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Morphometric Analysis Of Kharun River Basin Chhattisgarh, India

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Abstract

The Kharun River Basin, a significant watershed of the Sheonath River within the larger Mahanadi River Basin, represents a critical hydrological system in India that demands focused study for sustainable management. As natural resources like land, water, and soil face intense pressure due to increasing population and resource utilization, it is vital to understand the dynamics of these resources to ensure their sustainable usage and management. In this study, a range of morphometric parameters—categorized as linear, areal, and relief aspects—are analyzed to understand the spatial variations within the basin. The methodology incorporates digital elevation model (DEM) data to derive critical morphometric features, including stream order, bifurcation ratio, drainage density, stream frequency, and relief ratio, which are essential indicators of the hydrological behavior of the basin. These parameters are not only indicative of the basin's potential for water retention and flow regulation but also serve as a basis for assessing the susceptibility of the area to erosion, sediment transport, and flooding. Using SRTM (Shuttle Radar Topography Mission) data, the study delineates the Kharun River Basin's drainage network, highlighting its hierarchical structure and identifying critical zones for conservation. Furthermore, a detailed examination of the Digital Elevation Model (DEM) of the Kharun River Basin provides insights into elevation changes, slope distribution, and watershed boundaries, which are essential for water resource management and flood mitigation planning. The aspect analysis of the basin reveals directional slopes, which impact water flow direction and soil moisture distribution, influencing land use practices and vegetation patterns. The DEM and aspect maps, along with the morphometric analysis, offer a comprehensive understanding of the basin's hydrological framework.

The outcomes of this research are expected to aid in the effective management of the Kharun River Basin's natural resources. The findings support water catchment management by identifying potential water storage areas and areas at risk of soil erosion. Additionally, insights from the study can contribute to agricultural land-use planning by suggesting suitable zones for cultivation and advising on sustainable water usage for industrial activities. This study also addresses hazard management by identifying flood-prone areas and erosion-sensitive regions, thereby assisting policymakers in developing targeted strategies for disaster mitigation and resource conservation. Ultimately, the morphometric analysis of the Kharun River Basin provides a valuable scientific foundation for ensuring the sustainable development of the region's natural resources.

Keywords: *Kharun River Basin, Morphometric Analysis, STRM data, DEM and aspects maps, GIS.*

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I. Introduction

Morphometric characteristics refer to a quantitative and mathematical analysis of the structure of the Earth's surface as well as the shape and size of its landforms (Tiwari 2023). Drainage networks and flow pattern of the river are influenced by the local geology, structural elements, geomorphology, vegetation, and soils. These features are complex and vary with time and location. (Suresh, & Krishnan, 2022). Morphometric analysis, a mathematical and quantitative approach to studying drainage basins, is an effective method to analyze terrain features, flow patterns, and hydrological characteristics of a region. This study aims to apply morphometric techniques to the Kharun River Basin to evaluate its topographical, geological, and hydrological properties, which are essential for resource management, environmental planning, and risk assessment

It is advantageous to analyze watersheds using morphometric parameters because it shows how different catchment variables, such as stream order and length, are related to one another. (Tiwari P. 2023). Stream order, stream number, stream length, mean stream length, stream length ratio, bifurcation ratio, mean bifurcation ratio, drainage density, drainage texture, stream frequency, relief ratio, form factor, elongation ratio, circularity ratio, length of overland flow are the most common morphometric parameters. characteristics of these resources, especially within river basins, is through morphometric analysis. Morphometric analysis involves the quantitative study of landforms, terrain features, and flow patterns within a drainage basin, providing insights into the hydrological, topographical, and geological characteristics of the region. Such an analysis can reveal crucial information about river systems, guiding effective planning and sustainable management. The sustainable management of natural resources, particularly land, water, and soil, has become increasingly critical as human populations expand and resource demands escalate. These resources are finite and face significant pressure from overuse and environmental changes, making it essential to prioritize conservation efforts. One effective approach for understanding the distribution and The DEM allows for the extraction of detailed slope and aspect maps, which provide additional insights into the basin's terrain characteristics. Slope, a measure of land steepness, impacts the velocity and erosive power of surface water flow, with steeper areas contributing to faster runoff and potential soil erosion. Aspect, which represents the direction of slope faces, influences sunlight exposure, soil moisture, and vegetation distribution across the basin. These parameters are vital for land use planning, as they determine suitable zones for agriculture, afforestation, and other land management activities. Additionally, this thesis examines areal morphometric parameters, including drainage texture, form factor, and elongation ratio, which describe the basin's shape and spatial extent. These parameters are crucial for evaluating the basin's water-holding capacity, flood potential, and erosion susceptibility. Relief aspects, such as basin relief, relief ratio, and ruggedness number, further characterize the basin's vertical dimension, aiding in the assessment of topographical variation and energy available for erosion processes. By integrating the elevation data, river network characteristics, and other morphometric parameters, this study aims to provide a comprehensive understanding of the Kharun River Basin's hydrological behavior. The findings have practical applications in resource management, including the identification of potential water storage areas, erosion-prone zones, and suitable land for agriculture. Furthermore, the morphometric analysis can inform hazard management strategies, such as flood risk assessment and erosion control, thereby supporting sustainable development efforts within the basin.

In summary, this thesis seeks to elucidate the morphometric characteristics of the Kharun River Basin, combining topographical and hydrological analyses to create a robust framework for resource management. By focusing on the intricate relationships between elevation, slope, aspect, and drainage network properties, this study contributes to a deeper understanding of the basin's ecological and hydrological dynamics. The insights derived from this research are intended to aid policymakers, environmental planners, and local communities in making informed decisions for the conservation and sustainable utilization of the Kharun River Basin's natural resources.

II. Materials And Methods

Preparations for Study Aera Map from Google Earth Pro

This image shows the **Kharun River Network and Basin** region as displayed in Google Earth Pro, overlaid with a latitude and longitude grid. Here are the key properties and features visible:

Geographic Boundaries:

The basin spans from approximately **N20°30'** in the south to **N21°42'** in the north and from **E80°42'** in the west to **E82°42'** in the east. Major grid lines indicate latitude and longitude every few minutes, allowing precise localization within the region.

Key Landmarks:

Towns and Cities: Notable places within or near the basin include **Raipur**, **Atal Nagar-Nava Raipur**, **Bhilai**, **Dhamtari**, **Kurud**, and **Dongargarh**.

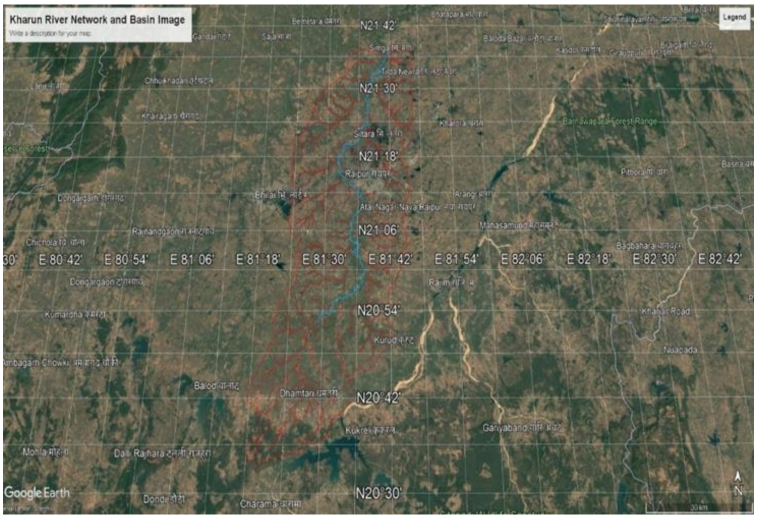

Fig.1: Kharun River Network and Basin

Natural Features: The area includes forest reserves like the **Barnawapara Forest Range** in the northeast and other green zones that are distinguishable by their dense coverage.

River Network:

The **Kharun River** is depicted as a prominent blue line flowing through the central basin area, indicating the primary river path. It is surrounded by a network of red lines, which represent tributaries or smaller drainage channels feeding into the main river. The river network is intricate, with many smaller streams branching throughout the basin, particularly concentrated in the central and northern parts of the region.

Terrain:

The basin area is largely rural and appears to have varied land cover, including agricultural fields, forested areas, and urban settlements. The **terrain elevation** and **slope** seem gentle to moderate, as there are no high-altitude labels, indicating the basin lies in a relatively flat or rolling landscape.

Scale and Orientation:

The image has a **north arrow** in the bottom right corner for orientation. A **30 km scale** bar is also provided, giving a sense of distance and scale within the image.

Use of Grid and Coordinates:

The grid lines with precise latitude and longitude values help in locating specific points within the Kharun River Basin. This coordinate system is helpful for further geographic or environmental studies, especially for mapping and spatial analysis.

Potential Applications:

This visualization of the Kharun River Network and Basin could be used for hydrological analysis, land use planning, conservation efforts, or studying environmental impacts. It also serves as a base map for overlaying additional data layers such as soil type, land cover, or population distribution if needed for further research.

Study Area Map of Kharun River Basin using SRTM DEM Data

The present study focuses on the Kharun River Basin, a sub-basin of the Sheonath River and join at Somnath, which forms part of the Mahanadi River Basin in central India. It originates from village petechua hill in Balod district, Chhattisgarh. This river determines the boundary of Raipur and Durg District. Geographically, the Kharun River Basin is located between latitudes approximately 20°35'N to 21°32'N and longitudes 81°20'E to 82°2'E. Covering a significant area, the Kharun River Basin serves as an essential watershed that influences the region’s agriculture, water resources, and ecology. The basin’s diverse topography, elevation, and landforms make it an ideal candidate for morphometric analysis to support resource management and hazard mitigation planning.

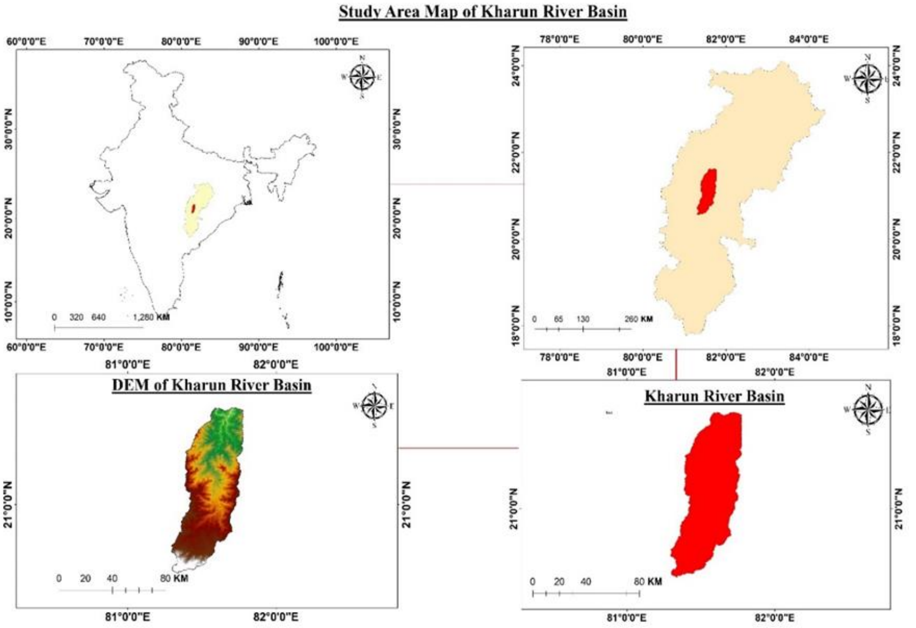

Fig.2: Location Map of Kharun River Basin

Study Area Map Layout:

A layout was designed to showcase the basin within multiple geographic contexts: (a) within India, (b) within the state boundaries, (c) as a standalone basin, and (d) through a Digital Elevation Model (DEM) representation to highlight elevation changes.

Top Left: Map of India with the Kharun River Basin highlighted in red, showing its position within the country.

Top Right: A zoomed-in view of the basin within the state boundary, giving a regional context.

Bottom Left: DEM of the Kharun River Basin, showing the elevation variations with a color gradient from green (lower elevations) to brown (higher elevations), which helps identify the topographic profile.

Bottom Right: A focused map of the Kharun River Basin, showing its precise boundaries and extent.

Cartographic Elements:

Each map includes a **north arrow** to indicate orientation and a **scale bar** for distance reference, which enhances readability and spatial understanding.

Coordinate Grids were added to all maps to provide latitude and longitude information, facilitating precise location referencing within each frame. Labels were incorporated to clearly identify each component of the map, such as “India,” “Kharun River Basin,” and “DEM of Kharun River Basin.”

Data Integration and Processing: All spatial data layers were projected to a common coordinate system (e.g., WGS 84) to ensure alignment and accuracy. The basin area was clipped to match the study boundaries, and any extraneous map elements were removed or masked to focus solely on the area of interest.

Additional Details:

To make the map more informative, towns and geographic features near the Kharun Basin were labelled, where necessary, to provide context. The DEM color gradient was carefully chosen to emphasize elevation differences, facilitating the identification of potential flood-prone and highland areas within the basin.

Finalization of the Study Area Map

This study area map serves as a foundational tool for various analyses related to hydrology, land use, and environmental planning in the Kharun River Basin. The multi-panel layout allows for both a broad and detailed view, aiding in visualizing the basin’s relationship to the larger geographic setting. The integration of DEM data adds a layer of detail that is valuable for topographic analysis, water flow simulation, and understanding watershed characteristics, which are essential for hydrological modelling and environmental assessments.

The methodology outlined ensures that the map is accurate, informative, and effectively communicates the geographic and topographic context of the Kharun River Basin. This map will serve as a critical reference for future studies focused on water resource management, soil analysis, and land cover change within the basin.

Analysis of STRM DEM data

Aspects Map Analysis

Aspect is a critical terrain attribute that indicates the direction of slope faces relative to the compass, which significantly influences hydrology, vegetation, and microclimates in a region. This analysis focuses on creating an aspect map of the Kharun River Basin using SRTM DEM data to understand the orientation of slopes within the basin. The DEM allows for the extraction of detailed slope and aspect maps, which provide additional insights into the basin’s terrain characteristics. Slope, a measure of land steepness, impacts the velocity and erosive power of surface water flow, with steeper areas contributing to faster runoff and potential soil erosion. Aspect, which represents the direction of slope faces, influences sunlight exposure, soil moisture, and vegetation distribution across the basin. These parameters are vital for land use planning, as they determine suitable zones for agriculture, afforestation, and other land management activities

The aspect data is valuable for various environmental and land management applications, including watershed management and agricultural planning. The DEM data used for this analysis is sourced from the Shuttle Radar Topography Mission (SRTM), which provides 30m resolution global elevation data. The Kharun River Basin DEM data was downloaded from [specify source, e.g., USGS Earth Explorer or a relevant open-access platform] and clipped to the study area.

The aspect map reveals the directional characteristics of the Kharun River Basin's slopes:

Dominant Directions: Observing the map, certain orientations, such as northeast or southwest, may dominate due to regional topographic patterns.

Land Use Implications: These directional trends can inform land management practices, as different slopes receive varying amounts of sunlight, impacting vegetation growth and soil moisture.

Hydrological Implications: The orientation of slopes affects water flow and erosion patterns, which are crucial for watershed management.

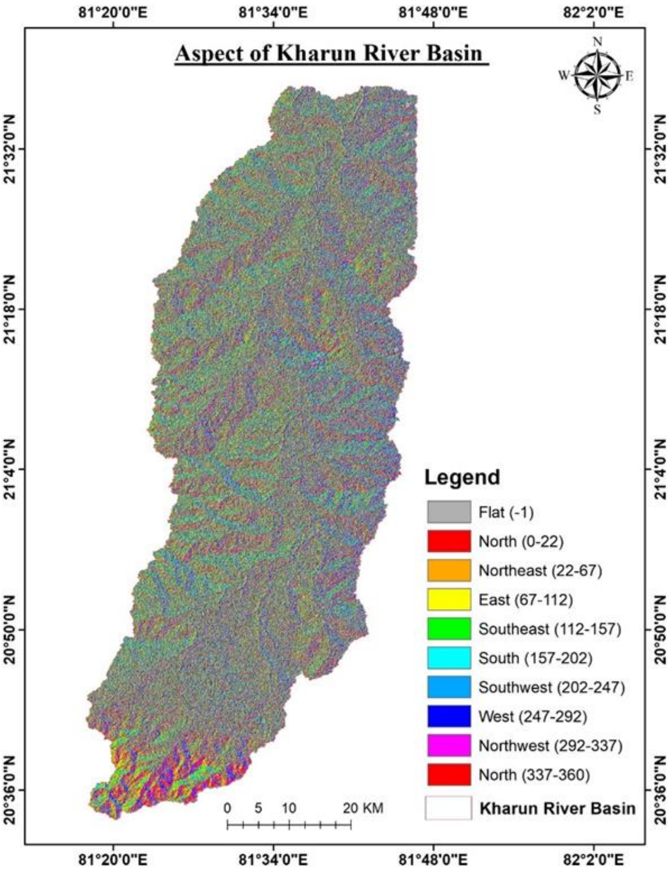

Fig.3. Aspects Map of Kharun River Basin

Analysis and Application of the Slope Map

The river network of the Kharun River Basin plays a pivotal role in the basin’s hydrology. The drainage system of the Kharun River is hierarchically structured, comprising multiple stream orders that help regulate water flow, sediment load, and nutrient distribution. By analyzing stream order, bifurcation ratio, drainage density, and other linear morphometric parameters, the study assesses the connectivity and complexity of the river network. High bifurcation ratios, for example, may indicate a rugged terrain with less infiltration, while drainage density provides insight into the permeability and surface runoff characteristics of the basin. The slope map of the Kharun River Basin, derived from SRTM DEM data, provides valuable insight into the terrain's gradient, which is crucial for understanding erosion patterns, water flow, and land stability. This analysis offers an understanding of the distribution and range of slope percentages within the basin, assisting in hydrological studies, land management, and environmental planning.

Hydrological Modelling and Erosion Potential: Slope data is critical in hydrological modeling as it influences water flow direction and accumulation. Areas with higher slopes tend to have faster runoff, while flatter regions retain water, impacting erosion and sediment deposition. The slope map helps in predicting erosion-prone areas, especially in steep regions, which is essential for soil conservation and watershed management.

Land Use Planning and Agricultural Suitability:

Slope information guides land use decisions, identifying areas suitable for agriculture, construction, and conservation. Gentle slopes (0 - 5.2%) are generally more suitable for agriculture, while steeper slopes may require terracing or erosion control measures if used for cultivation.

Infrastructure Development:

The slope map is valuable in planning infrastructure such as roads and buildings, as it highlights areas that may require additional engineering measures to ensure stability. Identifying flatter regions helps locate suitable sites for construction, minimizing risks associated with landslides and erosion.

Environmental and Biodiversity Conservation:

The distribution of slopes can influence biodiversity by creating various habitats based on gradient and moisture retention. Steeper areas may serve as natural conservation zones, protecting vegetation and wildlife by limiting human interference and agricultural activities.

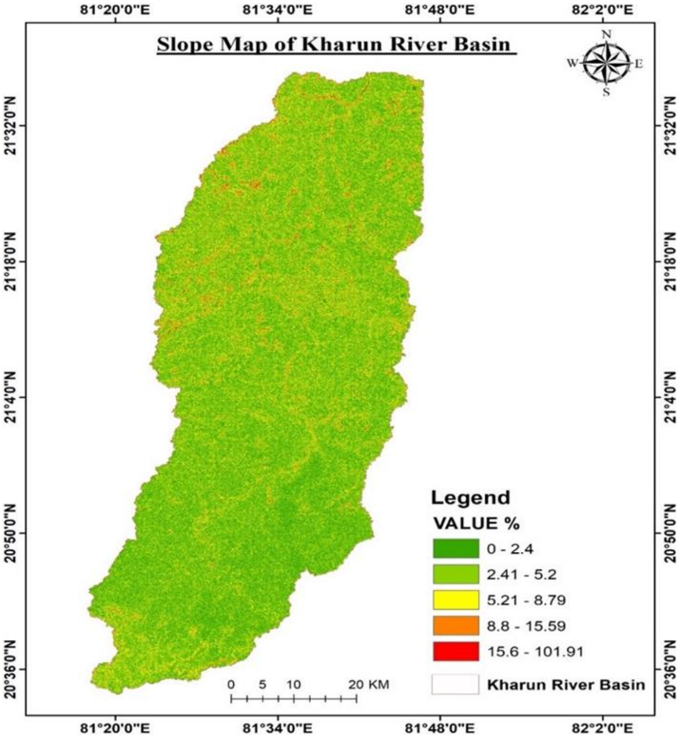

Fig.4: Slope Map of Kharun River Basin

Analysis and Application of the Elevation Map

Elevation is a fundamental characteristic of the Kharun River Basin, influencing various hydrological processes such as rainfall distribution, surface runoff, and erosion patterns. Using Shuttle Radar Topography Mission (SRTM) data, this study generates a Digital Elevation Model (DEM) to represent the basin's elevation range, from approximately 212 meters in the low-lying areas to 453 meters in the higher regions. This elevation data is critical for analyzing slope, aspect, and other morphometric parameters that affect water flow direction, sediment transport, and soil moisture retention across the basin. The elevation map created using SRTM DEM data provides a clear representation of the topographic features within the Kharun River Basin. This map is essential for hydrological studies, as it highlights areas of varying elevation, which are critical in determining water flow, erosion patterns, and potential flood zones.

Overview of the Basin's Topography:

The map displays the Kharun River Basin, with elevation values ranging from 212 meters to 453 meters. The color gradient represents different elevation levels: green for lower elevations, yellow for mid-range elevations, and red for higher elevations. This color scheme allows for a quick visual interpretation of the terrain.

Legend and Elevation Values:

The map includes a legend indicating the elevation range with a gradient bar, which helps in understanding the elevation variations within the basin. The values of "Low: 212" and "High: 453" show the minimum and maximum elevation points within the basin, respectively, providing insight into the basin's topographic range.

Coordinate System and Scale:

The map is aligned with a coordinate grid, showing latitude and longitude for spatial reference. This grid ensures accuracy in positioning and allows users to pinpoint exact locations within the basin.A scale bar at the bottom of the map provides a distance reference, enabling viewers to measure distances within the basin. This is helpful for analyzing the spatial distribution of features in the context of elevation.

North Arrow and Orientation:

A north arrow at the top right corner indicates map orientation, helping users understand the directionality of the map.

Hydrological Relevance:

The elevation information is crucial for understanding water flow and river network patterns in the basin. Higher elevations (red zones) are typically the sources of runoff, while lower elevations (green zones) are potential accumulation areas. This information is beneficial for water resource management, as it can help identify areas prone to erosion or flooding.

Basin Boundary:

The boundary of the Kharun River Basin is marked in a thin red outline, emphasizing the study area. This boundary provides a clear demarcation of the basin's extent, distinguishing it from surrounding regions. The elevation map of the Kharun River Basin offers numerous applications and insights, especially for environmental and hydrological studies. Here's how this map can be utilized:

Hydrological Modelling:

The elevation data is essential for performing hydrological analyses, including calculating flow direction, flow accumulation, and identifying potential water bodies or streams. By using the DEM, one can model the river network and predict the movement of water within the basin, which is valuable for flood risk assessment.

Soil Erosion Studies:

Elevation maps are useful in predicting areas of high erosion potential, especially in steep regions. The slope can be derived from the DEM, and combined with land use data, it can help identify vulnerable areas within the basin. Erosion studies can guide land management practices and suggest appropriate soil conservation measures.

Land Use Planning:

Elevation data supports land use planning by indicating suitable areas for agriculture, urban development, and conservation. For example, flatter areas at lower elevations may be suitable for agriculture, while steep regions may be preserved as natural areas. This is particularly relevant for sustainable development in regions surrounding the Kharun River Basin.

Biodiversity and Habitat Analysis:

The elevation map can assist in understanding the distribution of various ecosystems within the basin. High-altitude areas may harbour unique flora and fauna, while low-altitude areas may support different species. This knowledge can guide conservation efforts aimed at protecting biodiversity hotspots within the basin.

Infrastructure Development:

Elevation maps are essential for planning infrastructure like roads, bridges, and dams. Understanding elevation changes helps engineers design structures that are resilient to natural forces, such as erosion and flooding. The map can aid in identifying suitable locations for building reservoirs and other water storage facilities within the basin.

Climate Change Impact Assessment:

Analyzing the basin's topography in relation to climate change impacts is crucial, as changes in precipitation patterns could alter water flow and increase the likelihood of extreme weather events. The elevation data can contribute to models predicting how climate change may affect water availability and flood risks in the Kharun River Basin.

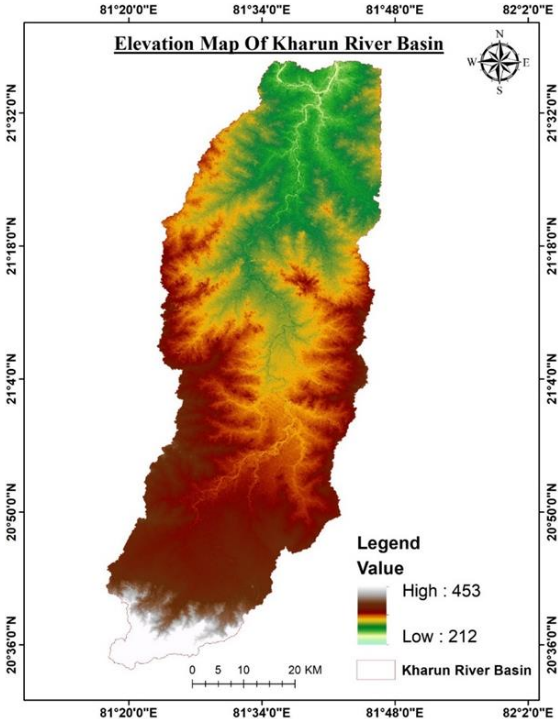

Fig.5: Elevation Map of Kharun River Basin

Soil texture Classifications Analysis

This study utilizes the soil texture class data from the OpenLandMap dataset, specifically the "SOIL_TEXTURE-CLASS_USDA-TT_M/v02" image layer. This dataset provides information on soil texture classification following the USDA system, an established framework for categorizing soils based on particle size and composition. Each soil texture class represents a unique soil structure based on proportions of sand, silt, and clay, critical factors that influence hydrological characteristics, plant growth, and nutrient availability. The dataset covers a wide geographic region and provides soil texture data as categorical values. Each pixel value represents a specific soil type, ranging from clay (Cl) and clay loam (ClLo) to sandy clay loam (SaClLo) and loam (Lo). These soil classes have unique implications for soil properties such as permeability, water retention, and nutrient dynamics, which are significant in agricultural, ecological, and hydrological studies. The region of interest (ROI) for this analysis is defined by a geographic boundary known as the "Kharun Basin," a significant watershed area used to analyse spatial variations in soil properties. By using this specific basin, the study can assess how soil texture varies across different parts of the basin and contributes to watershed hydrology.

To present the results, the soil class names were combined with the calculated areas (now in square kilometres) for each class. This step enabled the creation of a structured output in the format:

Object 1: area km^2: 41.047, soil type: Cl
Object 2: area km^2: 3585.228, soil type: ClLo
Object 3: area km^2: 1.022, soil type: SaClLo
Object 4: area km^2: 3.147, soil type: Lo

This structured output was printed for review and further analysis, forming the basis of the area summary for each soil type.

Results And Interpretation

The results of the analysis show the spatial distribution and area of each soil type within the Kharun Basin. The area for each soil type was summarized as follows:

Clay (Cl): Covering an area of approximately 41.05 km², clay soils in the basin are expected to have high water retention due to fine particles that limit permeability. This can affect runoff patterns and soil moisture content.

Clay Loam (ClLo): With an extensive area of around 3585.23 km², clay loam represents the dominant soil type in the region. The composition of clay loam balances water retention and drainage, providing a fertile medium ideal for vegetation and agricultural activities.

Sandy Clay Loam (SaClLo): Occupying about 1.02 km², sandy clay loam has higher sand content than clay loam, leading to better drainage while retaining sufficient nutrients for plant growth. This texture type supports vegetation but may be less effective for retaining moisture in arid conditions.

Loam (Lo): Covering approximately 3.15 km², loam is characterized by balanced proportions of sand, silt, and clay. This soil type is generally favourable for agricultural use, as it combines good water retention with adequate drainage, allowing crops to access moisture while avoiding waterlogging.

These findings provide a spatial overview of soil types within the Kharun Basin, highlighting variations in soil composition that impact water dynamics, agriculture, and ecosystem health. By identifying and quantifying these soil textures, the study enables targeted recommendations for land management, agricultural planning, and conservation efforts within the basin.

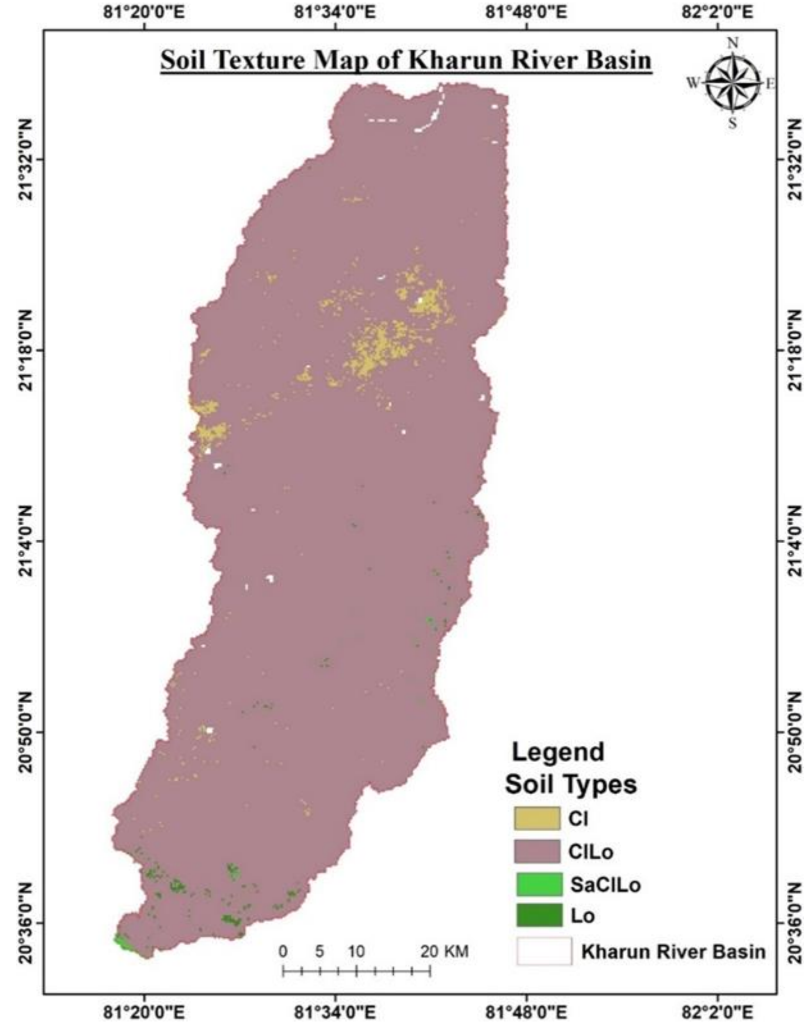

Fig.6: Soil Texture Map of Kharun River Basin

Stream Network analysis and Stream Order Classification

The river network of the Kharun River Basin plays a pivotal role in the basin's hydrology. The drainage system of the Kharun River is hierarchically structured, comprising multiple stream orders that help regulate water flow, sediment load, and nutrient distribution. By analyzing stream order, bifurcation ratio, drainage density, and other linear morphometric parameters, the study assesses the connectivity and complexity of the river network. High bifurcation ratios, for example, may indicate a rugged terrain with less infiltration, while drainage density provides insight into the permeability and surface runoff characteristics of the basin. The stream network map of the Kharun River Basin, developed from SRTM DEM data, serves as a powerful tool for hydrological and environmental analysis. This map provides insights into the river and tributary system within the basin by displaying hierarchical ordering, which is essential for understanding water flow, drainage patterns, and potential flood zones. The classification of streams into five distinct orders offers a comprehensive view of the river system's structure, aiding studies related to hydrology, water resource management, environmental conservation, and land use planning.

Applying Strahler's Method: Use the "Strahler Stream Order" tool in QGIS to classify the streams into hierarchical levels. The Strahler method is a widely used approach that assigns stream order based on tributary connections:

Order 1: Small headwater streams with no tributaries. These streams generally form in higher elevation areas and flow towards larger tributaries.
Order 2: Formed by the confluence of two order 1 streams.
Order 3: Formed by the confluence of two order 2 streams, and so on.

This classification process continues until the primary river, the Kharun River, is designated as the highest order (order 5 in this case).

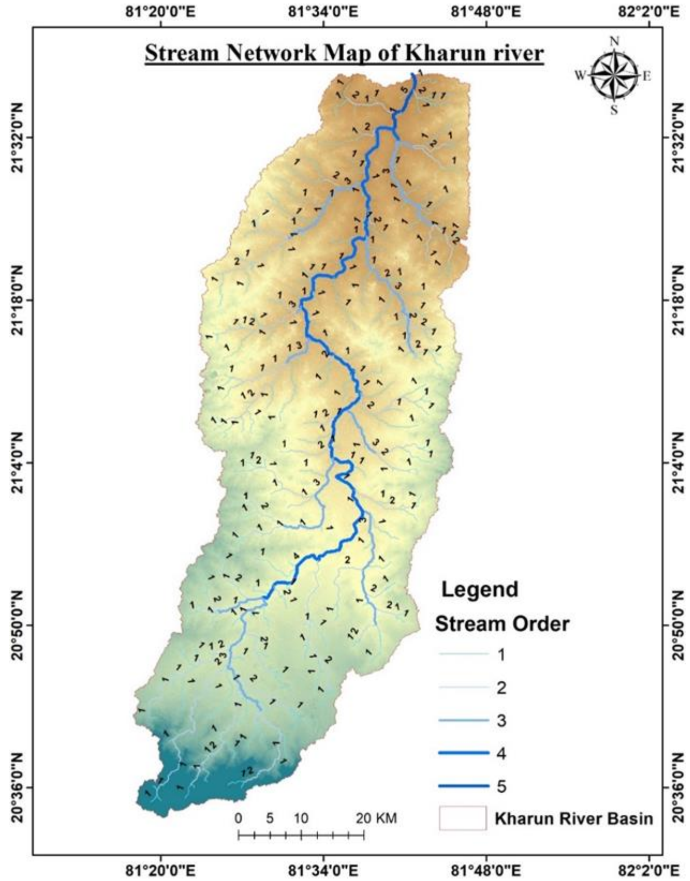

Fig.7. Stream Network Map of Kharun River Basin

III. Results And Discussion

Table: - Morphometric parameters (linear, areal and relief aspects) used for Kharun River Basin.

S.N.	Morphometric Parameters	Methods	References	Results
LINEAR ASPECTS (La)				
1.	Stream order (U)	Hierarchical order	Strahler, 1964	1st order-258 2nd order-125 3rd order-72 4th order-54 5th order-6
2.	Stream Number (Nu)	Nu= N1+N2…+Nn	Horton (1945)	(Nu)-515
3.	Stream length (Lu) in km	Length of the stream Lu=L1+L2…. +Ln	Horton 1945	1st order-712.15km 2nd order384.08km 3rdorder-158.57km 4th order-117.81km 5th order- 10.65km
4.	Mean stream length (Lsm) in km	Lsm=Lu/Nu; where, Lu=Stream length of order 'u', Nu=Total number of stream segments of order 'u'.	Strahler, 1964	1st order- 2.76km 2nd order- 3.073km 3rd order- 2.21km 4th order- 2.181km 5th order- 1.775km
5.	Stream length ratio (Rl) in km	Rl=Lu/Lu-1; Where, Lu=Total stream length of order 'U', Lu-1=Stream length of next lower order.	Horton, 1945	2ndorder -0.898km 3rd order -1.391km 4th order -1.013km 5thorder- 0.814km

6.	Bifurcation ratio (Rb)	Rb=Nu/Nu+1; where, Nu=Total number of stream segment of order 'u', Nu+1=Number of segments of next higher order.	Schumn, 1956	1st order - 2.064 2nd order - 1.736 3rd order - 1.333 4th order- 9 5th order-
7.	Mean Bifurcation Ratio (Rbm)	Average of Rb ratio of all orders	Strahler, 1964	3.533
8.	Basin Length (Lb)	Google Earth software analysis	Schumn, 1956	127.34 km

S.N.	**Morphometric Parameters**	**Methods**	**References**	**Results**
AREAL ASPECTS (Aa)				
9.	Basin Area (A)	GIS software analysis	Schumn, 1956	3628.3sq.km
10.	Basin Perimeter (P)	GIS software analysis	Schumn, 1956	430.042sq.km
11.	Drainage density (Dd)	Dd=Lu/A; where, L=Total length of streams, A=Area of watershed	Horton, 1932	0.381 km/km^2
12.	Stream Frequency (Fs)	Fs=Nu/A; where, Nu=Total number of streams of all orders, A=Area of the Basin.	Horton, 1932	0.142 km^{-2}.
13.	Form factor (Rf)	Rf=A/(Lb)^2; where, A=Area of watershed, Lb=Basin length.	Horton, 1932	0.224
14.	Circularity Ratio (Rc)	Rc=4πA/P2; where, A=Area of watershed, π = 3.14, P=Perimeter of watershed.	Miller, 1953	0.247
15.	Elongation Ratio (Re)	Re=2$\sqrt{}$ (A/π)/Lb; where, A=Area of watershed, π = 3.14, Lb=Basin length.	Schumn, 1956	0.301
16.	Drainage Texture (T)	Rt=Nu/p; where, Nu=Total number of streams of all orders, P=Perimeter of watershed.	Horton, 1945	1.198
17.	Length of overland flow (Lg or AOLF)	1/ (Dd X 2), Where Dd (Drainage density) is in km/km^2	Horton,1945	1.31km
18.	Constant of Channel Maintenance(C)	C=1/Dd, Where Dd (Drainage density) is in square feet per foot	Horton,1945	2.63km
S.N.	**Morphometric Parameters**	**Methods**	**References**	**Results**
RELIEF ASPECTS (Ra)				
19.	Basin relief (H)	H= Z-z where Vertical distance between the lowest (z) and highest (Z) points of watershed.	Strahler, 1952	241 m. 0.241 km
20.	Relief Ratio (Rh)	Rh=H/Lb; where, H=Basin relief, Lb=Basin length.	Schumm, 1956	1.892 0.001
21.	Ruggedness Number (Rn)	Rn= Dd X BH where, BH=Basin relief, Dd=Drainage density.	Schumm, 1956	0.089

Basic Morphometric Parameter of Kharun River Basin

Linear Aspects morphometric parameters: -

The linear aspects parameters give the information about one- dimensional parameters like stream order, stream number, stream length, mean stream length, stream length ratio, bifurcation ratio, mean bifurcation ratio, basin length. These parameters are indicating Channel patterns of the drainage network with the topological characteristics of the stream segments and analysis are based on open links of the stream network.

Stream Order (U)

A variety of ordering systems for streams are available (Horton, 1945; Strahler, 1952; Scheidegger, 1965). For the analysis modified Horton's law (Strahler law) has been flowed of its simplicity. The smallest, unbranched fingertip streams are referred to as first order, and the confluence of two first order channels yield a segment of second order, while two second order streams join to form a segment of third order, and so forth. The following higher order is maintained when two channels of the same smaller order join. The highest order stream segment is known as the trunk stream (Lama, 2021). The Kharun River is a fifth order stream according to the Strahler (1952) method. A total of 515 streams were identified, of which 258 are first order, 125 are second order, 72 are third order, 54 are fourth order, and 6 is fifth order.

The Kharun river basin area's overall drainage system includes dendritic, parallel and angular pattern due to the network of numerous tributaries and its main stream running along the general slope direction, which is in turn well adhered to the related geological features. Dendritic drainage has a spreading, tree-like pattern with an irregular branching of tributaries in many directions and with any angle. In the present study work the stream ordering has been ranked depended on a method suggested (Strahler, 1960) from the extracted stream from ASTER data. The drainage pattern study of the Kharun river basin specified that the area comes under structural tectonic control.

The Kharun river basin could be designated as a maximum fifth order stream (). The maximum stream order frequency is detected in case of first order stream and then for second order. Hence, it is observed that there is a decrease in stream frequency as the stream order increases and vice-versa. Higher stream order is released with larger discharge and higher velocity of the stream flow.

Stream number (Nu)

The stream segment numbers and the order number eventually combine to form an inverted geometric sequence, according to Horton. A watershed's stream branching complexity is being numerically evaluated here (Horton, the watershed since most first-order streams come from ridges and hills, which have steeper slopes; second-order streams form downstream, and so forth. (Lama, 2021). The Kharun river basin stream number of different orders and the total number of streams in the basin are calculated in GIS domain. During calculation it is identified that the stream number progressively decreases as the stream order increases; the variation in stream order and size of tributary basins is largely influenced on physiographical, geomorphological and geological situation of the area. Stream number is directly proportional to size of the contributing watershed and to channel dimensions. A total 515 stream line including Kharun river is recognized in the whole basin, out of which 50.09% (258) is first order, 24.27% (125) is second order, 13.98% (72) is third order, 10.48% (54) is fourth order, 1.16% (6) is fifth order. The maximum first order stream number shows the intensity of the area's lesser porousness or permeability and infiltration features.

Stream Length (Lu)

The sum of the stream lengths in each order determines the overall length of the individual stream segments in that order. By dividing the total length of all streams in a given order by the number of streams in that order, stream length can be determined as the average (or mean) length of a stream in each order. The hydrological properties of the bedrock and the extent of drainage are measured by the length of the stream. In a well-drained watershed, where the limited number of longer streams occur wherever the bedrock and formation are permeable; in contrast, a large number of shorter streams develop where the bedrocks and formations are less permeable (Sethupathi et al., 2011). Usually, as stream order increases, the length of the stream increases exponentially (Lama, 2021). However, the distribution of stream length in the Kharun basin changes significantly as order increases. The length of first order stream is 712.15km, which are followed in order by second order streams (384.08 km), third order streams (158.57 km), fourth order streams (117.81 km) and fifth order streams (10.65 km).

Mean stream length (Lsm)

Mean stream length is calculated by dividing the overall stream length of an order by the total number of order segments. The mean stream length is related with the topography and permeability. The mean stream length usually increases with the increase in the order of stream (Lama, 2021). In the Kharun River basin, the mean stream length of the first to fifth order streams are 2.76, 3.073, 2.21, 2.181 and 1.775 respectively. Permeability increases as stream order increase.

Stream Length Ratio (Rl)

The whole stream length of one order divided by the next lower order of stream segment is known as the stream length ratio. Their mature geomorphic state is indicated by a pattern of increasing stream length ratio from lower order to higher order (Tiwari, 2023). The stream Length Ratio of 1st order (0.898), 2nd order (1.391),3rd order (1.013) and 4th order (0.814) Stream in the Kharun river basin indicates moderate percolation of runoff water through there streams. 1.39 stream length ration for the 2nd order stream indicates higher percolation through the Kharun River in this region structural control of the Kharun River Further explains this value.

Bifurcation Ratio (Rb)

The ratio of the number of stream segments of a particular order to the number of segments of the next higher orders is known as the bifurcation ratio (Rb), according to Schumm (1956). Bifurcation Ratio (Rb) is dimensionless and it integrates the degree of integration between stream segments of different orders in drainage basin (Gutema et al. 2017). The bifurcation ratio of Kharun river basin varies from 2.064 To 9. while the mean bifurcation ratio is 3.533. Strahler (1964) states that drainage basins with geological structures that do not alter the drainage pattern often have bifurcation ratio values between 3.0 and 5.0. The mean bifurcation ratio of drainage network (Rbm) typically falls between 3.0 and 5.0 for a basin where the impact of geological structure is minimal.

Basin Length (Lb)

Schumm (1956) defined it as the longest dimension of the basin that is parallel to the main drainage line. According to Gregory and Walling (1968), the basin length is the longest section of the basin, with the mouth at its end (Lama, 2021). the Kharun river basin is 127.34 kilometres long. (Lama, 2021).

Areal Aspects morphometric parameters: -

The Areal aspects deal with two-dimensional parameters like basin shape and area, drainage density, drainage texture, stream frequency, elongation ratio, circularity ratio, from factor, length of overland flow, and constant channel maintenance.

Basin Area (A)

Similar to the length of the stream drainage, the area of the watershed is a further essential aspect (Lama, 2021). The entire amount of water can be precisely represented by the Kharun River basin's watershed area. The basin area of Kharun River basin is 3628.3 km2. Which falls under the category of large basin, large basin of the Kharun River suggests extensive drainage network with potentially higher runoff and sediments yield, impacting larger river system.

Basin Perimeter (P)

The outer border of the watershed enclosing the basin is known as the basin perimeter. It can be used as a guide for the size and shape of a watershed. The Perimeter of the Kharun River basin is 430.042 km^2. Which categorize the Kharun River basin as large basin. Large basin indicates irregularly shaped basin with longer boundaries may have more complex drainage pattern and longer flow.

Drainage Density (Dd)

Horton states that drainage density can be calculated by dividing the entire length of the stream by the area of the basin. However, the Kharun river basin has lowest drainage density (0.381) results from indicates the basin is a highly permeable subsoil and thick vegetative cover (Nag and Chakraborty, 2003). However, based on some definitions about Dd classes, it can be highlighted that there are two main classes, low/coarse and high/fine class. The Kharun river basin is low class of Dd shows a poorly drained basin with a slow hydrologic response. Surface runoff is not rapidly removed from the watershed making it highly susceptible to flooding, gully erosion, etc. Besides, low class of Dd has permeable subsoil material, dense vegetation and low relief. (S Sukristiyanti, R Maria and H Lestiana, 2017).

Stream Frequency (Fs)

According to Horton (1945), Stream Frequency is the number of streams per unit area, which is calculated by dividing the total number of streams by the area of the drainage basin. (Tiwari, 2023). Stream Frequency of Kanger River basin is very low (0.142 sq.km). Very low Stream Frequency Kharun River basin indicates presence of highly permeable rock and low relief prevails in this region.

Drainage Texture (T)

The total number of stream segments in a basin of all orders per basin perimeter is known as the drainage texture, according to Horton,1945. Given that it denotes the relative spacing of drainage lines, it is significant to geomorphology. The relief aspect of the terrain, infiltration capability, and underlying lithology all influence drainage texture. Five distinct textures can be identified in drainage: extremely coarse (<2), coarse (2–4), intermediate (4–6), fine (6–8), and very fine (>8) (Tiwari, 2023). The drainage texture of Kharun River basin is 1.198 km/km2, which indicates an extremely coarse drainage texture suggesting a high rate of infiltration.

Form Factor (Rf)

The ratio between the basin's area and square of its length is known as the form factor. Various basin shapes are typically represented by it (Horton, 1932). The form factor has a value in the range of 0.1 to 0.8. An entirely round basin would always have a form factor value greater than 0.78. The basin will be more elongated the lower the form factor is. The form factor of the Kharun River basin is 0.224. Low form factor indicates that the shape of the Kharun River basin is elongated therefore during period of heavy rainfall, threat of flooding in this region is minimum.

Circularity Ratio (Rc)

The ratio between the basin's area and the circle's area with the same circumference as the basin's perimeter as established by Miller in 1953.The length and frequency of streams, geological structures, land use and cover, climate, relief, and basin slope are the primary factors that affect the circulator ratio. An increased circulatory ratio indicates a watershed's dendritic stage. The tributary watershed's youthful, mature, and old life stages are represented by low, medium, and high levels, respectively. Circularity ratios range in value from 0 (in a line) to 1 (in a circle). Greater circularity in the basin's shape is indicated by higher values, and vice versa. Naturally, in order to reach the mature stage, all basins have a tendency to elongate (Lama, 2021). The circulatory ratio of Kharun River basin is 0.247. The structural control of the Kharun River is probably responsible for the value of circularity ratio.

Elongation Ratio (Re)

According to Schumm (1956), an elongation ratio (Re) is the ratio of a circle's diameter in the basin's maximum length in the same area. It is a measurement of the river basin's shape, which is determined by the geology and climate. In a highly elongated shape, the value of Re ranges from 0 to unity, or 1.0, in a circular shape. Therefore, a basin with a larger elongation ratio will have a more circular form, and vice versa. Four distinct shapes can be distinguished by the elongation ratio, namely: elongated (<0.7), Less elongated (0.807), oval (0.9-0.8), and circular (>0.9). Higher elongation ratio values indicate little runoff and high infiltration capacity, whereas lower Re values indicate very susceptible to erosion and sediment load (Lama, 2021). With an elongation ratio of 0.301, the Kharun River Basin is a drainage basin that is extremely elongated.

Length of Overland flow (Lg)

The Length of Overland flow is defined as the length of water over the ground before it gets concentrated into mainstream which after hydrologic and physiographic development of the drainage basin (Horton, 1945). Lg is significantly affected by infiltration (exfiltration) and percolation through the soil, both varying in time and space (Schmid, 1997). The high Lg value indicate that the rainwater had to travel a relatively longer distance before getting concentrated into stream channels (Chitra et al. 2011). The value of the length of overland flow in this study is 1.31km which shows higher distance runoff, gentle slopes and long flow paths, more infiltration, and reduced runoff in the study area.

Constant Channel maintenance (C)

Constant channel maintenance (C) is reciprocal of drainage density as property to define overland flow (Schumm, 1956) and expressed in km$^{2/}$km. Plateau and plain areas tend to have high C value due to low drainage density and high infiltration capacity (Mahala, 2020). On the other hand, mountain environment generally has lower C values due to lower infiltration and high overland flow which indicate young geomorphological adjustment and higher flood potential. The C values of Kharun river basin is 2.63km. It indicates a higher infiltration capacity of the soil, which means lower flood potential.

Relief Aspects morphometric parameters: -

Relief aspects deal with three-dimensional parameters like basin relief, relief ratio, ruggedness number etc.

Basin Relief (H)

Basin relief is the difference in height between the highest and lowest locations of the basin (Lama, 2021). In the Kharun River basin, the maximum basin relief is 241 meters The highest point of Kharun River basin is 453 meters and lowest point is 212 meters. It determines the slope, which has an impact on silt movement and runoff.

Relief Ratio (Rh)

According to Schumm (1956), it is the ratio of the maximum basin relief to the horizontal distance along the basin's longest dimension that runs parallel to the main drainage line. The relief ratio of the Kharun River Basin is low (1.892) which indicates gentle slope and lower intensity of erosion.

Ruggedness Number (Rn)

Ruggedness number (Rn) is defined by Strahler (1964) as the combination of drainage density and maximum basin relief; it typically combinations of slope steepness with length. When the basin's slopes are both longer and steeper, the roughness number might reach extremely high values (Tiwari, 2023). Ruggedness number of the Kharun River Basin is 0.089; this value indicates relatively smooth geomorphic landforms occur in this area. However, some segments show structural control whereas major area does not show much structural complexity.

IV. Conclusion

This study area map serves as a foundational tool for various analyses related to hydrology, land use, and environmental planning in the Kharun River Basin. The multi-panel layout allows for both a broad and detailed view, aiding in visualizing the basin’s relationship to the larger geographic setting. The integration of DEM data adds a layer of detail that is valuable for topographic analysis, water flow simulation, and understanding watershed characteristics, which are essential for hydrological modelling and environmental assessments.

The slope map of the Kharun River Basin, derived from SRTM DEM data, is a key resource for understanding the basin's topography. It supports hydrological modelling, land use planning, and environmental conservation efforts within the region. The map’s slope classification allows for a clear interpretation of the terrain gradient, assisting in identifying erosion-prone areas, planning agricultural and infrastructure projects, and assessing habitat diversity. In summary, the slope analysis offers valuable insights for sustainable management of the Kharun River Basin, promoting informed decision-making in environmental and developmental initiatives.

The aspect map of the Kharun River Basin is an essential tool for understanding the spatial distribution of slope orientations within the area. By revealing how each slope faces, this map provides insights into sunlight exposure, temperature variations, soil moisture retention, and water flow direction. Such information is invaluable for hydrological studies, land management, agricultural planning, biodiversity conservation, and infrastructure development.

The analysis of aspect within the Kharun River Basin highlights how natural terrain characteristics impact ecological and human activities. By incorporating aspect data into environmental management, planners and researchers can make informed decisions that align with the basin’s unique topographic properties, promoting sustainable and resilient practices for the region’s development and conservation.

Creating an aspect map using SRTM DEM data provides valuable insights into the topographic and hydrological features of the Kharun River Basin. This methodology demonstrates the practical steps in processing and visualizing DEM data to derive meaningful information about slope orientations. Such maps support environmental planning, conservation efforts, and land use management.

The stream network and stream order classification of the Kharun River Basin, developed using SRTM DEM data and QGIS, provide a detailed understanding of the river system’s structure. By classifying streams into five hierarchical orders, the map highlights the connectivity and flow dynamics within the basin, serving as an essential tool for hydrological studies, environmental conservation, and land management. The hierarchical stream classification enables comprehensive flood risk assessment, water resource planning, biodiversity management, and land use decision-making, supporting sustainable management of the Kharun River Basin.

This structured methodology and analysis demonstrate the utility of SRTM DEM data and QGIS software in creating a stream network map, enhancing understanding of the basin’s hydrological characteristics. The resulting map not only facilitates scientific research but also aids policymakers and planners in promoting effective water resource management and environmental stewardship within the Kharun River Basin.

The elevation map of the Kharun River Basin, created using SRTM DEM data, is a fundamental tool for understanding the region's topographic and hydrological characteristics. By visually representing elevation gradients, this map provides a basis for hydrological modeling, environmental management, and infrastructure planning.

The map highlights elevation variations crucial for water flow analysis, soil erosion studies, land use planning, and biodiversity assessments. Additionally, the detailed cartographic elements, such as the coordinate grid, north arrow, and scale bar, enhance the map's usability, allowing for precise spatial analysis.

In summary, this elevation map of the Kharun River Basin not only serves as a valuable resource for scientific studies but also supports decision-making processes in water resource management, land use planning, and sustainable development efforts within the region. The SRTM DEM data, processed to create this elevation map, thus plays an instrumental role in promoting an in-depth understanding of the basin's physical landscape and guiding future research and policy initiatives.

The soil texture classification analysis provides essential insights into the physical properties of soils within the Kharun Basin. These properties influence water availability, nutrient content, and land suitability for agriculture and ecological conservation. Using Google Earth Engine for spatial analysis proved efficient for handling large datasets and calculating soil class areas with accuracy. The resulting classification informs land-use planning and helps identify areas prone to erosion, waterlogging, or nutrient depletion, thereby contributing to more effective resource management within the watershed.

This analysis could be extended by incorporating temporal soil data or overlaying additional environmental layers, such as vegetation indices or hydrological data, to better understand how soil texture affects and is affected by other ecological factors. The methodology established here offers a replicable framework for soil analysis in other regions, supporting sustainable land management and ecological research.

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