IMPACT: International Journal of Research in Applied, Natural and Social Sciences (IMPACT: IJRANSS)
ISSN (P): 2347-4580; ISSN (E): 2321-8851
Vol. 6, Issue 10, Oct 2018, 15-28

ANALYSIS OF BASIN GEOMORPHOMETRY THROUGH THE USE OF REMOTE SENSING AND GIS TECHNIQUES: A STUDY ON GANDESHWARI RIVER BASIN, BANKURA DISTRICT, WEST BENGAL, INDIA

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Received: 07 Oct 2018 **Accepted:** 16 Oct 2018 **Published:** 26 Oct 2018

ABSTRACT

The present study deals with the GIS-based morphometric analysis of Gandeshwari drainage basin. For extraction of the river basin and its stream networks, ASTER (DEM) with SRTM Data and Survey of India Topographical Map of 1: 50000 scales have been used. Morphometric parameters of linear, areal and relief aspects viz. Stream order, bifurcation ratio, stream length, drainage density, drainage frequency, circularity ratio, form factor analysis, relative relief, slope analysis etc. are calculated for analysis. The gandeshwari river basin is basically a 7^{th} order drainage basin in the elongated shape. The total area of the basin is 388.60 km^2 and the drainage pattern is Dendritic. The mean bifurcation ratio of this basin is 2.494; it is due to its varying topography and lithological condition. The average drainage density of the basin is 12.8 km^2. This study would be important to understand the basin morphological characteristics, its hydrological response, and resource utilization.

KEYWORDS: *Morphometric Analysis, River Basin, SRTM Data, DEM, Topographical Map, Hydrological Response*

INTRODUCTION

Geomorphology deals with the origin and evolution of topographic features and morphology deal with the quantitative determination of landforms. The quantitative descriptions of the landforms are called 'Morphometry'. Morphometry is defined as the measurement and mathematical analysis of the configuration of the earth's surface and of the shape and dimension of its landforms **(Agarwal, 1998, Reddy et al, 2002).** A drainage basin is a hydrological entity. By which all surface water can sink into a point. The drainage basin is highly valuable in morphometric analysis. Basically, morphometric analysis tries to find out the relationship between morphometric characteristics of a river basin and the climate, relief, Lithology, structure and tectonic condition of that particular place. **Horton (1932)** was the first who introduced the morphometric analysis of river basin and elaborated by Strahler (1957), Smith (1945), Miller (1953), Schumm (1956), Morisawa (1962) and Leopold (1964); those who later established the quantitative fluvial geomorphic research.

Now a day, morphometric analysis technique is used in various fields like resource management, mitigating geo-environmental hazard, watershed management and to control floods. This technique also applied to evaluate the potentiality of groundwater and hydrological behavior of watersheds. Watershed of a river basin prioritization for soil and

water conservation measurement was accomplished in several parts of India. According to S.D.Vikhe & Dr. K. A. Patil (2016), GIS is an efficient tool in the delineation of drainage pattern and groundwater potentiality mapping. Those tools are very helpful as resources.

Location of the Study Area

Gandeshwari River is one of the most important tributaries of Dwarkeshwar River with an area 221.695 sq.km. The study area is extent between 23°12’55”N to 23°30’52”N and from 86°52’27”E to 87°07’27”E. The river totally flows through the Bankura district, West Bengal. It is a left bank tributary of Dwarkeshwar River with a total length of 47.3 km. The river is originated from Upargara of Chhatna Block in the district of Bankura and meets with Dwarkeshwar River at Bhutsahar near Bankura District. The river has covered the following blocks respectively Chhatna, Bankura-I and Bankura-II Block of Bankura District. The direction of Gandeshwari river is north-west to south-east (i.e. Source to sink).

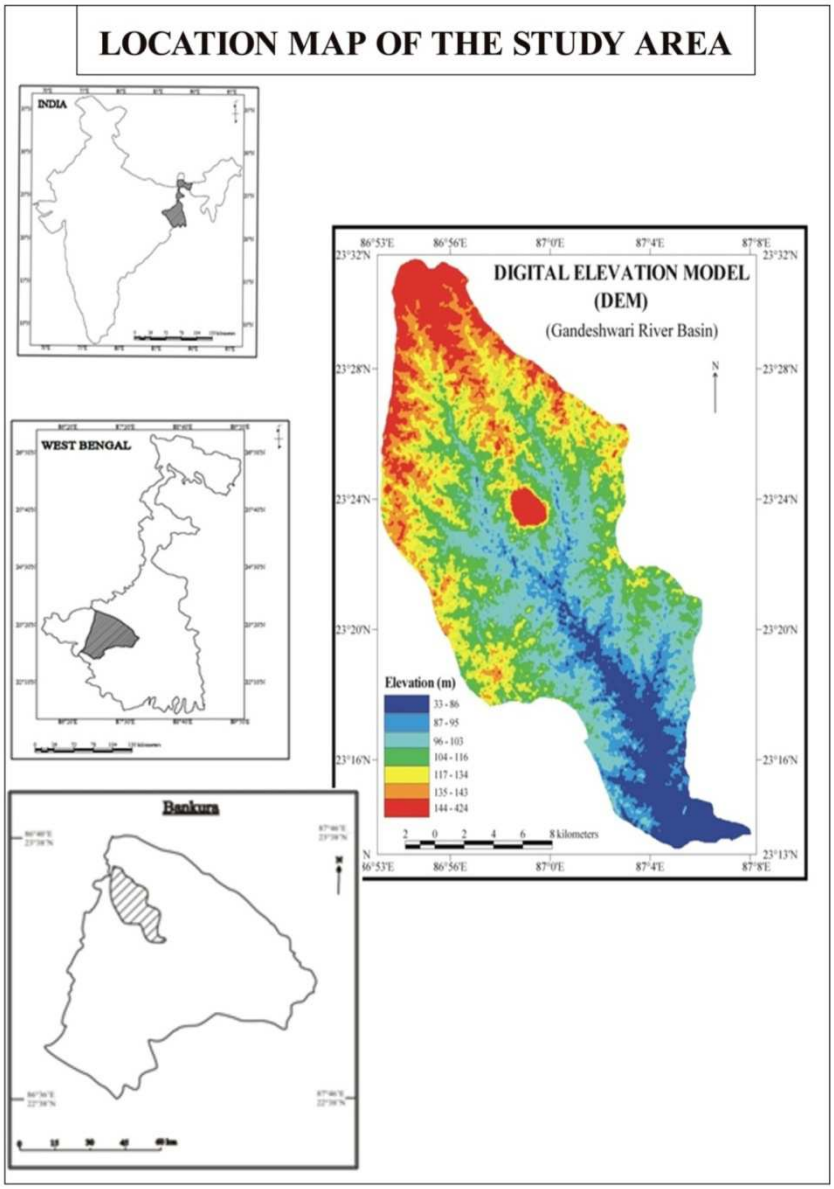

Figure 1: Location Map of the Study Area

Physical Environment

The Gandeshwari river basin is located in the north western part of Bankura district. The upper part of the basin is actually a part of the lower Purulia upland and it meets in the southern plain land with Darkeswar River of Bankura district.

The basin has a diversified geological structure. Most part of the basin, mainly the middle part which are underlying by pink granite or biotic granite, gneiss of Archean period and the southern part of the basin. Near the confluence is underlined by sandy alluvium deposition. The basin is underlined with six different types of rocks i.e. Grabboie Anorthosite, Pyroxene, Granulite, Biotite Granite Gneiss, Granite Gneiss, Felspathic schist and recent sand, silt, and clay. Lineaments are shown mainly in the lower middle to lower upper course of the basin.

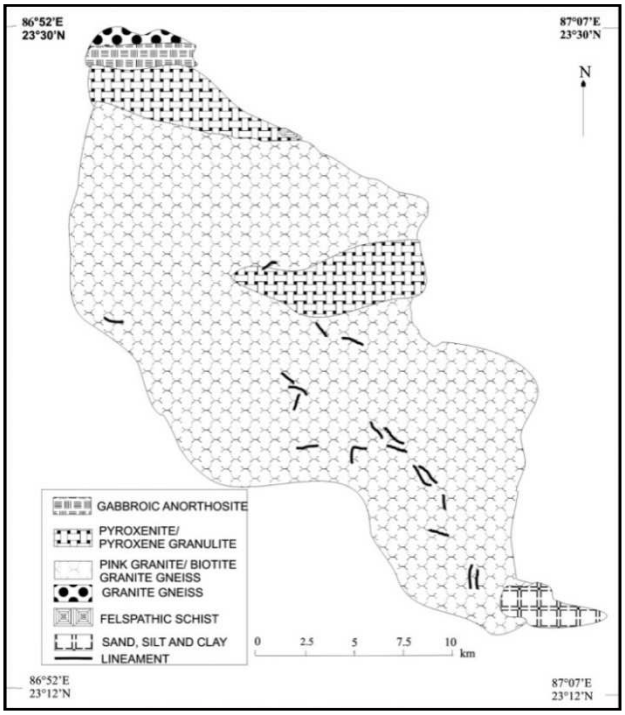

Figure 2: Geology of the Study Area

(Source: Geological Survey of India)

Climate

The basin area, as a part of Bankura district, has experienced the monsoon climatic condition. According to the weather report of Alipore, West Bengal, in this area, 1400 millimeters rainfall has occurred in the month of June to September.

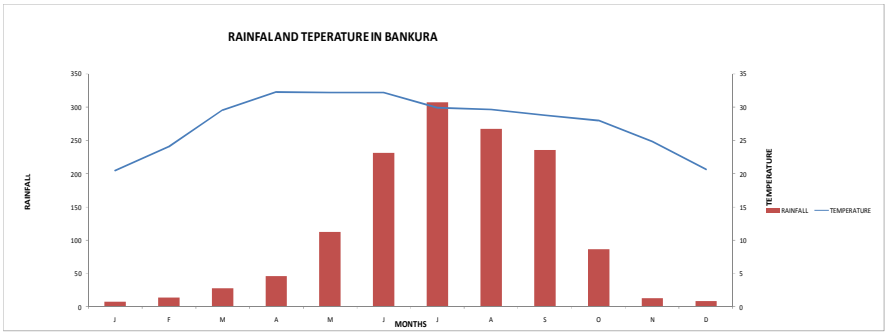

Figure: 3. Climate

(**Source:** Alipor, West Bengal)

Objectives

- The main objective of this study is to analyze the basin Morphometric characteristics of Gandeshwari River.
- To find out the relation between Geological structure and drainage pattern.
- To find out the relation between relief structure and drainage pattern.

METHODOLOGY

In this present study, the morphometric characteristics have been analyzed using the remote sensing data in a GIS environment. To demarcate the Gandeshwari river basin by the Topo map of 73I/15, 73I/3 and 73I/4 with the scale of 1:50000 have been used. ASTER DEM 30 m. (USGS/NASA) and the SRTM data have been applied to extract the streamlines and relief features. Standard formulas have been used to calculate the morphometric parameters of Gandeshwari river basin (table-1). On the basis of these calculations, different morphometric mapping has been done using the GIS software (TNTmips Pro 2014, Arcgis10.3.3).

Table1: Linear, Areal and Relief Morphometric Parameters used for Gandeswari River Watershed

Aspects	Parameter	Formula	References
Linear aspect	Stream order (U)	Hierarchial rank	Strahler (1964)
	Stream length (Lu)	Length of the stream	Horton (1945)
	Mean stream length (Lsm)	Lsm = Lu/Nu	Strahler (1964)
	Stream length ratio (RL)	RL = Lu/(Lu - 1)	Horton (1945)
	Bifurcation ratio (Rb)	Rb = Nu/Nu? 1	Schumn (1956)
	Mean bifurcation ratio (Rbm)	Rbm = average of bifurcation ratios of all order	Strahler (1957)
Areal aspect	Drainage density (Dd)	Dd = Lu/A	Horton (1945)
	Drainage texture (T)	T = Dd 9 Fs	Smith (1950)
	Stream frequency (Fs)	Fs = Nu/A	Horton (1945)
	Elongation ratio (Re)	Re = D/L = 1.128HA/L	Schumn (1956)
	Circulatory ratio	Rc = 4pA/P2	Strahler (1964)
	Form factor (Ff)	Ff = A/L2	Horton (1932)
	Length of overland flow(Lg)	Lg = 1/D 9 2	Horton (1945)
Relief aspect	Relief	R = H – h	Hadley and Schumn (1961)
	Relief ratio	Rr = R/L	Schumn (1963)

Source: Savindra Singh (1981)

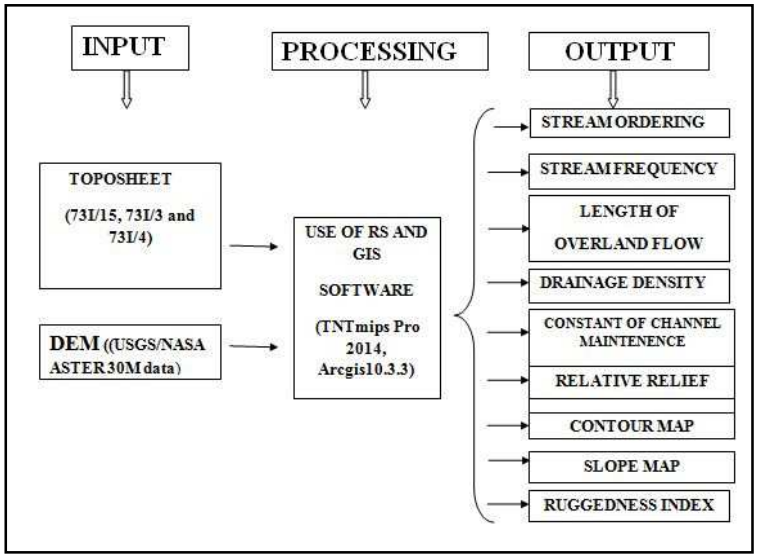

Figure 4: Flow Diagrams of Research Methodology

RESULTS AND DISCUSSIONS

Generally, Morphometric analysis is the quantitative description and analysis of landforms as practiced in Geomorphology that may be applied to a particular kind of landform or to drainage basins and large regions. In this study, an attempt has been made to correlate the statistical parameters defining drainage basin characteristics and basin hydrology of Gandeshwari river basin. All the parameters have been categorized into linear aspect, areal aspect, and relief aspect

Table 2: Results of Morph Metric Analysis

Parameter	Result
SINUOSITY INDEX	1
MEAN BIFURCATION RATIO	2.494
STREAM ORDER & FREQUENCY	1st-959,2nd-434,3rd-92,4th-17,5th-5,6th-2,7th-1
AREA OF THE BASIN	388.60 sq.km
PERIMETER OF THE BASIN	117.5 k.m
BASIN LENGTH	47.5 k.m
ELONGATION RATIO	0.13
CIRCULATION RATIO	0.11
FORM FACTOR	0.13
DRAINAGE TEXTURE	12.85
AVERAGE DRAINAGE DENSITY	12.34

Source: Computed by Author

Linear Aspects

Linear Aspects of the basins are related to the channel pattern of the drainage network.

Stream order & Stream Number

The Gandeshwari river basin area is a 7thorder drainage basin. In this study, the highest number of the stream is found on pyroxene granulise rocks. Highest numbers of streams are found in 1st order (959) and the lowest position is occupied by 7th order with one stream. The number of streams decreases with increasing of stream order. The number of streams decreases towards the alluvial plains from plateau areas (Table: 2). The drainage pattern of the river is dendrite

because the tributary rivers meet with the mainstream in acute angle and the mainstream is flowing according to the regional slope (Figure 5).

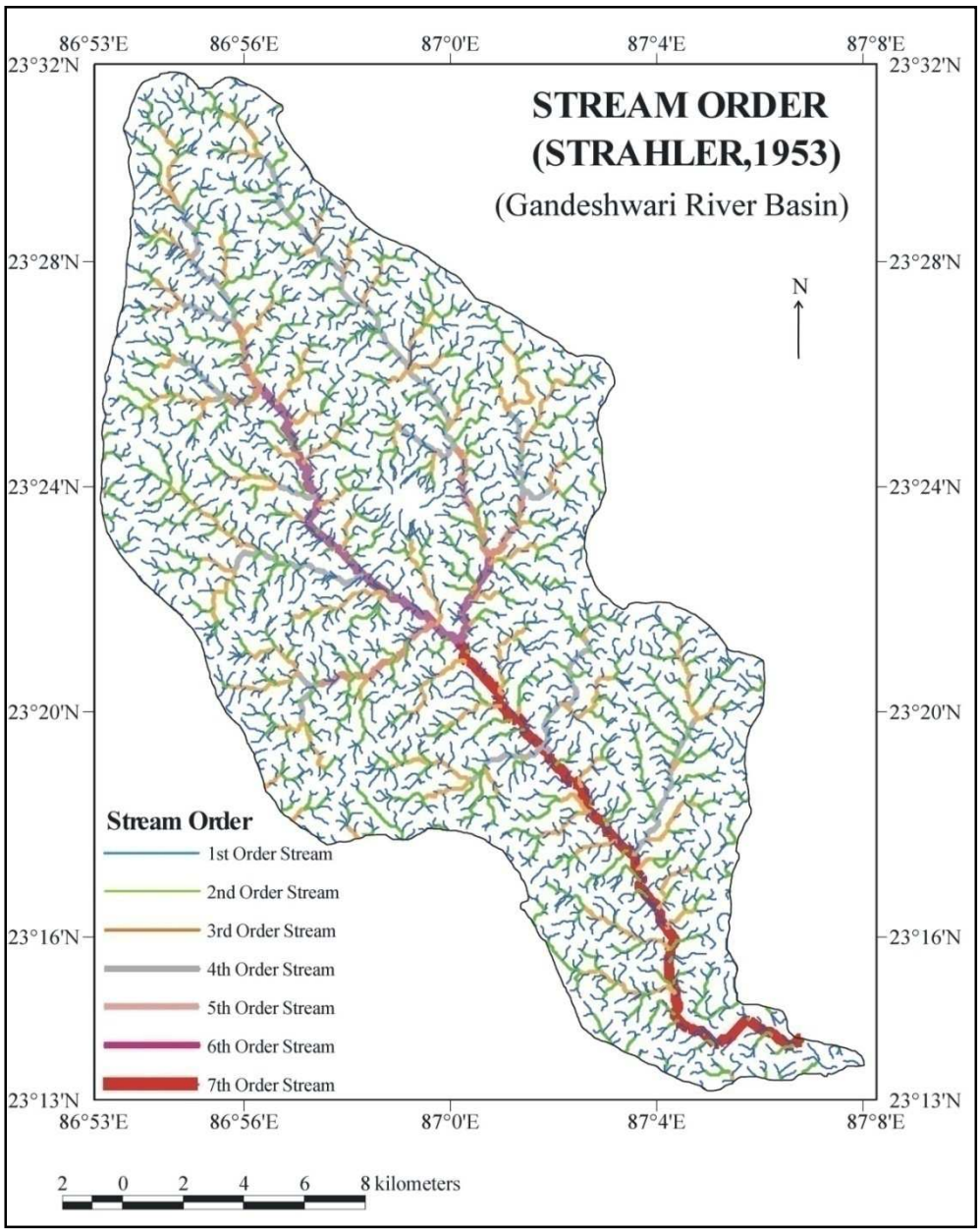

Figure 5: Stream Order & Stream Number

Bifurcation Ratio (R_b)

Bifurcation Ratio may be defined as the ratio of a number of streams given an order to number stream in next higher order (Schumn1956). Bifurcation ratio is a dimensionless property of drainage basin and is supposed to be controlled by drainage density, stream entrance angle, lithological characteristics, basin shapes, basin areas etc (...Sing2014). According to Sing et.al (1984) mean bifurcation ratio show a stable trend in a region of uniform geologic structure and lithological condition but they show variable trends over varying geological structure. R.E.Horton (1945) mentioned that mean bifurcation ratios vary from about 2.0 for the flat or rolling basin to 3.0 to 4.0 for mountainous, hilly

dissected basin. In the present study, the elongated Gandeshwari river basin has developed over the dissected rolling topography with a diversified lithological condition. After the calculation of bifurcation ratio of this basin, it is found that the bifurcation ratio is varying with the increasing of order, i.e. bifurcation ratio between 1st and 2nd order is 2.2, between 2nd and 3rd order is 4.66, between 3rd and 4th order, is 5.11 and ratio between 4th and 5th order is 2.83 and bifurcation ration between 5th and 6th is 1.66 and 6th and 7th order is 1. The mean bifurcation ratio of this basin is 2.494, it is due to its varying topography and lithological condition (Table: 2).

Sinuosity Index

The analysis of deviation of the course of drainage line from the straight path is called Sinuosity. It may help to study the effect of terrain characteristics on the river course and vice versa. Here the sinuosity index value of the Gandeshwari river is 1 (Table: 2). It indicates that the course of Gandeshwari River is straight in nature.

AREAL ASPECTS

It deals with the total area projected upon a horizontal plane contributing overland flow to the channel segment of the given order and includes all tributaries of the lower order. Basin area is depended upon the morphometric attribute as it is related to the spatial distribution of a number of a significant attribute such as drainage density, stream frequency etc.

Drainage Density (D_d)

According to Horton (1932) Drainage density (Dd) refers to total stream length per unit area. It is the ratio of total channel segment length cumulated for all orders within a basin to the basin area. According to the geomorphologists like melton (1957),R.J.Chorley(1957),Carlton(1963),Cotton(1964),Sing et.al(1974) the spatial variation in drainage density has been related to precipitation effectiveness, vegetation index, permeability of train, rainfall intensity, geological and lithological structure, Vegetation cover etc. Low drainage density leads to coarse drainage texture (Strahlerv1964). In this study, the total Gandeshwari basin has been divided into three classes on the basis of drainage density i.e. Low (-0.78-.00), Medium (0.00-0.01) and high (0.01-8.02). In the upper and lower portion of the drainage basin, the drainage density is low due to the presence of highly permeable subsoil material, dense vegetation cover and low relief. On the other hand, Moderate to high D_d has been observed in the upper and middle part of the basin due to the presence of impermeable sub-surface materials, sparse vegetation and high mountain relief (Figure 6.a). The average drainage density of the Gandeswari drainage basin is high i.e. 12.3km^2(Table-2) which clearly indicates that the basin has low infiltration of water and high overland flow.

Drainage Texture

According to Smith (1950), Drainage texture means the relative spacing of drainage lines. He had classified drainage texture into five different texture classes

Table 3: Drainage Texture

Class	Characteristics
> 0.8,Dt_{VC}	Very Coarse drainage texture
0.8-0.6,Dt_C	Moderate drainage texture
0.6-0.4,Dt_m	Fine drainage texture
Table 3: Contd.,	

0.4-0.2,Dt_f	fine drainage texture
0.2-0.001,Dt_{VF}	Very fine drainage texture

Source: (Savindra Singh, 1981)

Here the Drainage Texture value is 12.85 (Table: 2) which indicate that the Gandeshwari Basin area has a very fine drainage texture. A large number of tributaries have been closely streamed with each other along with the main channel.

Stream Frequency (F_S)

It depends mainly on the lithological structure of the basin that reflects the texture of the drainage network. It related to rock structure, infiltration capacity, vegetation cover, relief, nature and amount of rainfall and subsurface material permeability of basins. The study basin has been classified into three classes on the basis of stream frequency i.e., Low (-0.0025-.0000), Medium (.0000-.0001) and high (.0001-.0174). The low stream frequency is observed in the eastern side and lower part of the basin. Medium stream frequency is observed mostly in northeastern to northwestern part of the middle portion. Similarly, the highest stream frequency is observed in the upper middle portion (Figure 6.b). So the stream frequency established that this river basin is spreading throughout both plateau and plain areas.

Form Factor (F)

The form factor may be defined as the ratio of the area of the basin and square of basin length (Horton1932). According to him, the form factor value varies from 0(highly elongated shape) to the unit 1(perfect circular). Here the F value is 0.13(Table-2) which indicates that the Gandeshwhari Basin is most probably elongated in shape.

Circulatory Ratio (R_C)

The circulation Ratio is influenced by the length and frequency of streams, geological structures, land use, climate and slope of the basin. The value of circulatory ratio varies from 0 to 1. The circulatory ratio of Gandeshwari river basin area is 0.11(Table: 2).The structural control of drainage is probably responsible for the low values of circularity ratio. The lower circulatory ratio represents an elongated basin and the higher represents the more circulatory shape.

Elongation Ratio (R_e)

Schumn (1956) defined elongation ratio (Re) as the ratio of the diameter of a circle of the same area as the drainage basin and the Maximum length of the basin. The values of R_e varies from 0 (in high elongated shape) to 1 (in circular type). (**Circular-** More than 0.9, **Oval**-0.9-0.8, & **Elongated-** Less than 0.8)

The Elongation Ratio value of Gandheswari river basin is 0.13(Table: 2), indicating a sharp elongated shape with low relief.

Constant of Channel Maintenance

In the Gandeshwari river basin has been classified three classes on the basis of constant of channel maintenance i.e. Low (123-281), moderate (281-321) and high (321-742). A low constant of channel maintenance has seen in the most part of the river basin, mainly in the middle part and a lower portion of the basin it is because of high permeable rock surface, dense forest cover and low relief of the area. A moderate constant of channel maintenance has been seen in the foothills of the high elevated areas, mainly western and eastern part of the basin. A high constant of channel maintenance

has been found in the eastern and western part of the river basin due to the impermeable rock surface, sparse vegetation and high mountain relief of that region (Figure 6.c).

Length of Overland Flow (Lg)

The Length of overland flow of a river is one of the most important variables which affecting hydraulic and physiographic developments of drainage basins. Here the Gandeshwari river basin has been classified into three classes on the basis of length of overland flow i.e. Low (45.35-128.14), Moderate (128.14-201.62) and High (201.62-375.10). High '**Lg**' has been observed in the upper western and Middle Eastern part of the basin that indicates the youthful stage of the river in these portions of this basin. Moderate to low **Lg** has been observed in most parts of the basin area mainly middle and lower portion that indicates the maturity of the river basin. (**Figure 6.d)**

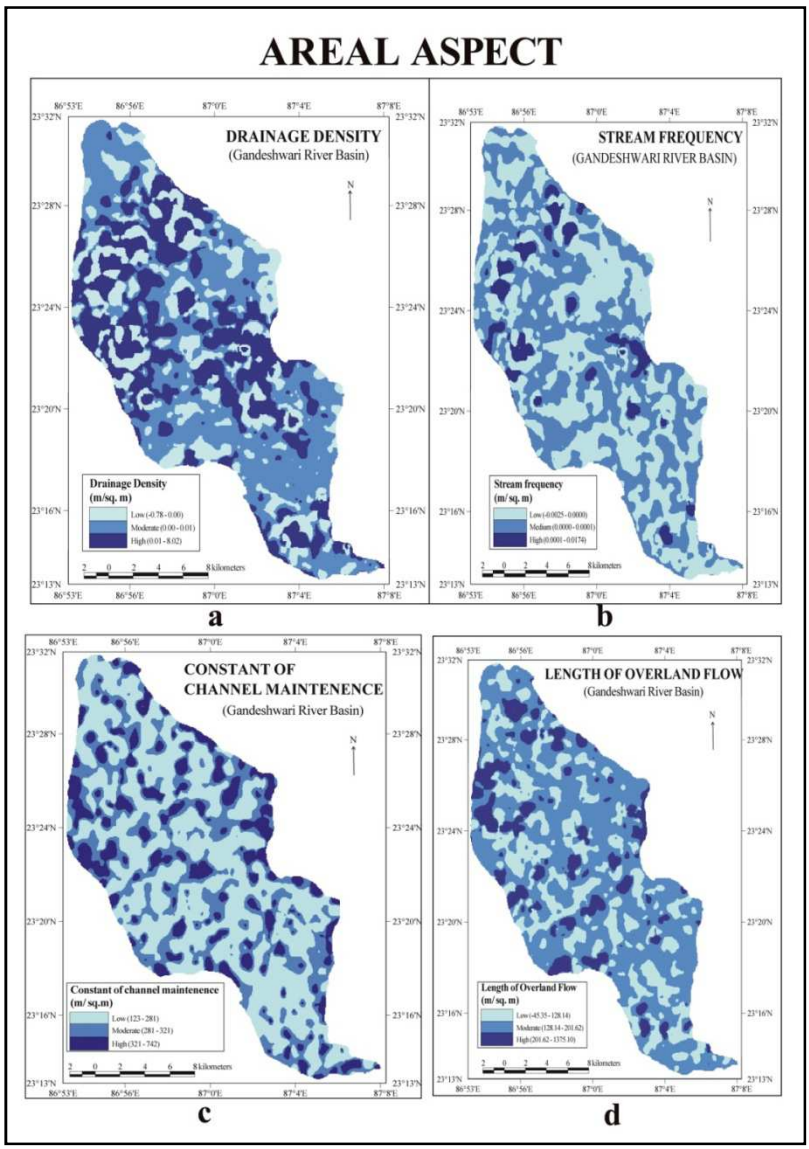

Figure 6: a. Drainage density, b. Stream Frequency, c. Constant of Channel Maintenance &d. Length of Overland Flow

RELIEF ASPECTS

The relief aspects of the drainage basin are related to the study of three-dimensional features of the basins involving area, volume, and altitude of the vertical dimension of landforms where different Morphometric methods are used to analyze terrain characteristics, which are the result of basin process.

Relative Relief

The term relative relief means the actual variation of height i.e. difference between the maximum height and the minimum height in per grid. Relative relief is the technique which is effectively capable of presenting the relief characteristics without considering sea level (Singh, 1992). **The** first time a scientific and systematic study of relief was done by Smith (1935). Relative relief is a very important Morphometric variable which is used for the overall assessment of morphological characteristics of terrain and degree of dissection.

The Gandeshwari river basin has been classified into three classes on the basis of relative relief. The relative relief ranges from 7m to 336m. Relative relief in the upper and lower part is low because the upper portion of the basin area is made of high resistant rocks (Granite) and lower part of the basin is mainly a low depositional plain land of river Gandeshwari. High relative relief has seen in the middle part of the basin mainly near the 'Susunia' hill region which represents highly undulated and eroded topography (Figure 6.a).

Ruggedness Index

Ruggedness index is the product of maximum basin relief (H) and drainage density (Dd), where both parameters are in the same unit. An extremely high value of ruggedness number occurs when both variables are large and the slope is steep (Strahler, 1956). The Gandeshwari river basin is classified into three classes i.e. low (-0.90-8.40), moderate (0.09-0.39) and high (0.39-8.40). The ruggedness index value is low mostly in upper eastern part, middle-west and lower eastern part of the basin because of less undulation and less roughness area. High and Moderate ruggedness index value is seen in the middle part of the basin which indicates that this area is highly eroded and undulated (Figure 6.b).

Slope Map

A slope is an area of land that makes a definite angle to the horizontal landscape. Strahler (1964) expressed "the inclination or gradients of the surface of a basin in terms of maximum valley side slope, measured at interval along the valley walls in the steepest part if the contour orthogonal running from divides to adjacent steam channels". Penk (1953) emphasis to work on the slope, forms, and angle and process through waxing and waning developments leading the stage of pediplanation and the recent quantitative approaches and method of morphometric evolution of an area. Therefore, hill slope is an important component of the complex landscape that forms a drainage basin (Chorley, 1958).

The Gandeshwari river basin has been classified into three classes on the basis of slope i.e. Low (0.00-1.50), Medium (1.50-3.17) and high (3.17-34.75). The slope of the basin is low in the upper western and eastern part and lower part because of less erosion and presence of thick forest cover. The slope of the basin is high in the middle part. This area is associated with deforestation and excessive rate of soil loss. (Figure 6.d).

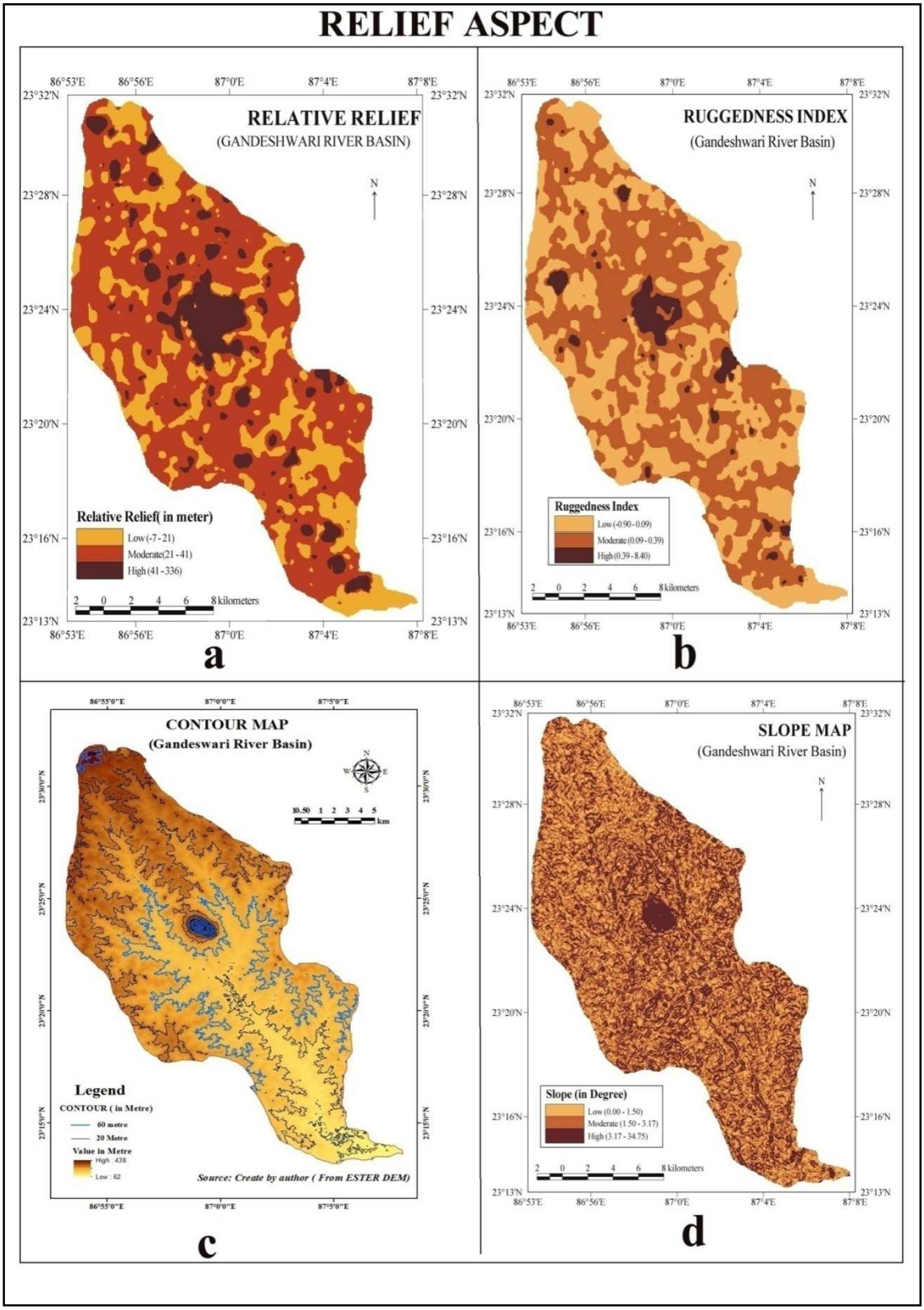

Figure 7: a Relative relief, b. Ruggedness Index c. Contour Map & d. Slope Map

CONCLUSIONS

In the present study morphological features of Gandeswari drainage basin are being extracted utilizing satellite Imagery and analysis of assessing for the drainage pattern. Different morphometric analysis has been done through the measurement on linear, areal and relief aspects of the basin. The basin is a 7^{th} order drainage basin, covering 388.60sq km. The mean Bifurcation ratio is 2.494. So it indicates that the topography of the basin is rolling in nature and highly dissected. The elongated shape of the basin suggests that the basin area is under a wide variety of climatic and geological regime. The mean drainage density (12.24sq km) indicates that the drainage basin is mature and exist channel system is well developed.

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