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Morphometric Analysis of Drainage using Remote Sensing and GIS: A case study of Hamirpur District.

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Abstract:

Remote sensing and GIS technique are very significant tools for analyzing morphometric characteristics of watersheds related to drainage. Morphometric parameters are very useful to understand any watershed. Drought-prone area like Bundelkhand needs a proper detailed study to create effective watershed-based planning. This study is conducted in the Hamirpur District of the Bundelkhand region in India, which is one of the most drought-prone districts of Uttar Pradesh. These morphometric parameters are created through ASTER DEM in Arc-SWAT. The area shows a dendritic drainage pattern, which is characteristic of a massive hard rock terrain. In this Quantitative morphometric analysis, the highest order stream of the area is found to be 6th order. The mean bifurcation ratio and length of the overland flow of the study area are 4.4 and 2.28 km, respectively which indicate high surface runoff in the basin and the late youth stage of geomorphic development of the basin.

Keywords: Morphometric analysis, Drainage, STRM, Remote sensing & GIS, Hamirpur, Bundelkhand region.

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1. Introduction:

Land, water and soil are initial natural resources and their extensive utilization with the increased population is a major concern for humanity. Further, dealing with the increasing demand for land and water resources is a major essential step to conserving natural resources for sustainable development. The morphometric analysis provides a quantitative description of the drainage system which is an important aspect of micro & mini watershed prioritization. The large use of available innate resources like soil and water is essential for an agriculture-based country like India (Sangale and Yannawar, 2014). Bundelkhand has a maximum dependency on agriculture, a similar status found in the Hamirpur district. Mismanaged and extensive use of natural resources seriously deteriorates and degrades their quality for sustainable development (Muhammad *et al.,* 2015). Due to the quality degradation of water resources, most available water is not sufficient for consumption and drinking (Aravinda and Balakrishna, 2013). over-exploitation of natural resources for maximum agricultural production creates problems due to defective agro-based practices and the absence of watershed development practices, these types of issues become more serious for human society. resultant it reduced groundwater recharge, increased runoff, increased soil erosion and depleted the storage capacity of the reservoir (Chougale and Jagdish, 2017). Earlier, morphometric analysis techniques have been used by different scholars (Srivastava and Mitra, 1995; Srivastava, 1997; Nag,1998; Agarwal, 1998) and all have concluded their research with the help of remote sensing and GIS technique is a prominent tool for watershed analysis & drainage morphometry.

2. Description of Study Area:

Hamirpur District is located in the Bundelkhand Region, which is part of Uttar Pradesh, this is the one of districts, out of seven districts of this region (Fig.1). other districts of Uttar Pradesh in the Bundelkhand region are Lalitpur, Jhansi, Jalaun, Hamirpur, Banda, Mahoba, and Chitrakoot. The Bundelkhand Region lies Between **23°08′N** and **26°30′N** latitude and **78°11′E** and **81°30′E** longitude, while the Hamirpur district is located at**25°07′N** and **26°07′N** latitude and **79°17′E** and **80°21′E** longitude. The total area of Bundelkhand is **71, 619 km2**, and Hamirpur District extended in 4,121 km2 or 41,8870 hectares. Four Main Tahsils (Hamirpur, Sarila, Rath, and Maudaha) are located in Hamirpur District (Fig-1)

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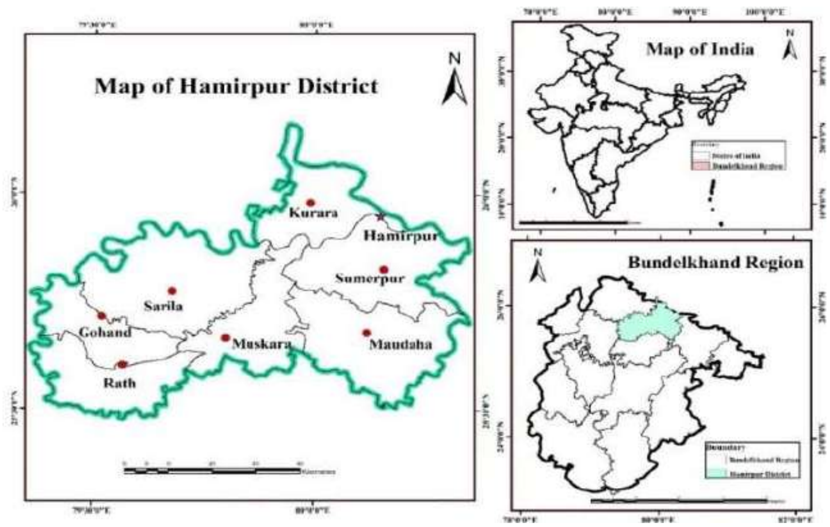
Location map of the study area:



Location Map of study Area (Figure- 1)

3. Data Requirement:

The survey of India topographic sheets (54O/4-7, 54O/9-13, 54N/16, 63C/2, 63C/5, 63B/4) on 1:50,000 and SRTM (Spectral Radar Topographic Mission) digital elevation model of Hamirpur district of 30 m resolution was used for morphometric analysis and stream processing. The Survey of India topographic map was georeferenced using World Geodetic System (WGS) 84 datum, Universal Transverse Mercator (UTM) zone 43N projection in ESRI ArcGIS desktop 10.3 (Table 1)attached below with the details.

Table1: Data and sources of study

Data	Sources
Toposheet No. 54O/4-7, 54O/9-13, 54N/16, 63C/2, 63C/5, 63B/4 on 1:50,000 scale.	Nakshe portal - Survey of India
Digital Elevation Model (DEM)	STRM Data (Srtm.csi.cgiar.org)
Geology and	CGWB,2017
Drainage Data	Drought management report, Hamirpur District, 2017
Administrative boundary	Digitized from the Nakshe portal
Software used	QGIS, Arc-SWAT

3.1. Methods and Materials for the Study –

Remote Sensing and GIS advanced techniques have been used for morphometric analysis. This study area is covered in the Survey of India toposheets series number 54O/4, 54O/5, 54O/6, 54O/7, 54O/9, 54O/10, 54O/11,54O/12, 54O/13, 54N/16, 63C/2, 63C/5, 63B/4 on 1:50,000 scale. ASTER (DEM) with 30m from STRM was used to generate different morphometric parameters in Arc-GIS software 10.3. The drainage map has been extracted using SRTM images and by giving pour points. and it has been projected on WGS 1984 UTM zone 44N. The slope and relief of the basin were examined using digital elevation model data (DEM) available at USGS Earth Explorer on NASA Website. Shuttle Radar Terrain Mapper (SRTM) data on 90 m resolution.

3.2. Morphometric Parameters –

morphological features are very important parameters of spatial analysis.to understand any watershed body, these morphometric parameters are developed and practised by many scholars (Table 2) attached below with the details.

Table 2- Analytical approaches for morphometric measurements.

	Morphometric Parameters	Methods	References
Linear Aspects	Stream order(U)	Hierarchical order	Strahler, 1964
	Stream number (Nu)	Number of streams of each order	Strahler, 1964
	Stream length (Lu)	Length of the stream	Horton, 1945
	Mean stream length (Lsm)	Mean stream length (Lsm)	Horton, 1945
	Stream length ratio (R_L)	R_L =Lu/Lu-1; where Lu=Total stream length of the order 'U', Lu-1=Stream length of next lower order.	Horton, 1945
	Bifurcation ratio (Rb)	Rb = Nu/ Nu+1; where, Nu=Total number of stream A segment of order 'u'; Nu+1=Number of a segment of next higher order	Horton, 1932
	Length of overland flow (Lof)	Lof = 1/2Dd where, Dd=Drainage density	Horton, 1945
Areal Aspects	Drainage density (D_d)	D_d = L/A where, L=Total length of streams;A=Area of watershed	Horton, 1945
	Constant channel maintenance (C)	Lof = 1/D_d where, D_d=Drainage density	Horton, 1945
	Stream frequency (Fs)	Fs = N/A where,	Horton, 1945

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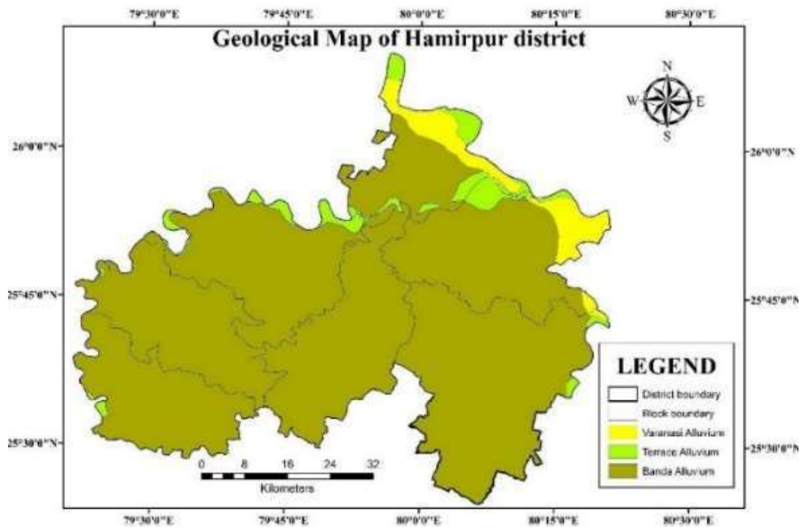
		N=Total number of streams; A=Area of watershed	
	Drainage texture ratio (T)	$T = N_1/P$ where N_1=Total number of first order streams; P=Perimeter of watershed	Horton, 1945
	Form factor (R_f)	$R_f=A/(L_b)$ 2; where A=Area of the watershed, L_b=Basin length	Horton, 1932
	Circulatory ratio (Rc)	Rc=4πA/P2 where A=Area of the watershed, π=3.14, P=Perimeter of watershed	Miller, 1953
	Elongation ratio (Re)	$Re=2\sqrt{(A/\pi)}/L_b$;where, A=Area of the watershed, π=3.14, L_b=Basin length	Schuman,1956
Relief Aspect	Basin relief (B_h)	The vertical distance between the lowest and highest points Of watershed.	Schuman,1956
	W15706	$R_h=B_h/L_b$; where, B_h=Basin relief; L_b=Basin length	Schuman,1956
	W15707	Rn= Bh × Dd; where, Bh =Basin relief; Dd=Drainage density	Schuman,1958
	Relative relief (R_r)	$R_r = B_h/B_p$; where,B□=Basin relief; B_p=Basin perimeter	Melton (1957)

These morphometric parameters are divided into three categories 1. Linear aspects, 2. Areal aspects and 3. Relief Aspects (Table 5.1). The morphometric parameters such as stream order (U), stream length (Lu), mean stream length (Lsm), stream length ratio (RL), bifurcation ratio (Rb), mean bifurcation ratio (Rbm), relief ratio (Rh), drainage density (Dd), stream frequency (Fs), drainage texture (Rt), form factor (Rf), circulatory Ratio (Rc), elongation ratio (Re) and length of overland flow (Lg). The methodology for the calculation was based on the formula suggested by Horton (1945), Strahler (1964), Hardly (1961), Schumn (1956), Nookara-tanm et. al. (2005) and Miller (1953) which are mentioned in (Table 5.1) all three types of morphometric aspects could be delineated through the help of Remote sensing and GIS technique.

4. Result and Discussion:

4.1. Geomorphology and Geology of Hamirpur –

Morphometric analysis has been created through remote sensing and GIS technique. The outcome of this research has been shown as the thematic map. (CGWB,2017)



Geological map of Hamirpur District (Figure- 2)

The rocky surface, attaining elevations of 225 to 335m, from the sea level, contains pediment and dissected denudational hills (Fig 2), which are part of Pre- Cambrian Basement massif (Table 3). That is igneous hard rock, due to seasonal rainfall-based erosion, it eroded maximum along with the bank of rivers like Yamuna and Betwa. The Upper Ganga Plain, with an elevation of 110 to 250 m in the northern part, consists of upland and lowland. Banda Plain and also Varanasi Plain constitute the upland. While Banda Plain is rolling with inselbergs and is sandy to gravelly, whereas Varanasi Plain is flat and silty in nature (Fig 2).

Table 3: Geomorphology of Hamirpur district:

A	**Major Physiographic units**	1.Pre-Cambrian Bundelkhand massif as the basement.
		2 Quaternary alluvium comprising sands, clay and silt.

(Source: District gazetteer)

The lowland is 10 is 30m lower than the Bundelkhand upland. It is developed along Yamuna, Betwa and Dhasan rivers and comprises Older Flood Plain and Active Floodplains due to the Youngness of both rivers.

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i. *Digital Elevation Model (DEM) –*

Digital Elevation Model is the one of most important data set for morphometric parameter calculations to represent accurate land aspect. Digital Elevation Modal (DEM) consists of a sampled array of elevation of ground Positions that are normally at regularly spaced intervals. 30m DEM, ASTER- STRM (Shuttle Radar Topography Mission) is downloaded from the USGS website, GIS open-source software is used to geo-referenced and digitize to Toposheet no DEM data also proceed with the help of this software. In the region highest elevation is 194 and the low elevation is 0. it means, the maximum sallow land is found on the bank of rivers, like Ken and Chandrawal rivers. High elevation area covered by Rath and Sarila tahsil.

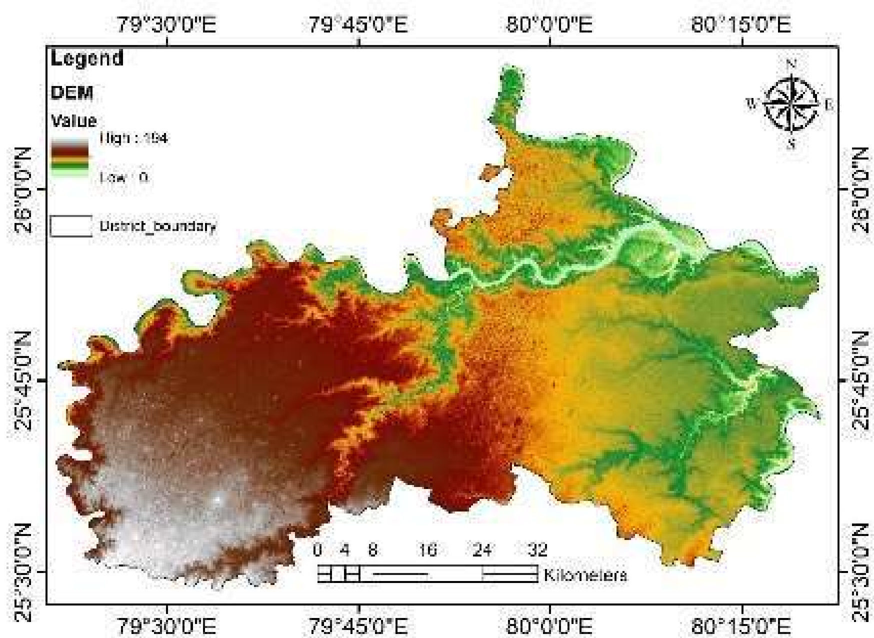

Figure 3: Digital Elevation Model (DEM) of Hamirpur District

4.2. Drainage system –

In Hamirpur district, **Yamuna**, **Betwa**, **Dhasan**, **Ken**, **Urmil**, **Bhima Pandwaha** and **Chandrawal** are very important rivers of the drainage system (Table4) This drainage system is part of the Upper Ganga Agro-climatic zone which is dependent upon agricultural outcomes. It is also part of 'Ken and Betwa doab', the Yamuna River creates the north boundary of the Hamirpur district, and it has a very short length in this district and river

'Urmil' river' is running in the southern boundary of this district. The Birma river flows through the middle part of the district (Fig 4). The 'Swami-Bramha-Nand Dam' is constructed in the Bharma river, due to the suitability of gathering water between the highland and the lowland of the 'Bundelkhand Upland' and surrounded by the high altitude. (Fig 3) Betwa river flows along with the northeast border of Hamirpur district where the Dhasan river joins it at Kuprat village of Rath, and Betwa meets with the Yamuna River at Sangmeshawar. Chandrawal is a tributary river of Ken they both flow in the eastern part of the district.

Table 4: Drainage of Hamirpur district:

A	**Major Drainage**	Two major rivers, namely Yamuna and Betwa meet in the north-eastern part of the district. Dhasan river flows along The north-west part of the

(Source: District gazetteer)

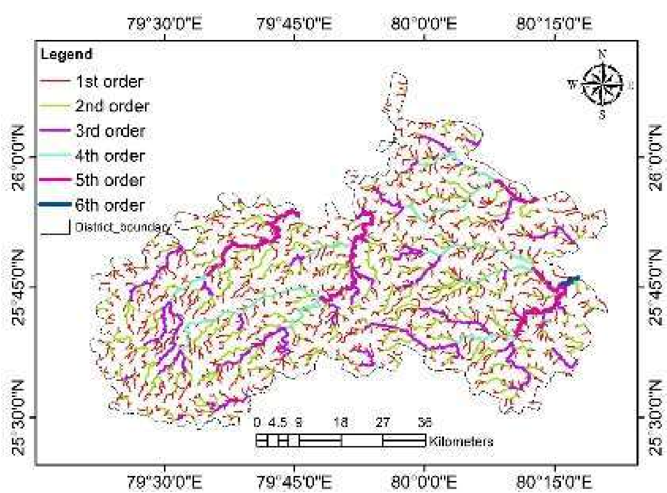

Figure 4: Drainage map of Hamirpur District

This is a seasonal river but it has more water capacity than the other rivers in the district. These rivers play a very important role to run the irrigation system in the Hamirpur district. (Table 4) This district has very poor surface water storage despite the proximity to many rivers, which also results due to a lack of surface water availability contribution in the bounded watersheds of this specific region. The analysis was done based on stream length and total water capacity (Figure 5) in the area.

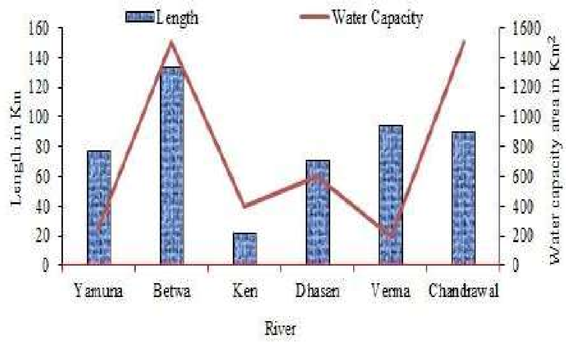

Figure 5: River length and water capacity of the area

The study area encompasses part of the 'Yamuna River basin' but the length and water capacity of the river stretch are very less in this district. 'The river Betwa' which flows centre of this district flows West to East direction in this district and has very significant in this district. It has more length as well as a large capacity to hold monsoon water for this region. While the 'Chandrawal river' is small and seasonal, it has a wide basin than the other rivers which hold heavy water resources during better monsoon season, sometimes it's affected by the flood also due to excess rainfall. Generally, all these rivers create a large basin in this district. But the quantity of water is very fluctuating due to its geomorphology. Maximum water resources are stored along with the river banks while all other drainages only hold water resources during the monsoon season. After this, it gets dried or used due to the over-exploitation of water resources. Without proper conservation of water resources, it gets wasted.

5. Conclusion:

Identification and quantification of water resources have become an alarming issue that needs to address at the earliest. Morphometric parameters are authentic and less manually tempered, as well as time savers also. This concept have become prevalent only after society became aware of the irreversible value of water resources that were exploited unsustainably to meet their demands. Remote sensing and GIS have highly revolutionized this field mainly due to their user-friendly programming, and feasible accessibility. The GIS technique is very useful for understanding landscape features. This tool can help to create many thematic maps for watershed development, this technique is very useful for micro-level planning programs for water resources.

The Watershed is a very important factor in drought vulnerability mitigation. A well-planned and effective strategy can be a better solution for mankind because the livelihood of people exists surroundings water resources. In this situation, the government play a very crucial role to manage resources sustainably and tackling the hazardous situation. Miss management and harnessing of water resources, people force to face water crises. This study is conducted in the Hamirpur district of Uttar Pradesh which is part of Bundelkhand high land, In the study, we are examining the role of government in watershed management to the enhancement of water resources and depends upon the livelihood.

References:

1. A. K. L. Asthana, Anil K. Gupta, Khayingshing Luirei, S. K. Bartarya, S. K. Rai, S. K. Tiwari. (2015) "A quantitative analysis of the ramganga drainage basin and structural control on drainage pattern in the fault zones, Uttarakhand", Journal of the Geological Society of India.
2. Agarwal, C. S. (1998). Study of drainage pattern through aerial data in Naugarh area of Varanasi district, UP, *Journal of the Indian Society of Remote Sensing*, Vol. *26, Issue* (4), pg. 169-175.
3. Ahmad, Abdulla (Aydın, Cumhur). "Change detection in a high-density urban area and rural area using high-resolution satellite image", Atılım Üniversitesi
4. Alen Shrestha, Md Mafuzur Rahaman, Ajay Kalra, Balbhadra Thakur, Kenneth W. Lamb, Pankaj Maheshwari (2020), "Regional Climatological Drought: An Assessment Using High-Resolution Data", Hydrology.
5. Aravinda, P. T., & Balakrishna, H. B. (2013). Morphometric analysis of vrishabhavathi watershed using remote sensing and GIS, *Int. J. Res. Eng. Tech*, Vol. *2, Issue* (8), pg. 514-522.
6. Chougale Sujit, S., & Sapkale Jagdish, B. (2017). Morphometric Investigation of Morna River Basin, Maharashtra, India using Geospatial Techniques, *Networks*, Vol. *1, Issue* (11), pg. 12-17.
7. Dipak R. Samal, Shirish S. Gedam, R. Nagarajan. (2015) "GIS-based drainage morphometry and its influence on hydrology in Western Ghats region, Maharashtra, India", Geocarto International
8. Elewa, Hossam H., El-Sayed M. Ramadan, and Ahmed M. Nosair. (2016) "Spatial-based hydro-morphometric watershed modelling for the assessment of flooding potentialities", Environmental Earth Sciences.
9. Farid Radwan, AA Alazba, Amr Mossad. (2017) "Watershed morphometric analysis of Wadi Baish Dam catchment area using integrated GIS-based approach", Arabian Journal of Geosciences.
10. Horton, R. (1932) Drainage Basin Characteristics. Transactions, American Geophysical Union, Vol. 13, pg. 350-361, Available at: http://dx.doi.org/10.1029/TR013i001p00350
11. Horton, R.E. (1945). Erosional development of streams and their drainage basins: hydrophysical approach to quantitative morphology, *Bulletin of the Geological Society of America*, Vol. 56, Issue 2, Pg. 75-370; Progress in Physical Geography: Earth and Environment, Vol. 19, Issue (4), pg. 533–554. Available at: https://doi.org/10.1177/030913339501900406
12. Indarto Indarto, Entin Hidayah. (2019) "Preliminary Assessment of Morphometric and Hydrological Properties of Six Watersheds in the Eastern Part of East Java", Forum Geografi
13. Kandpal, Himanshu & Kumar, Anil & Malik, Anurag. (2018). Morphometric Analysis and Prioritization of Sub-Watersheds in Bino Watershed, Uttarakhand: A Remote Sensing and GIS Perspective, Indian Journal of Ecology, pg. 43.

14. Karuna Nidhan Singh, Ramesh Singh, Dhiraj Khalkho, Mahendra Prasad Tripathi. (2022), "Morphometric analysis for sustainable development of natural resource management by using remote sensing and GIS techniques in Tikamgarh District, M.P., Central India", Environment Conservation Journal
15. Melton, M. (1957) An Analysis of the Relations Among Elements of Climate, Surface Properties and Geomorphology, Department of Geology, Columbia University, Technical Report, 11, Project NR 389-042. Office of Navy Research, New York.
16. Meshram, Sarita Gajbhiye, and S. K. Sharma. (2015) "Prioritization of watershed through morphometric parameters: a PCA-based approach", Applied Water Science.
17. Miller, V. (1953) A Quantitative Geomorphic Study of Drainage Basin Characteristics in the Clinch Mountain Area, Virginia and Tennessee. Project NR 389-402, Technical Report 3, Columbia University, New York.
18. Mohamed, E., Belal, A. A., Ali, R. R., Saleh, A., & Hendawy, E. A. (2019), Land degradation, *The soils of Egypt*, pg. 159-174.
19. Nag, S. K. (1998). Morphometric analysis using remote sensing techniques in the Chaka sub-basin, Purulia district, West Bengal. *Journal of the Indian society of remote sensing*, Vol. *26, Issue* (1), pg. 69-76
20. Nookaratnam, K., Srivastava, Y. K., Venkateswarao, V., Amminedu, E., & Murthy, K. S. R. (2005). Check dam positioning by prioritization micro-watersheds using the SYI model and Morphometric analysis—Remote sensing and GIS perspective, *Journal of the Indian Society of Remote Sensing, Vol. 33, Issue* (1), pg. 25–38.
21. Pratik Ranjan Chaurasia, Subhash Chandra. (2021) "Bundelkhand Water Woes: Paradigm Shift is Needed in the Strategy", Journal of The Institution of Engineers (India): Series A.
22. R. Poongodi, S. Venkateswaran. (2018) "Prioritization of the micro-watersheds through morphometric analysis in the Vasishta Sub Basin of the Vellar River, Tamil Nadu using ASTER Digital Elevation Model (DEM) data", Data in Brief.
23. Report of CGWB: (2017) Available at: www.cgwb.gov.in Central Ground Water Board, Ministry of Jal Shakti, Department of Water Resources, RD &GR Government of India (cgwb.gov.in)
24. S. Kanhaiya, B. P. Singh, S. Singh, Preeti Mittal, V. K. Srivastava. (2019) "Morphometric analysis, bedload sediments, and weathering intensity in the Khurar River Basin, central India", Geological Journal.
25. S. C. Bhatt, Rubal Singh, M. A. Ansari, S. Bhatt. (2020) "Quantitative Morphometric and Morphotectonic Analysis of Pahuj Catchment Basin, Central India", Journal of the Geological Society of India
26. Sangle, A. S., & Yannawar, P. L. (2014). Morphometric analysis of watershed using GIS and RS: A Review, *International Journal of Eng. Res Technol*, Vol. 3, pg. 599-602.
27. Schuman, S. A. (1956). The Evolution of drainage systems and slopes in badlands at Perth, Amboy, New Jersey, *Geological Society of America Bulletin, Vol. 67, Issue (5)*, pg. 597–646.
28. Srivastava, V. K. (1997). Study of drainage pattern of Jharia Coalfield (Bihar), India, through remote sensing technology. *Journal of the Indian Society of Remote Sensing*, Vol. *25, Issue* (1), pg. 41-46.

29. Srivastava, V. K., & Mitra, D. (1995). Study of drainage pattern of Raniganj Coalfield (Burdwan District) as observed on Landsat-TM/IRS LISS II imagery. *Journal of the Indian Society of Remote Sensing*, Vol. *23, Issue* (4), pg. 225-235.
30. S. Srinivasa Vittala, S. Govindaiah, H. Honne Gowda. (2004) "Morphometric analysis of sub-watersheds in the pavagada area of Tumkur district, South India using remote sensing and GIS techniques", Journal of the Indian Society of Remote Sensing.
31. 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, pg. 439-476.
32. Sujit Mandal, Subrata Mondal. (2019) "Geoinformatics and Modelling of Landslide Susceptibility and Risk", Springer Science and Business Media LLC.
33. T. Thomas, P. C. Nayak, Narayan C. Ghosh. (2015) "Spatiotemporal Analysis of Drought Characteristics in the Bundelkhand Region of Central India using the Standardized Precipitation Index", Journal of Hydrologic Engineering.
34. Varsha Mandale, Ravindra Bansod. (2019) "Quantitative Morphometric Analysis of the Adula Watershed, in Ahmednagar Maharashtra Using the ESRI- ArcGIS Tool", Current Journal of Applied Science and Technology.
35. Vikash Shivhare, Chanchal Gupta, Javed Mallick, Chander Kumar Singh. (2021) "Geospatial modelling for sub-watershed prioritization in Western Himalayan Basin using morphometric parameters", Natural Hazards Journal.