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GEOSPATIAL MORPHOMETRIC ANALYSIS OF THE HANDRI RIVER BASIN, KURNOOL DISTRICT, ANDHRA PRADESH, INDIA

Geology

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ABSTRACT

The river basin's morphometric features were calculated and delineated using a Geographical Information System (GIS). Secondary sources were used to conduct the morphometric investigation of the Handri river basin. The research area's Digital Elevation Model (DEM) data was taken from the USGS Earth Explorer website. Arc GIS Software was used to analyze the downloaded data. Relevant indices have been estimated using the drainage basin's linear, relief, and aerial parameters. The basin's stream order runs from first to sixth orders. According to the findings, the total number and length of stream segments are greatest in first order streams and decrease as stream order increases. The basin contains 2932 streams, 1471 of which are first order, 694 of which are second order, 364 of which are third order, 197 of which are fourth order, 155 of which are fifth order, and 51 of which are sixth order. The streams in the basin have a dendritic drainage pattern, with a drainage density of 0.92km2, indicating a less permeable surface with scant vegetation and a moderate to high elevation. The bifurcation ratio (Rb) between successive orders fluctuates, exposing geostructural form factors. The circulation ratio (Rc) is 0.40, the elongation ratio (Re) is 0.38, and the form factor (Rf) is 0.36, indicating that the basin is elongated, which enhances the possibility of infiltration. These data particularly beneficial in terms of identifying and planning groundwater potential zones, as well as watershed management.

KEYWORDS

SRTM-DEM, Handri river basin, Morphometry, Arc GIS

1. INTRODUCTION:

The evolution of a drainage network across space and time is shaped by numerous factors, including geological composition, structural attributes, geomorphological features, soil composition, and the presence of vegetation within its path. Morphometry is the measurement and mathematical analysis of the configuration of the earth's surface, shape and dimension of its landforms the Earth's surface and its various landform dimensions (Clarke 1996).

Conducting a drainage basin analysis is crucial for the evaluation and effective management of both groundwater and surface water resources. Vital attributes of the drainage basin, including its configuration, extent of tributaries, dimensions, and gradient, exhibit strong interconnections with the hydrological processes within the basin (Rastogi and Sharma 1976; Rai et al. 2017).

Morphometric indicators offer relatively straightforward methodo logies to depict basin dynamics and juxtapose basin attributes (Mesa 2006), thereby facilitating an enriched comprehension of the geological evolution of a drainage basin (Strahler 1964).

Madhu T et.al (2015) and Kumar DN (2023) were studied morphometric studies in the field of hydrology. The morphometric analysis involves the analysis of various linear, areal, and relief parameters of watershed these parameters are very significant for watershed management and hydro-geomorphological investigation.

Remote sensing and Geographical Information System (GIS) methodologies are progressively being employed for morphometric assessment of fluvial basin across the globe. This trend reflects an escalating inclination towards utilizing cutting edge technologies to scrutinize the geometric attributes of drainage system. The amalgamation of remote sensing and GIS augment the precision and comprehensiveness of basin morphometric analysis, facilitating a holistic understanding of watershed characteristics. (Williams 1972;Lyew et al.2007;Buccolini et al. 2007)

In this study, we'll utilize Remote Sensing (Lillisand Thomas, 2002) and Geographic Information System (GIS) as tools for handling and examining spatial information. ArcGIS is potent software for analysing, visualizing, and updating geographical data, creating impactful interactive maps and analyses.

Numerous scientists have extensively investigated the morphometric properties of diverse basins utilizing established and conventional techniques and remote sensing and GIS methods(Melton MA, 1957; Mall R.K. 2016; Appanna. B et al.,2021).The current research focuses on an integrated approach of Remote sensing and GIS techniques used for morphometric analysis of the Handri river basin.

2. Study Area

Handri River starts from South-Western part of Kurnool District and joins Tungabhadra at Kurnool town covering parts of 13 survey of India toposheets on 1:50,000 scale, 57E/6, E/7, E/8, E/10, E/11, E/12, E/13, E/14, E/15, E/16, 57I/1, I/2, and I/3. The catchment of Handri River lies in between latitudes of 15°12 '37 "N to 15 ° 49 '20 " N and longitudes 77°16 '49 " E to 78°04 '52 " E with an area of 3548 sq.km (Figure.1). The average elevation of basin 469.5 m with maximum and minimum., the climate is hot and dry for major part of the year, the summer months are very hot and the mercury rises to +42° Celsius, winter months are pleasant, when the night temperature is about 13° Celsius. The Lower Proterozoic (closepet granite, basic dykes, quartz reefs), Archean crystalline formations (Granite, Granite gneiss), Dharwar (Meta basalt, Meta rhyolite/Meta andesite, volcanic conglomerate), Cuddapah supergroup (Vempalle dolomites, Basic flows, Gulcheruvu quartzites), and Kurnool group (Banaganapalli quartzites, Narji limestones Flaggy, Narji limestones massive, Paniam quartzites, and Koilakuntala limestones) are the geology of the study area. The basin's terrain is diverse, with hills, plains, and agricultural areas. It is critical in supporting agriculture, industries, and urban settlements.

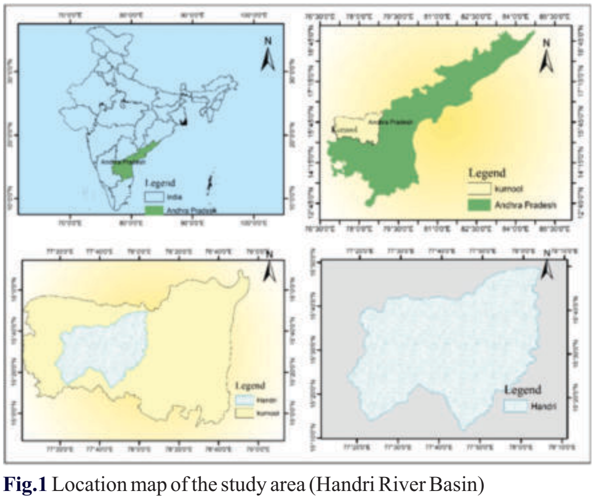


Fig.1 Location map of the study area (Handri River Basin)

3. METHODOLOGY

Quantitative morphometric attributes have been utilized in the current investigation to scrutinize the basin through Remote Sensing (RS) and Geographic Information System (GIS) methodologies. By using the methods outlined by Horton (1945) and Strahler (1964), the drainage system of the basin was examined. In ArcGIS desktop 10.4, SOI topographic maps were georeferenced using WGS-84 datum and zone 44N of the UTM projection.The Shuttle Radar Topographic Mission (SRTM) digital elevation model (DEM) with a spatial resolution of 30 meters was acquired from the United States Geological Survey (USGS) Earth Explorer website (http://earthexplorer.usgs.gov/) to outline the boundary of the basin and establish its drainage network, the Hydrology tool within the Spatial Analysis Tools suite of the ArcGIS desktop software was employed. Furthermore, the Slope, Aspect, Elevation, and Drainage Density maps of the Handri River basin were generated as part of the analysis.The Flow Diagram illustrates the comprehensive methodology for processing the SRTM DEM and extracting morphometric data related to the drainage system (Fig.2)

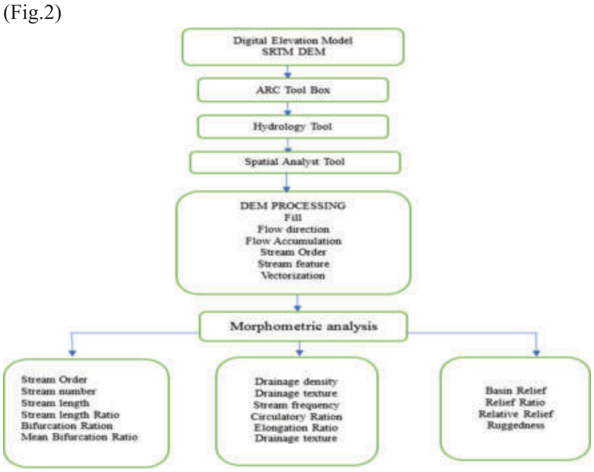


Figure:2 Methodology

In the assessment of basin morphometry, a comprehensive analysis of numerous parameters has been conducted using established mathematical formulae provided in (Table.1) These parameters encompass stream characteristics such as stream number, stream order, and stream length, as well as other factors including stream length ratio, bifurcation ratio, basin length, basin area, relief ratio, elongation ratio, length of overland flow, drainage density, stream frequency, drainage texture, form factor, and circulatory ratio.Furthermore, the aspect and slope representation of the study area were obtained through the utilization of the STRM DEM dataset, employing the aspect and slope analysis technique.

4. RESULTS AND DISCUSSION

Table.1 Methodology used to calculate morphometric parameters.

S. No	Parameters	Formulae	References
1	Stream order (U)	Hierarchical rank	Strahler (1964)
2	Stream length (Lu)	Length of the stream	Horton (1945)
3	Mean stream length (Lsm)	Lsm= Lu/Nu	Strahler (1964)
4	Stream length Ratio (RL)	RL =Lu/(Lu-1)	Horton (1945)
5	Bifurcation ratio (Rb)	Rb =Nu/Nu+1	Schumm (1956)
6	Mean bifurcation ratio (Rbm)	Rbm= average of bifurcation ratios of all order	Strahler (1957)
7	Drainage density (Dd)	Dd=Lu/A	Horton (1945)
8	Drainage texture (T)	T= Dd * Fs	Smith (1950)
9	Stream frequency (Fs)	Fs =Nu/A	Horton (1945)
10	Elongation ratio (Re)	Re =D/L	Schumm (1956)
11	Circulatory ratio (Re)	Rc =4pA/P2	Strahler (1964)
12	Form factor (Ff)	Ff =A/L2	Horton (1945)
13	Relief	R=H-h	Hadley and Schumm 1961
14	Relief ratio	Rr =R/L	Schumm (1963)

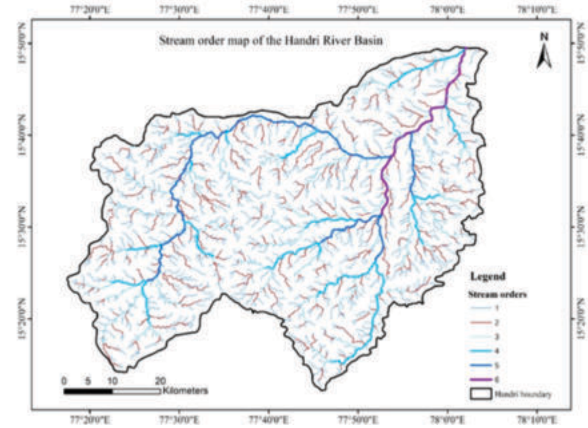


Figure:3. Drainage map of the Handri river basin

Table:2 Result of morphometric analysis in liner aspects.					
Stream order	Number of streams	Bifurcation ratio Rb	Stream length (Lu) km	Stream length ratio (RL)	Main stream length (Lsm)
1	1471	--	1669.57	0.20	1.13
2	694	2.11	846.46	0.47	1.21
3	364	1.90	399.80	0.8	1.09
4	197	1.84	192.12	0.69	0.97
5	155	1.27	133.25	0.34	0.85
6	51	3.03	46.17	--	0.90

The results of linear, relief and Arial properties of Handri river basin are given below

Table:3 Results of morphometric analysis in Arial and Relief aspects	
Morphometric parameters	Results
Basin area (km2)	3548
Perimeter (km)	330.86
Basin Length (km)	97.80
Basin relief (m)	405
Relief ratio	4.14
Relative relief	1.22
Ruggedness	0.372
Drainage density	0.92
Stream frequency	0.82
Texture ratio	4.4
Form factor	0.36
Circulatory ratio	0.40
Elongation ratio	0.38
Length of over land flow	0.54
Constant channel maintenance	1.11

4.1 Linear aspects:

Linear aspects in morphometric analysis of a river basin are essential components that help understand the shape and organization of river networks of river basin. The drainage basin's linear features are discussed below.

4.1.1 Stream order:

In drainage basin analysis, the initial stage involves determine the stream orders, In the present study, the channel segments of the drainage basin used Strahler's system for stream ordering system Appanna B., Y.sujatha, (2021). First-order streams, the ones without any tributaries, initiate the network. Second-order streams serve as tributaries to the first-order channels exclusively. Second-order channels combine with segments of third-order streams. Similarly, two third-order channels channel water into fourth-order channels, and this pattern continues. The main river, which carries the total flow of water and sediment, represents the segment of the highest order.The stream order of the basin ranges from first order to sixth order. The total number of streams in the basin is 2,932, out of which 1,471 are first order, 694 are second order, 364 are third order, 197 are fourth order, 155 are fifth order streams, and 51 are sixth order streams, as indicated in the table(2).

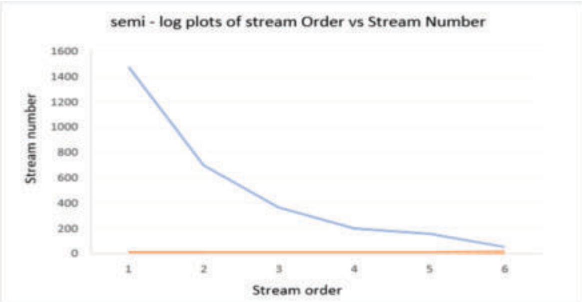


Figure:4 Semi - log plots of stream Order vs Stream Number

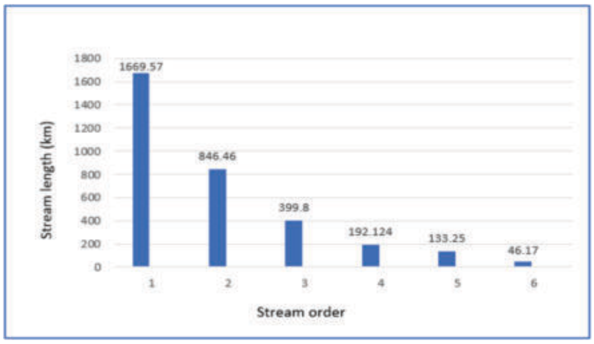


Figure:5 Graphical representation of stream order vs. stream length

4.1.2 Bifurcation ratio (Rb):

The Bifurcation Ratio (Rb) can be defined as the ratio between the number of stream segments of a given order and the number of segments of the next higher orders, as stated by Schumm (1956). The value of Rb is influenced by factors such as slope, physiography, and climate. It is commonly used to assess the level of integration within a drainage basin. Lower values of Rb indicate a lesser degree of structural complexity, suggesting that the drainage pattern of the basin remains relatively undistorted (Strahler 1964). In the Handri river basin being studied, the bifurcation ratio ranges from 2.11 to 3.03. The linear morphometric parameters calculated for the basin are presented in Table 2.

4.1.3 Stream length (Lu):

The length of a stream provides insight into the surface runoff properties of the basin. A stream with a relatively shorter length is indicative of areas with steeper slopes and more refined surfaces. Generally, the total length of stream segments is highest in first-order streams and decreases as stream orders increase. Horton's law of stream length proposes a geometric correlation between the number of stream segments in consecutive stream orders and the landforms they traverse (Horton, 1945). The lengths of various stream orders in the drainage basin have been calculated using Arc GIS. Table 2 shows that the length of first-order streams is 1669.57, second-order streams are 846.46, third-order streams are 399.80, fourth-order streams are 192.12, fifth-order streams are 133.25, and sixth-order streams are 46.17. It is evident that the length of stream segments is highest for first-order streams at 1669.57 and lowest for sixth-order streams at 46.17. Additionally, the length of stream segments decreases as the stream order increases.

4.1.4 Mean stream length (Lsm):

The calculation of the average length of a river or stream is a fundamental aspect of understanding the characteristics of a basin and the land it drains. This process involves determining the average length of a particular stream order, and then dividing it by the total number of individual stream segments within the watershed.In the study area, the mean stream length for first order is 1.13, second order is 1.21, third order is 1.09, fourth order is 0.97, fifth order is 0.85, and sixth order is 0.90, as presented in Table 2. This variation is likely attributed to changes in topographic slope and elevation.

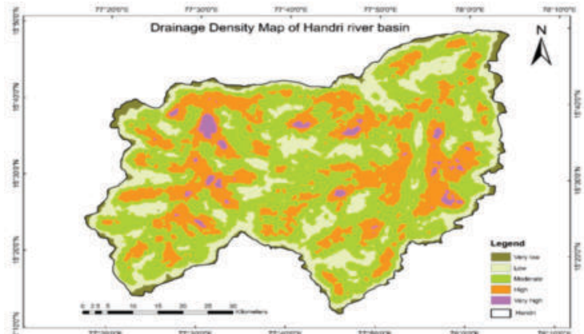
4.1.5 Stream length ratio (RL):

The stream length ratio is defined as length of a stream of any given order divided by the average length of the next lower order. Horton stated that the length ratio tends to remain constant over the stream's successive orders.The stream length ratio is computed using the formula presented in Table 1. The stream ratios of the handri River basin range from 0.34 to 0.69(Table 2). The change in stream length ratios may be caused to differences in slope and topographical factors.

4.2 Areal aspects:

4.2.1 Drainage density:

The drainage density is defined as the ratio of the total length of all orders to the size of the basin and is represented in kilometres per square kilometre. The drainage density can be used to determine the closeness of channel spacing. This is useful for calculating the average length of the stream over the whole basin. It is divided into five categories: very coarse (1.2), low (1.2 to 2.4), moderate (2.4 to 3.6), high (3.6 to 4.8), and extremely high (4.6 to 6). lesser values indicate higher permeability, sparse vegetation, and rough topography, whereas higher values indicate lesser permeability (Strahler, 1964). The drainage density of the Handri basin is around 0.92/km^2, which is fairly coarse indicates that the drainage density is low, suggesting permeable subsurface with thick vegetation and low topography.



Figire:6 Drainage density map of the Handri river basin

4.2.2 Stream frequency:

Stream frequency can be defined as the overall count of stream segments in proportion to a given area (Horton, 1932). Stream frequency typically exhibits a positive correlation with drainage density. The current study area has a stream frequency of 0.37/km^2 as shown in Table 3. Therefore, there is a potential for recharge in more porous subsurface areas. The stream frequency value for the basin shows a positive Correlation with the area drainage density value indicating an increase in stream population with an increase in drainage density.

4.2.3 Texture ratio:

The texture ratio is determined by the underlying lithology, permeability and relief characteristics of the terrain. (Smith 1939)established a five-fold classification for texture, ranging from very coarse texture (<2), through coarse texture (2 to 4), moderate texture (4 to 6), fine texture (6 to 8), to very fine texture (greater than 8). The handri basinexhibits a drainage texture value of 4.4, which indicates that it falls within the category of moderate drainage texture.

4.2.4 Form factor:

The Form Factor (Ff) parameter is used to predict the size of a basin in a particular area and is directly linked to the peak discharge (Horton, 1945). Ff is calculated by dividing the area of the basin by the square of its length. A perfectly circular basin will always have an Ff value greater than 0.78. On the other hand, a lower Ff value, such as 0.36(Table 3), indicates a more elongated shape, highlighting the elongated nature of the basin.

4.2.5Circulatory ratio:

The circularity ratio provides a useful tool for assessing flood hazard, which is affected by the length and frequency of streams, the geological structures of the basin, the land use/land cover, the climate, the relief and the slope. The higher the Rc value, the more likely the flood hazard is to be observed at a given point in time at the outlet. According to Miller's (1953) and Mesa, L.M., (2006).,a basin with a circularity ratio of 0.4-0.5 is defined as a strongly elongated, highly permeable, homogeneous geologic material. The circularity ratio of

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the handri basin of 0.40 suggests that the basin has an elongated shape, minimal discharge of runoff, and is highly permeable of the subsoil condition.

4.2.6 Elongated ratio:

The elongation ratio is defined as the relationship between the diameter of a circle with an equivalent area to that of the basin and the maximum length of the basin (Schumm 1956).Re values typically range from 0.6 to 1.0 across a diverse range of climate and geology. Values near 1.0 are common in areas with minimal elevation differences, while values between 0.6 and 0.8 are typically found in regions with high relief and moderate to steep slopes (Strahler's1964).These values can be categorized as follows: (a) circular (>0.9), (b) oval (0.9 to 0.8), (c) elongated (<0.7).The Handri River basin has an elongation ratio of 0.38, indicating that the basin exhibits highly elongated.

4.2.7 Length of overland flow:

The length of water over the ground before it becomes concentrated into definite stream channels is referred to as the length of overland flow. This variable plays a significant role in the hydrologic and physiographic development of a drainage basin. On average, the length of overland flow is approximately half the average distance between stream channels, which is equivalent to half the reciprocal of drainage density (Horton, 1945). The length of overland flow of the study area is measured at 0.5 indicating a low value. This suggests that rainwater travels a relatively shorter distance before becoming concentrated into channels.

4.2.8 Constant channel maintenance:

The Constant of Channel Maintenance is determined as the reciprocal of the drainage density, (Schumm1956). Consequently, a higher drainage density results in a lower constant of channel maintenance, and vice versa. In the Handri basin, the C value is measured at 1.11, indicating a moderate level of constant channel maintenance.

Relief aspects:

Relief characteristics play a significant role in understanding the level of denudational processes that have occurred within a given catchment area. They provide evidence of the ways water has altered the landscape. These features of relief include basin relief, relative relief, relief ratio, and ruggedness number

Basin relief:

Strahler (1957) defined river basin relief as the difference in altitude between the highest point of a watershed and the lowest point on the valley floor.It is an essential tool for understanding the drainage basin's denudational features, as it controls the stream gradient and hence influences surface run-off, sediment pattern, and flood trend. The highest point of the handri basin is 674 m and lowest point is 265 m. Hence the relief is 405 m (table 3).

Relief ratio:

The relief ratio, as defined by Schumm in 1956, is calculated by dividing the maximum relief by the horizontal distance along the longest dimension of a basin that runs parallel to the main drainage line. In the Handri basin area, the relief ratio has been determined to be 4.14 as shown in table 3.This ratio is used to indicate the overall steepness of the river basin.

4.3 Relative relief:

Relative relief (Rr) is a key parameter in morphometric analysis of a basin, and it's calculated by dividing the maximum basin relief by the perimeter of the basin(Melton 1957 and Rastogi R, Sharma T (1976). The Rr value of the study area is 1.22 as shown in table (**3**).The Rr value is a dimensionless quantity. A higher Rr value indicates that the basin has greater elevation differences relative to its size, suggesting a more rugged or steep terrain. Conversely, a lower Rr value suggests a basin with relatively consistent elevations in relation to its perimeter.

4.3.1 Ruggedness number:

The ruggedness number, is described by is a quantitative measure that takes into consideration both topographic relief and the density of streams within a specific geographical area(Strahler 1968,). The ruggedness value tends to increase in proportion to the complexity and hardness of the terrain.The roughness number in the Handri basin, as shown in Table 2, is relatively low, particularly 0.37. This lower score implies that the region has a more gentle slope, making it less prone to soil erosion.

5. NDVI analysis:

The NDVI (Normalized difference vegetation Index) is a dependable tool for assessing changes in vegetation. It is determined by measuring the reflectance in the near-infrared and red bands of the electromagnetic spectrum. Specifically, the Red (R) (0.64–0.67 µm) and near-Infrared (NIR) (0.85–0.88 µm) bands of Landsat imagery are utilized. The NDVI scale ranges from -1 to +1, where negative values signify the absence of vegetation, values close to zero indicate minimal or no vegetation, and values close to +1, (0.8–0.7) indicate healthyvegetation. NDVI= (NIR-R)/ (NIR+R)(Mall, R. K et al., 2005). Spatio-temporal fluctuation of NDVI in the Handri basin, with most of the buildup land concentrated in the basin's southwest and east the vegetation dynamics in the centre and eastern sections are indicated by NDVI values. The predominant vegetation types were sparse vegetation, scrub grasslands, and a small amount of thick vegetation. Because of the area covered by habitations, industries, and agricultural practices, the eastern side of the basin has more buildup land and scarce vegetation. The lower the NDVI, the less stable the local ecology, which can increase soil erosion and reduce river or water quality

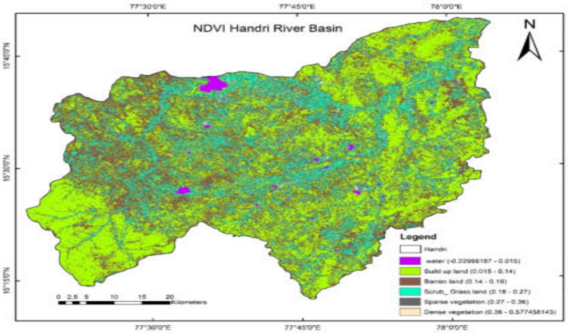

Figure:7 NDVI analysis of handri river basin

CONCLUSION:

The use of Geographic Information System (GIS) to quantitatively analyse morphometric parameters is extremely valuable in river basin studies. For instance, when looking at the Handri river basin, it's classified as a 6th order basin with a dendritic pattern. The Bifurcation ratio in this study varies from 1.27 to 3.03.

Higher Bifurcation ratio values in this analysis show that the drainage pattern is substantially driven by geological structure, whilst lower values indicate that it is less influenced by such structural variables. The roughness number is predicted to be 0.251, indicating that the area is prone to erosion. The drainage density in the basin is 0.92/km2, indicating sparse vegetation and moderate relief.

The drainage texture is 4.4, pointing to a coarse texture. The circulatory ratio is 0.40, and the form factor is low at 0.36, which indicates that the basin is elongated in shape, facilitating water infiltration. These morphometric characteristics and essential hydrological parameters like bifurcation ratio, elongation ratio, circulatory ratio, texture ratio, drainage density, and relief ratio are crucial for assessing river basins, managing soil and water resourcesthis may help forconservation and development of water resource management. The above study was an effort with integratemorphometry, and NDVI parameters, and planning for sustainable development. They provide valuable information for decision-makers and planners working on natural resource management at a micro-level in various terrains.

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