Sustainability, Agri, Food and Environmental Research, (ISSN: 0719-3726), 11(X), 2023:
http://dx.doi.org/10.7770/safer-V11N1-art2387

Remote sensing and GIS based approach in morphometric analysis of Birma river basin (Central India).
Enfoque basado en sensores remotos y SIG en el análisis morfométrico de la cuenca del río Birma (India Central).

P. Sharma[1], M. M. Singh[1], R. S. Chaurasia[2], and Mohd. Sabir[3]

[1]Department of Geology, Bundelkhand University, Jhansi (U.P), India.

[2]Indian Grassland and Fodder Research Institute, Jhansi (U.P), India.

[3]Department of Geography, Vardhman College, Bijnor (U.P), India.

Correspondence author: purugeo@gmail.com

ABSTRACT

Birma river basin lies between two states of India (Uttar Pradesh and Madhya Pradesh). The parameters of Morphometric analysis were measured as Stream Order, Drainage Density, Stream Frequency, Bifurcation Ratio, Elongation Ratio, etc. Digital Elevation Model is downloaded from the USGS website. The results show that the Basin ranges from dendritic to sub-dendritic and is heterogeneous in texture and structurally controlled. The stream order ranges from first order to sixth order and the drainage density and elongation ratio is 1.23 and 0.59 respectively which specified that the basin is elongated in shape. The bifurcation ratio varies from 2.67 to 9.0 indicating that the basin has undulating topography. The analysis is contributed to understand watershed management sites for the conservation of soil and water. Assessment of these parameters ultimately gives information for the arrangement of sustainable water resource development and its management for the local people residing nearby the river.

Keywords: Birma River Basin, Digital Elevation Model (DEM), Geographical Information System (GIS), Morphometric analysis, Remote Sensing.

RESUMEN

La cuenca del río Birma se encuentra entre dos estados de la India (Uttar Pradesh y Madhya Pradesh). Los parámetros del análisis morfométrico se midieron como Orden de la corriente, Densidad de drenaje, Frecuencia de la corriente, Relación de bifurcación, Relación de alargamiento, etc. El modelo de elevación digital se descarga del sitio web del USGS. Los resultados muestran que la Cuenca varía de dendrítica a subdendrítica y es heterogénea en textura y estructuralmente controlada. El orden de las corrientes varía de primer orden a

sexto orden y la densidad de drenaje y la relación de alargamiento son 1,23 y 0,59 respectivamente, lo que especifica que la cuenca tiene una forma alargada. La relación de bifurcación varía de 2.67 a 9.0, lo que indica que la cuenca tiene una topografía ondulada. El análisis se contribuye a comprender los sitios de manejo de cuencas para la conservación del suelo y el agua. En última instancia, la evaluación de estos parámetros proporciona información para la organización del desarrollo sostenible de los recursos hídricos y su gestión para la población local que reside cerca del río.

Palabras clave: Cuenca del río Birma, Modelo Digital de Elevación (DEM), Sistema de Información Geográfica (GIS), Análisis morfométrico, Teledetección.

INTRODUCTION

The configuration, shape, dimension and landforms of the earth surface can be analyzed in mathematical way through Morphometry. It gives the detailed information about the drainage basin and can be performed taking different aspects such as areal, linear and relief network of the channel, basin aspect and slope. Such analysis also gives information about the formation of watershed. With Reference to Morphometric Analysis Gardiner (1990) specified that characteristics of the drainage basins can be used multi-purposely such as prediction of erosion rates and flood peaks can be done. Further, Manu and Anirudhan (2008) has indicated about the importance of drainage pattern morphometric analysis and the relationships between structures, rock type and drainage pattern in different parts of India. In order to study the geometry, related to the drainage basin network, morphometric techniques are found very stable and helps in characterizing the drainage network and the different variables such as Lithology, Rainfall and Structure. Thus, in the present study assessment of the drainage basin of Birma river with the help of quantitative morphometric analysis will indicate about the hydrological nature of the rocks and the Morphometric Parameters of Birma river are analyzed using Digital Elevation Model data, GIS and Remote Sensing. Digital Elevation Modal is the 3D representation of the earth surface and also used to determine slope, drainage network, natural resource explorations, hazards monitoring and aspects of the earth surface. The benefit of GIS over the traditional methods is that it has the potential to create, manipulate, store, display and analyze and make use of the spatial data with ease. The aim of the present study is to determine the hydrological parameters of the river for the management of water, water harvesting methods with the help of construction of the various structures such as recharge shaft, check dam, storage tanks etc. In the present study approaches have been applied over the traditional approaches for exploring the study

area of the river. The aforesaid characteristics of GIS have been used to determine the aerial, relief and linear features of Birma river drainage system.

MATERIAL AND METHODS

Study area: The Birma river is an important lower part tributary of Betwa river. Birma river Basin is situated between Uttar Pradesh and Madhya Pradesh of Bundelkhand region, in India. It originates nearby Chaukhra district Chhatarpur, Madhya Pradesh 25°5'24.14" N to 79°33'34.90" E. It flows through three districts named as Chhatarpur, Mahoba and Hamirpur and meets Betwa river near Bhojpur in Hamirpur district Uttar Pradesh 25°52'57.086" N to 79°54'3.249" E. The basin is distinguished into four districts- Chhatarpur, Mahoba, Jhansi and Hamirpur (Fig.1). It covers an area of 2494.71 km^2 in Uttar Pradesh and 130.64 km^2 in Madhya Pradesh. From the origin point the path of the river is tortuous. Climatic variation reported in the region is that summers are hot and winters are cold. The area receives precipitation from the south-west monsoon and maximum precipitation is received in the months of July, August and September.

Methodology: Assessment of the drainage basin of the Birma river by using quantitative morphometric analysis explains about the hydrological characteristics and background of the rocks present within the basin. With the help of morphometric analysis holding capacity of the rocks, Permeability, Productivity of the basin has been measured. Digital Elevation Model (DEM) is downloaded from https://earthexplorer.usgs.gov website for the study. After which, filling of the gaps, flow direction, flow accumulation, water shed and stream order was prepared with the help of Arc GIS software. Morphometric parameters as Drainage density, bifurcation ratio, drainage frequency, stream frequency etc. were calculated for entire Birma river. On the basis of aforesaid calculations, the river is classified in to six orders. Google Earth software is also used along with GIS and Remote Sensing to complete this study. The linear, areal and relief aspects of the Birma basin have been measured thorough morphometric analysis which is mentioned in the table below. (Table.1)

Sustainability, Agri, Food and Environmental Research, (ISSN: 0719-3726), 11(X), 2023:
http://dx.doi.org/10.7770/safer-V11N1-art2387

Study area

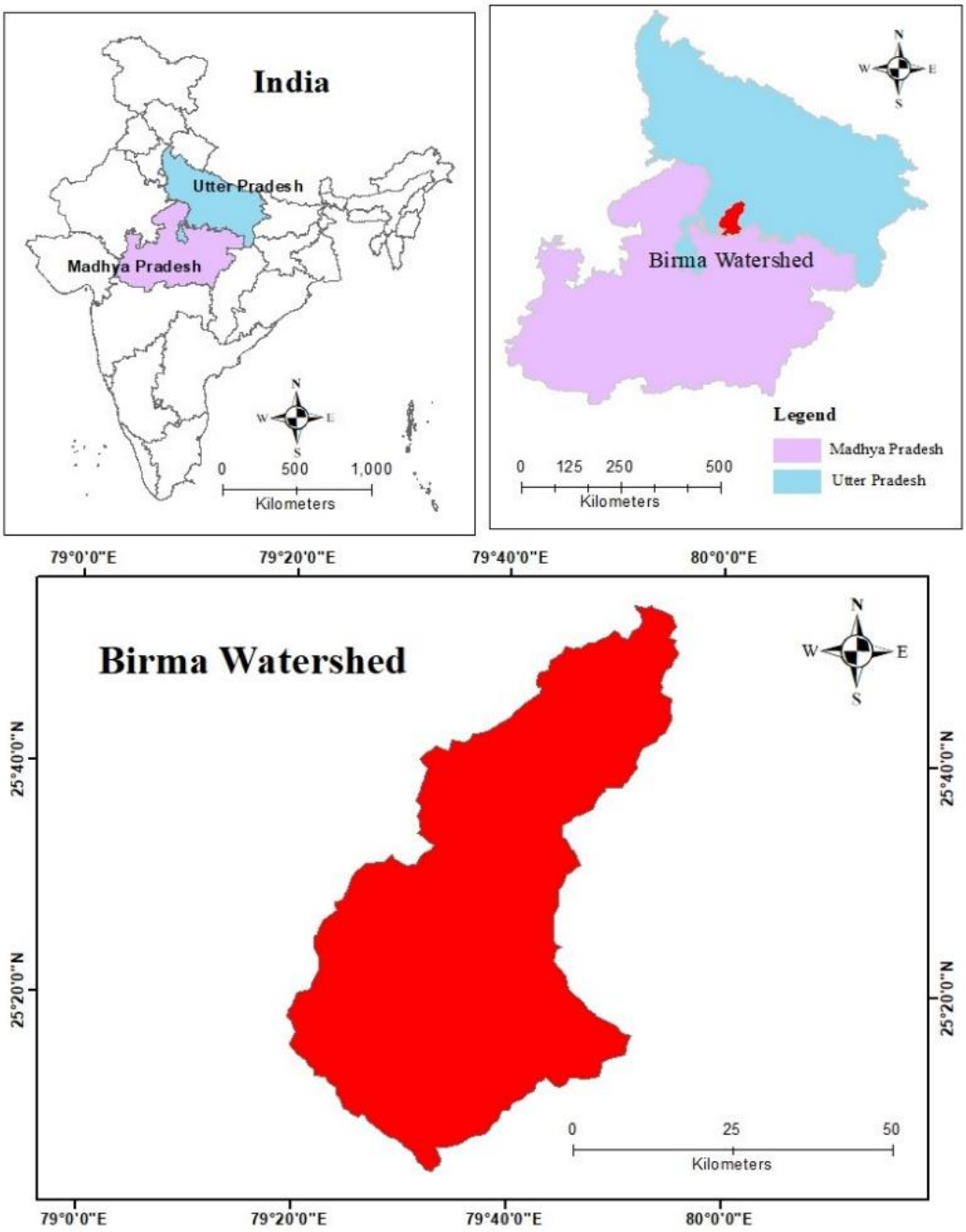

Fig. 1: Location Map of Birma River

Table 1: Methodology used to calculate the Morphometric Parameters of Birma River Basin.

S.no.	Morphometric Parameters	Formula	References
1	Stream order	Hierarchical rank	Strahler, 1952
2	Stream length (L_u)	Length of the stream	Strahler, 1964
3	Stream length ratio (R_L)	$R_L = L_u/L_u–1$	Strahler, 1964
4	Mean stream length (L_{sm})	$L_{sm} = L_u/N_u$	Strahler, 1964
5	Drainage density (D_d)	$D_d = L_u/A$	Horton, 1932
6	Drainage Intensity (D_i)	$D_i = F_s/D_d$	Faniran, 1968
6	Stream frequency (F_s)	$F_s = Nu/A$	Horton, 1932
7	Bifurcation ratio (R_b)	$R_b = N_u/N_u+1$	Strahler, 1964
8	Drainage texture (R_t)	$R_t = N_u/P$	Horton, 1945
9	Form factor (R_f)	$R_f = A/L_b^2$	Horton, 1932
10	Circularity ratio (R_c)	$R_c = 4\pi A/P^2$	Miller, 1953
11	Elongation ratio (R_e)	$Re=2\sqrt{(A/\pi)}/L_b$	Schumn, 1956
12	Relief ratio (R_h)	$R_h = H/L_b$	Schumm, 1956
13	Ruggedness Number (R_n)	$R_n = D_d*B_h$	Schumm, 1956
14	Length of overland flow (L_g)	$Lg = 1/2D_d$	Horton, 1945

L_u = Total Stream Length of order ''U'', L_u-1 = Total Stream Length of its next lower order, N_u = Total Streams of order ''U'', A = Area of Basin, D_d = Drainage Density, F_s = Stream Frequency, Di = Drainage Intensity, R_b = Bifurcation Ratio, N_u+1 = Number of Streams of the next higher order, R_t = Drainage Texture, P = Perimeter (km), R_f = Form Factor, L_b^2 = Square of the Basin Length, R_c = Circularity Ratio, P^2 = Square of the Perimeter, R_h = Relief Ratio, H = Total Relief of the Basin in km, B_h= Basin Relief, (R_n) = Ruggedness Number, (L_g) = Length of overland flow.

RESULT AND DISCUSSION

Morphometric analysis of the selected parameters based on Strahler's hierarchic ranking of streams, digital elevation model, stream density, and slope has been carried out with the help of Arc GIS and Google Earth software. Digital Elevation Model is showing the lowest point 61 meter and highest point 348 meter of the Birma basin (Fig.2). The length of the river is 141.32 km and covers an area of 2625.35 km^2 (Table 2a). There are some dams and reservoirs on this river as Swami Bramha Nand Dam, Arjun Sagar reservoir, Bela Sagar reservoir, Majhgawan tank and Bara Tal etc. It has sixth stream order drainage pattern. Topographic analysis of the basin exhibits dendritic to sub-dendritic drainage pattern of the

river. Bifurcation values varies from 2.67 to 9.0 and mean Bifurcation value is 4.02 that is near to 5 it means that the region is structurally controlled and thus, the streams are more bifurcated. Lower values of elongation (0.59) and circulatory ratios (0.37) also indicate that the region is less circular and more elongated. The slope map shows that the southern part has high relief about five degree and decreases in northern part progressing towards zero degree. However, slope is directed from south-east to north-east. Slope map is classified between 0 to 4.96 degree. Drainage density is divided in to five categories and record highest 4.12 which is signify highest strength of the streams and 0 lowest strength of streams. Based on the selected parameters, the results of morphometric analysis of Birma river basin Tables 2 and 3 are given below.

Stream order: In drainage basin analysis defining the stream order is the initial step. It depends on the different orders of stream based on hierarchy. The dissimilarities found in the different stream orders are due to structural and physiographic set up of the related region. In the present study different stream orders of the Birma river is examined. Strahler method has been used to measure the total streams of the Birma river which are 2265 in count. Out of these 2265 first order streams are 1726 in number. The second order streams are 402, third order 96, in fourth order 36, in fifth order 4 are there while last but not the least sixth order is one. The streams are formed under dendritic to sub-dendritic pattern and indicates uniform lithology. In the initial stage the number of streams is greater while in the next increasing order up to last that is sixth it has decreased gradually (Fig.3). The graph represents relation between Stream order and Stream Numbers (Fig. 4).

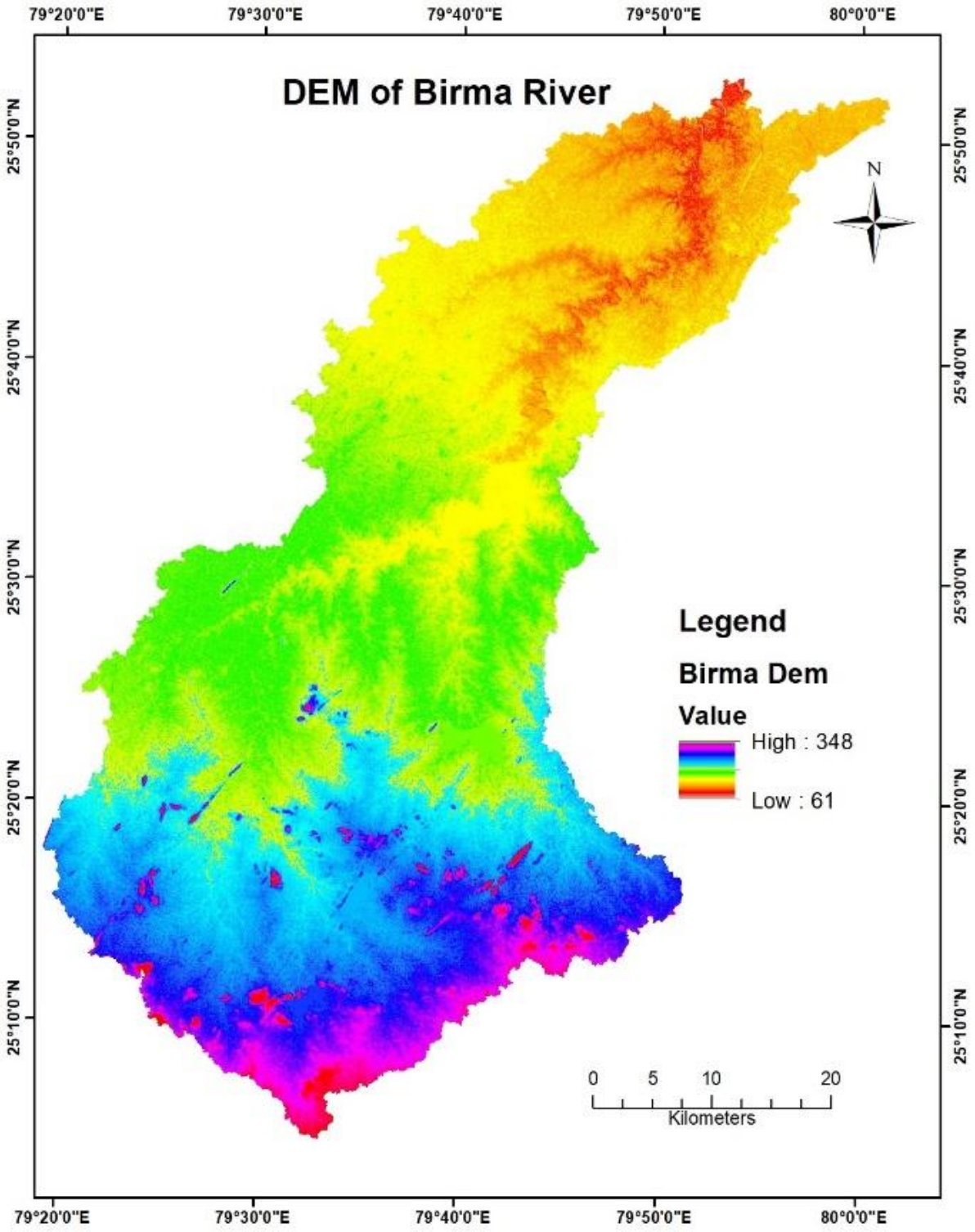

Fig. 2: Digital Elevation Model of Birma River.

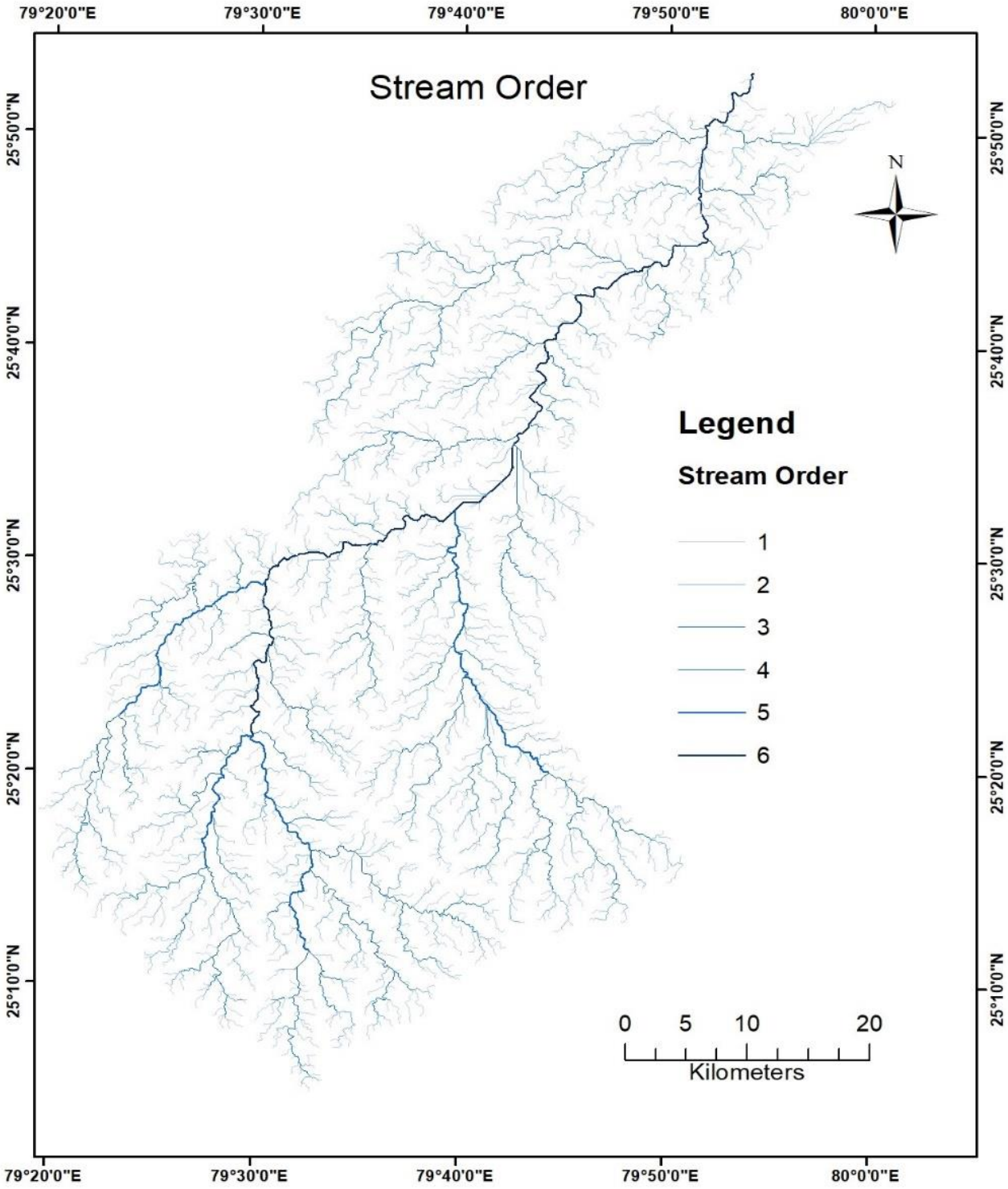

Fig. 3: Stream Order Map of Birma River

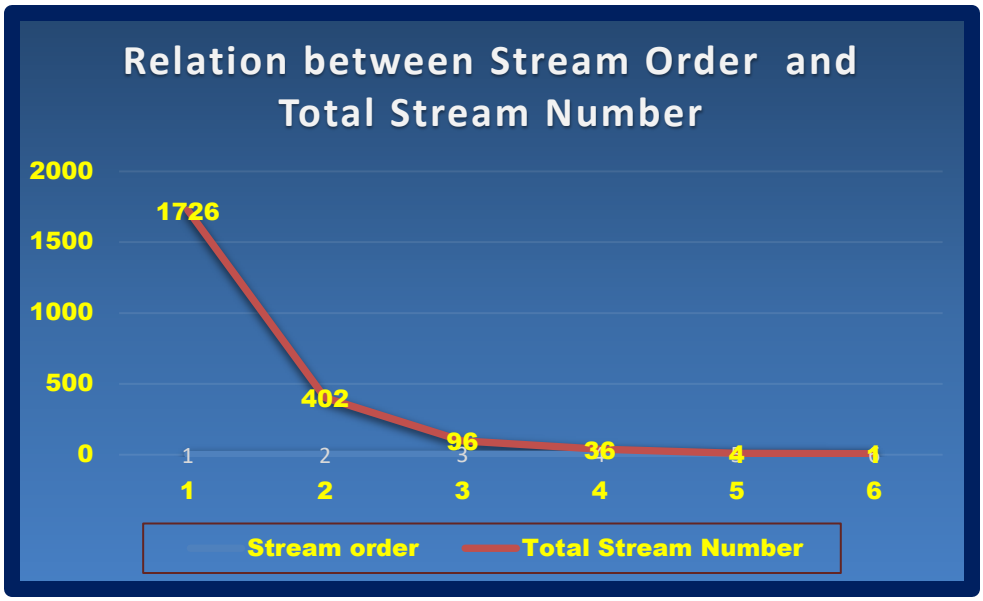

Fig. 4: Relation between Stream order and Stream Number

Stream length (L_u): With reference to the Birma river the length of the first order is 1643.46 km, second order is 798.81 km, third order is 387.06 km, fourth order is 216.07 km, fifth order is 92.69 km and sixth order 101.16 km. The length decreases with each stream order starting from first to the fifth order. Variation in stream order indicates that the terrain of that area has high relief. Slopes are moderately steeper in the study area. The graph represents relation between Stream order and Stream Lengths (Fig. 5).

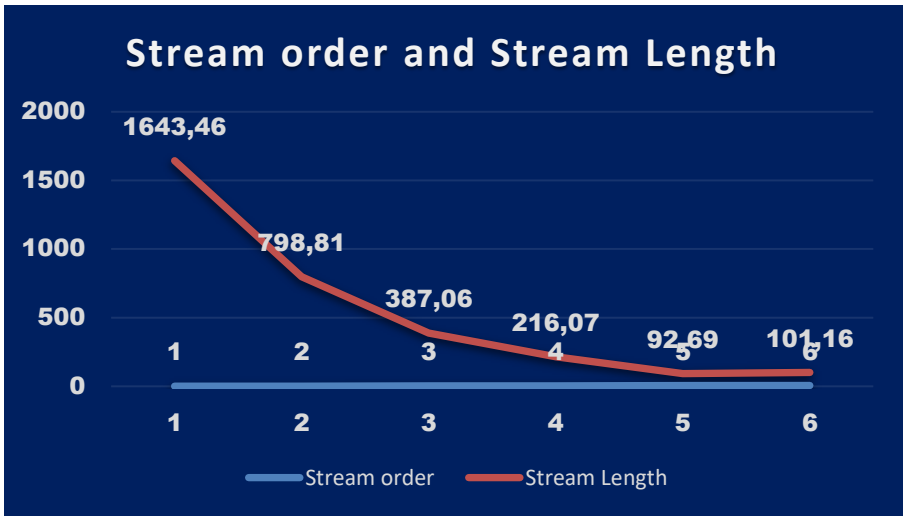

Fig. 5: Relation between Stream order and Stream Length

Mean stream length (L_{sm}): Mean stream length of any channel is the combination of the components of the network of the drainage as well as the surface of the basin. It can be obtained as a ratio between the stream lengths of the order to the order containing number of streams. Here in the present study the total length of the stream order in the study area is different from each order. The total mean length varies from 0.95 to 101.16 which are rapidly changing from lower to higher order.

Stream length ratio (R_L): Stream length ratio can be expressed as the ratio between the mean stream lengths of the order to the mean stream length of the next order (lower). In the study area of Birma river the ratio of the orders differs from one to other. The stream length ratio describes about the permeability of the rock formed in a Basin.

Bifurcation ratio (R_b): it can be defined as the ratio of the number of streams of the given order to the number of streams in the next higher order. Bifurcation ratio has been discussed as one of the most important factors for relief and dissection. Bifurcation ratio is easy measure regulated by different factors such as junction angle, drainage density, shape, area of the basin and lithology etc. Bifurcation ratio is also related to the pattern of branching of the drainage network. Bifurcation ratio hardly changes for the different kinds of environment, but in case of strong geology bifurcation ratio exhibits change. The Rb of the Birma river varies from 2.67 to 9.0 so the region is structurally controlled and thus, the streams are more bifurcated.

Relief ratio (R_h): Relief ratio is the ratio between the maximum reliefs to the horizontal distance. This horizontal distance is situated alongside the longest dimension of that basin which appears parallel to the main line of drainage. The Rh value of Birma river is 2.92 indicating high relief. It decreases in case the area and size of the sub basin of a certain drainage basin increase. Further relief ratio is a measurement of drainage basin steepness and also indicates about the erosion processes.

Ruggedness Number (R_n): It can be obtained as a product of density and maximum basin relief. Ruggedness number is higher in value when drainage density and maximum basin relief are large in value and the slope is long and steep. Rn value of the present study is 353.01 indicating the area is extremely rugged with high relief.

Drainage density (D_d): Drainage density can be explained as the sum of all the streams flowing in a watershed to the total area of the watershed. It can be used in knowing that how much a particular watershed is permeable and porous in nature. It also tells about the texture of the drainage. Where there is low drainage density the soil is permeable and where there is high drainage density the soil is impermeable. Birma river has 1.23 drainage density so it falls in low Dd category (Fig. 6).

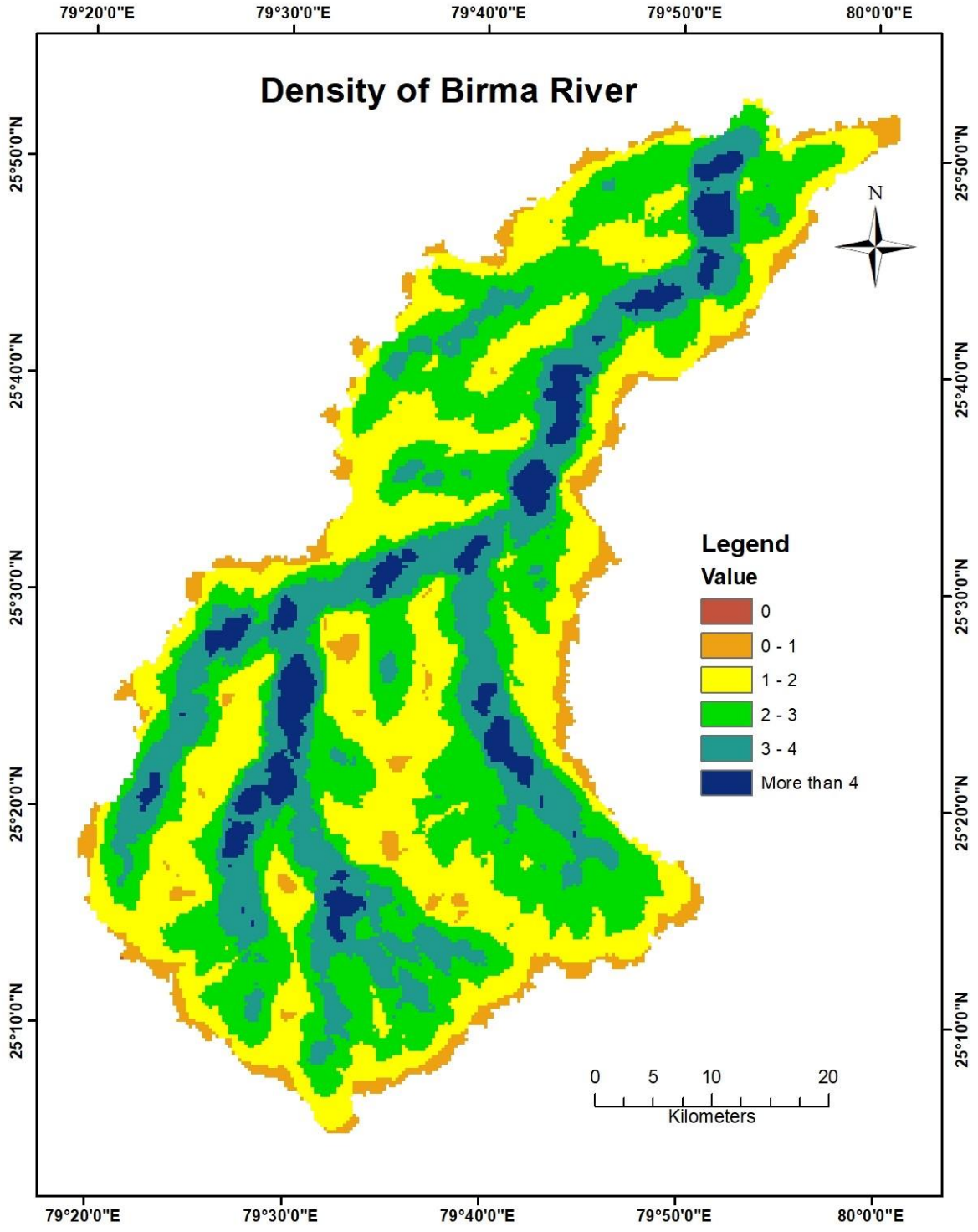

Fig. 5: Stream Density Map of Birma River

Stream Frequency (F_s): Stream frequency can be expressed as the ratio of the streams of all the orders in a unit area. A larger basin contains more and larger streams as well as

tributaries per unit area in comparison to the smaller basin. There exists a positive correlation between the stream frequency and drainage density which further indicates that stream population is increased in relation to the increase in drainage density. Temperature and rainfall also affected it. Fs of the study area are 0.86 and falls into low stream frequency per square kilometers.

Texture ratio (T): In the analysis of drainage Morphometry texture ratio plays important role. Texture ratio itself depends on capacity of infiltration, lithology and relief aspect etc. of a terrain. The Texture ratio of Birma river is 3.93 and categorized as lower in nature.

Form Factor (F_f): It can be expressed in the form of ratio. This ratio exits between basin area and the basin length square. In a circle equation the form factor will always be less than 0.785. In case of river if the form factor is 0.27 that is a smaller value indicates that the basin is elongated in shape. It has been found that the water shed continuing with lower form factors exhibit lower peak flow and longer time while on the other hand, basin with high form factor report high flows which are of shorter time.

Circulatory Ratio (Rc): Circulatory ratio is considered similar to the elongation ratio. It has been defined as the ratio between area of the circle and area of the basin. Circulatory ratio varies between 0 (in line) to 1 (in a circle) with reference to a circle. The range of 0.23 to 0.79 is maximum range for the circulatory ratio for all the basins. Generally, the greater value of the circulatory ratio indicates that the basin is mostly circular in shape and lower value indicates less circular shape. It has been observed that the natural tendency of the basin is to become elongated to get the maturity. The Rc of Birma river is 0.17 which indicates less circular and more elongated shape. Where there is structurally controlled drainage the value of Rc is also observed to be smaller in value.

Elongation Ratio (Re): It is the ratio of maximum basin length to the diameter of the circle which has same area similar to the basin. Different shapes can be predicated on the basis of elongation ratio. It lies between 0-1. The value of 0 indicates that the basin has elongated shape, while 1 indicates that it has circle shape. The value of elongation ratio which is about one indicates low relief and between 0.6 to 0.8 shows high relief and steeper ground slope. The elongation ratio of Birma river is 0.59 which approximates 0.6 as value. 0.6 shows that the river has elongated basin and high relief.

Slope: The slope map of the area falls under high slope and slope decreases from south-west to north-east (Fig. 7).

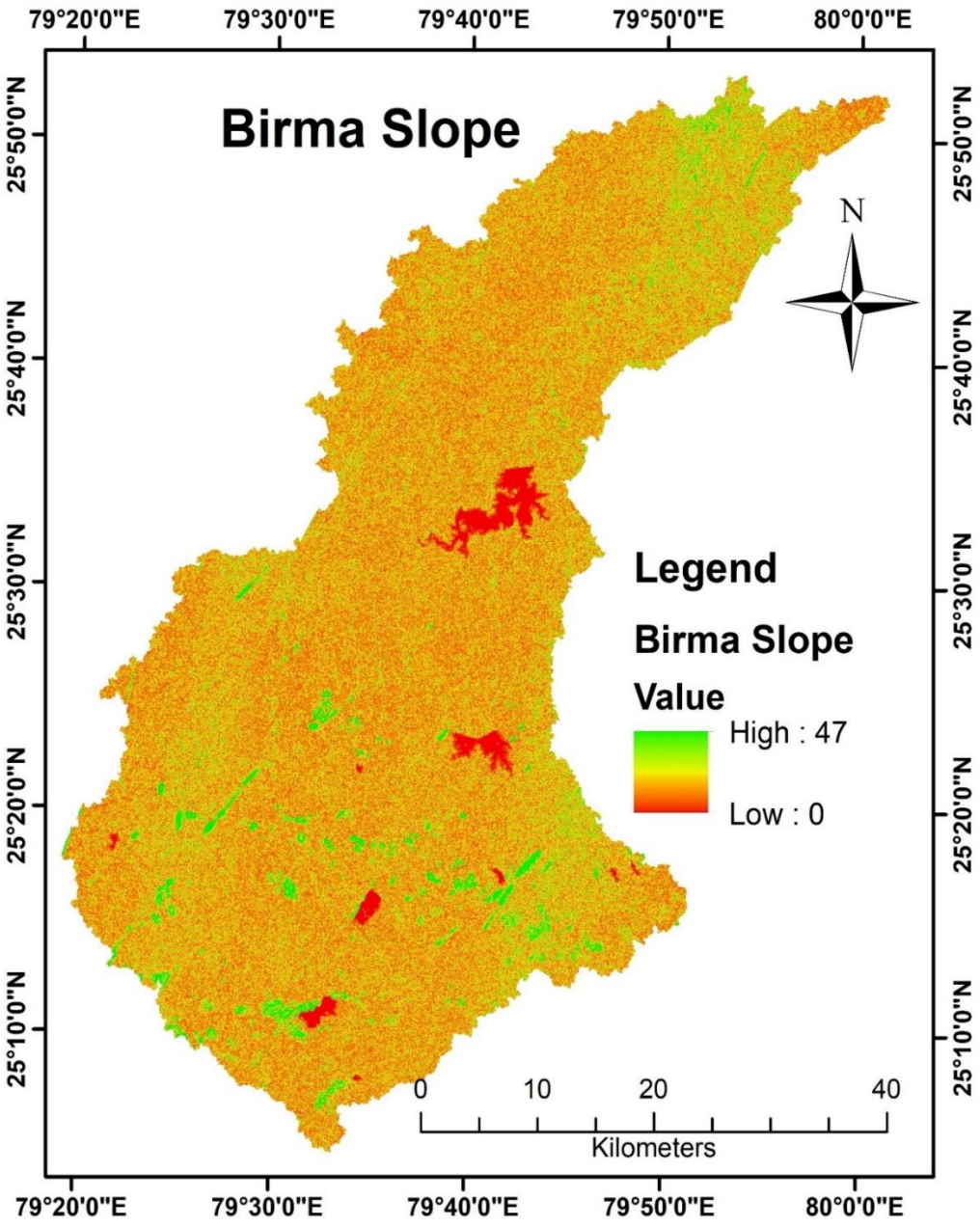

Fig. 6: Slope Map of Birma River

As conclusion, the present study shows that Birma river basin has dendritic to sub-dendritic drainage pattern with hard rock terrain. The drainage network has rolling topography. Bifurcation ratio of the basin varies from 2.67 to 9.0 which show that basin has undulating topography and Mean Bifurcation ratio is 4.02 which indicate that basin is highly structurally control. The area is structurally deformed and has mountainous relief. The runoff is moderate to high. The drainage density of the study is 1.23 Km which indicates that the

area is of coarser nature. After examining the slope map of this area, it falls under high slope and slope decreases from south-west to north-east and elongation or circulatory values indicates that the basin is less circular and more elongated. On the behalf of above statement, it can be said that morphometric analysis has important significance for watershed management, public related policies and the management of environment for local peoples.

REFERENCES

Faniran, A. (1968). The index of Drainage intensity- A Provisional New Drainage Factor. *Australian Journal of Science*, 31, 328-330.

Gardiner, V. (1990). Drainage Basin Morphometry. In Goudie, A., Ed., Geomorphological Techniques, Unwin Hyman, London,71-81.

Horton, R.E. (1932). Drainage Basin Characteristics. *Transactions, American Geophysical Union, 13*, 350-361.

Horton, R.E. (1945). Erosional development of streams and their drainage basins, hydrological approach to quantitative morphology. *Bulletin of the Geological Society of America*, 56, 275-370.

Manu, M.S. and Anirudhan, S. (2008). Drainage characteristics of Achankovil River Basin, Kerala. *Journal Geological Society India, 71*(6),841–850.

Miller, V.C. (1953). A quantitative Geomorphic Study of Drainage Basin Characteristics in the Clinch Mountain Area, Virginia and Tennessee, Project NR - 389 -042, Tech. Rept 3, Columbia University. Dept. of Geol. ONR, Geog. Branch, New York.

Schumm, S.A. (1956). Evolution of drainage systems and slopes in badlands at Perth Amboy, New Jersey. *Geological Society of America Bulletin*, 67, 597–646.

Strahler, A.N. (1952). Hypsometric Analysis of Erosional Topography. Bulletin of Geological Society of America, 63, 1117-1142.

Strahler, A.N. (1964). *Quantitative geomorphology of drainage basin and channel networks*. In: Chow, V.T. Ed., Handbook of applied hydrology, McGraw-Hill, New York, 4-39/4-76.

Web sources:

https://earthexplorer.usgs.gov/

Received: 11th January 2021; Accepted:02th Jule 2021; First distribution:16th September 2021.