymmetry for some selected parameters, logical weightage is provided to each one and thereby the level of asymmetry is measured. This technique is more down to earth for assessing basin asymmetry. According to the nature of width, depth, discharge, velocity, sediment load, slope of the land; the channel configuration of the river is characterized[3]. Although all these said parameters are natural but people are frequently tampering those parameters and often reshape the channel configuration. In natural condition the shape of the channel configuration is quite steep and narrow in upper catchment and gradually it becomes wider and flatter towards its confluence. Presently, most of the river is under the domain of human cultivation in terms of building of barrage, dam across river, embankment along river, diversion of water from the main river through irrigation projects. These again are regulating the behaviour of erosion, deposition as well as dynamism of channel configuration in different parts of the channel.

**Table-10**
**Some Assymetry Indices**

| Parameters | Left | Right | PAI | CAI | Wi | WAI= Wi*PAI | WAI= ∑(Wi*PAI) |
|---|---|---|---|---|---|---|---|
| Number of stream | 524 | 117 | 0.223 | | 0.2 | 0.0446 | |
| Length | 867 | 324 | 0.373 | 0.439 | 0.2 | 0.0746 | 0.4102 |
| Avg. RR | 11 | 8.5 | 0.77 | | 0.15 | 0.1155 | |
| Area | 948.72 | 606.52 | 0.39 | | 0.45 | 0.1755 | |

So along with structural and lithological control on channel configuration, channel asymmetry, human activities play vital role to determine the nature of asymmetry and dynamics. Here, some simplified techniques have been discussed to measure the degree of basin asymmetry, channel asymmetry of a river. It has also stressed on the stability of the bank with proper equation because stability of bank is rigorously related with channel width in particular and channel configuration in general.

Basin asymmetry index (BAI) or Areal Asymmetry Index (AAI) for Kuya river basin is 0.39. Basin has lopsided tendency toward right side as the proportion of area in the left side is far more than right side. All individual parameter specific Asymmetry Index (PAI) shows the same tendency as like areal asymmetry. Asymmetry regarding number of stream and stream length are extremely high in this basin. Stream length asymmetry is 0.223 indicates out of total stream diversity of the basin, left side catchment explains 78% and right side explains only 22%. Parameter specific Asymmetry Index is 1 means there is no disparaty of different parameter status between left and right catchment of the basin. Spatial narrowness has largely led to the small values in the right side catchment of the basin. Composite asymmetry index of the basin is 0.439 means the basin is on an average 56% away from achieving accordant distribution of the selected parameters as a whole between left and right catchment. Arbitrary weight has been assigned to the individul parameter as per logical understanding and thereby weighted asymmetry index has been calculated. WAI value 0.4102 also indicates high level asymmetry in the basin.

Channel asymmetry index (CAI) = 0.552 (average right width is 33.48m. and average left width from thalweg is 18.48m.). So, channel is tilted toward left.

## Conclusion

From the above analysis, it is articulated that relief parameters carry principal role for making variant morphometric surface. From morphometric characters found here, it can be predicted that probability of soil erosion will be high in the upper catchment due relatively greater slope and dense association of drainage. High sinuosity index in the lower catchment indicate wider river corridor with less erosion and enhanced deposition. From ground water availability point of view lower part is more viable. Surface water availability will also be high in the lower catchment where major tributary Bakreswar meet with Kuya because weighted junction score in these part are more.

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