PRIORITIZATION OF WATERSHED USING MORPHOMETRIC PARAMETRS- A CASE STUDY OF UPPER KANGSABATI BASIN, PURULIA

Submitted By

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CHAPTER-1: INTRODUTION

A watershed is a part of land where surface water from precipitation, melting snow, or ice amalgamates at the bottom point where the basin exits and the water joins another water body, such as a river, lake, reservoir, estuary, wetland, sea, or ocean. The study of drainage basins is important in geomorphic studies as watershed has a significant impact in the structural evolution of landform. Any discussion about drainage basin is highly important in any hydrologic perception like, identify groundwater potential zone, groundwater management, pedology, watershed prioritization, drainage basin evaluation etc. The variables that may have an impact on a watershed's behaviour can be divided into two categories: (1) fixed drainage features, such as drainage density, and (2) transient or variable characteristics, such as precipitation levels and land use (Manjare et al., 2018) .

Hard rock terrain of Purulia plateau requires prioritisation of watersheds, which are crucial for water and soil conservation practises in semi-dry climates. The increasing demand for water resources for various reasons has reached doubled due to the population boom (Pandey et al., 2011). But despite receiving an adequate amount of rain, the area's main issue—along with soil erosion—is water scarcity caused by excessive runoff. So, every sub-watershed must pay equal attention to its natural resources as well as its socioeconomic environment. Generally, assessing the linear, aerial, and relief characteristics of any river basin is vital for creating region-specific water resource management and soil conservation plans (Wagh et al., 2018). Where, Linear aspect includes stream order (u), length of stream (Lu), mean length of stream (Lsm) and bifurcation ratio (Rb). Areal aspect includes drainage density (D_d), stream frequency (Fu), elongation ratio (Re), circularity ratio (Rc), form factor (Rf). Relief aspect includes basin relief (Bh), ruggedness number (Rn), relative relief (Rh) (Zende et al., 2013; Kumar et al., 2022).

A quantitative analysis of the morphometric indices of a drainage basin is thought to be the most effective technique for the proper planning of watershed prioritisation. Morphometric parameters are very easy to understand basin processes and to compare sub-watershed characteristics and enable a better understanding of the paleo history of a drainage basin. The morphometric characteristics of the sub-watershed elucidate the hydrogeological characteristics of a drainage basin. For prioritisation of watershed and the implementation of soil and water conservation measures, morphometric analysis expresses physiographic parameters such as watershed slope, channel network configuration, location of the drainage divide, channel length, and geomorphologic parameters such as relative relief, shape factor, circulatory ratio, bifurcation ratio, and drainage density. Morphometry, along with lineament density, slope distribution, and flood plain characteristics, helps divide the watershed into three major categories, high, medium, and low for management and conservation of soil erosion (Ali et al., 2018).

In order to delineate micro-watersheds of the Kasai River basin watershed prioritisation by morphometric approach has been integrated through RS and GIS. Remote Sensing and GIS technologies can be the most convenient way to identify and analyse drainage morphometry of a large watershed. Remote sensing is an ideal tool for producing spatial information, also meets the demands of speed and reliability that is necessary for well-planned and balanced development at the watershed level. On the other hand, The Geographical Information Systems (GIS) offers appropriate alternatives for effectively manage the vast datasets. Thus, the integration of remote sensing data with GIS technologies has come out to be an effective tool for the development and management of water resources as well as the characterization and prioritisation of micro-watersheds. The technologies for water resources development are not only focused on annual rainfall, but terrain, soil type, drainage, land use/ land cover and time too makes it important in determining the suitable sites for water conservation. Thus, it is widely acknowledged that watersheds should serve as a fundamental unit of a basin and that sustainable land and water management requires the deployment of advanced technologies (Pandey et al., 2011).

OBJECTIVES

- Morphometric analysis of upper kangsabati river basin using RS and GIS techniques and generation of relevant thematic maps.
- prioritisation of watershed using morphometry and Analytical Hierarchy Process (AHP) techniques.
- To make a comparative assessment of vulnerable areas which require higher priority for soil and water conservation.Beside these, on the basis of watershed prioritization various artificial recharge structures are to be proposed.

CHAPTER-2: LITERATURE REVIEW

- In the recent past, morphometric analysis—a quantitative description of basin geometry—has been successfully determined using remote sensing and Geographic Information System (GIS) approaches. The findings imply that across a basin's consecutive orders, the relationship between cumulative stream length and stream order is continuous. The morphometric indices, drainage density and bifurcation ratio, demonstrate that the area is covered with dense vegetation and essentially no structural disruptions have had an impact on the drainage. The form factor values show that the basin has peak flows that are somewhat high and have a brief duration (Biswas et al., 1999).
- According to the study, remote sensing data and a GIS-based approach are more suitable than traditional methods for evaluating drainage morphometric parameters and their impact on landforms, soils, and eroded land characteristics at the river basin level. The investigation shows that drainage morphometry has a major impact on our comprehension of the processes that shape landforms, the physical qualities of soil, and erosional traits. The study shows that remotely sensed data and a GIS-based approach are more effective than traditional methods in evaluating and analysing drainage morphometry, landforms, and land resources and in understanding how they interact for river basin-level planning and management (Reddy et al., 2004).
- In arid and semi-arid areas, watershed development and management strategies are increasingly crucial for utilising surface water and groundwater resources. Using topographical maps, this study was conducted to ascertain the drainage parameters of the Pageru River basin. The complex morphometric properties are revealed by quantitatively analysing many parts of a river basin drainage network's characteristics. Most streams in the basin are of lower orders. Rainfall has some influence on how stream segments develop in the basin area. This study demonstrates some correlations between the various morphometric characteristics of the basin and aids in understanding how they shape the area's surface. The use of these studies' findings to find locations for artificial recharge emphasises their significance (Sreedevi et al., 2005).
- In the current study, sub watersheds of the Ret watershed are prioritised using morphometric parameters in an effort to find the best locations for soil and water conservation measures. The Ret watershed was divided into 26 sub watersheds, and for

each sub watershed, the following morphometric metrics were independently derived: bifurcation ratio, form factor, circularity ratio, elongation ratio, drainage density, stream frequency, and drainage texture. By combining data on land use/cover, soil, and slope with morphological factors, watershed prioritisation was carried out based on the morphometric parameters, and a water resource management plan was developed (Pandey et al., 2011).

- Prioritising watersheds is regarded as one of the most crucial elements of planning and developing natural resources for water conservation strategies. The comprehensive strategy used in the present study to create a tentative list of sub-watersheds in the Jaggar watershed is recapitulated. Measures for soil and water conservation may be implemented in the sub-watersheds that are given the highest priority. The study shows the value of remote sensing and GIS approaches in watershed prioritisation, which may be useful for planners and decision-makers for planning at the sub-watershed level (Javed et al., 2011).
- This experimental investigation is being conducted in Papua New Guinea's Morobe province on the Watut watershed. The area covered by the Watut watershed is roughly 5410.74 square km. This watershed's average drainage density is calculated to be 0.5 km/sq. km, with an average slope of roughly 31%. The findings show that the Watut watershed experiences average surface runoff of 68.23% of total rainfall, which results in an annual soil erosion rate of roughly 657.9914 tonnes (12.16 tons/ha). These findings are used to map the entire watershed from wall to wall. The work emphasises the significant potential for modelling various hydrological parameters and producing risk maps in any watershed region using the integrated approach of SCS and USLE model with RS and GIS technologies (Pal et al., 2012).
- Management of all natural resources, including land and water, is essential to attaining sustainable development since it lessens the effects of natural disasters. In the current work, a multi-criteria decision-making technique based on Saaty's analytical hierarchical process (SAHP) has been created for identification of priority sub-watersheds. Priority for the research area has been established using the EHP weights for each of the 28 sub-watersheds, which have all been determined, normalised, and weighted using the AHP comparison matrix. All sub-watersheds' priorities were divided into five categories: very high, high, moderate, low, and very low (Ranjan et al., 2013).
- To analyse many important criteria that could aid in groundwater exploration, planning, and management of the research area, a morphometric analysis study utilising remote

sensing and GIS method was conducted. The features of linear, aerial, and relief were used to categorise the parameters. Low density in the area denotes the presence of subsoil material that is porous and fractured. According to the figures for drainage texture, drainage density, and stream frequency, the area has a high rate of infiltration and little runoff, which makes it a major contributor to the subsurface water resources (Ndatuwong & Yadav, 2014).

- In order to identify critical sub-watersheds in the transition zone between the mountainous and water-scarce regions of the Kallar watershed, Tamil Nadu, the current research attempted to study various morphological characteristics and to implement Geographical Information System (GIS) and Multi Criteria Decision Making (MCDM) through Fuzzy Analytical Hierarchy Process (FAHP) techniques. The topographical and hydrological behaviour of the watershed could be distinguished thanks to the morphometric characterisation (Rahaman et al., 2015).
- Kuttiyadi is a sixth order basin, characterised by maximum relief and gradients in the eastern part, exhibiting highest runoff and susceptibility to flooding and inundation. Geohydrological behaviour of the watershed was analysed by calculating the morphometric parameters, and linear, relief, and areal parameters were determined using standard equations. Prioritising watersheds was done using a multi-criteria decision-making process. Given the interrelationship between the various morphometric factors and the complexity resulting from their combined influence (Gopinath et al., 2016).
- Geo-morphometric features of the catchment influence hydrological analysis and behaviour of the watershed. It has been done to critically evaluate and appraise geomorphometric constraints. After assigning the prioritised score based on each sub-watershed's morphometric behaviour, aggregated scores have been computed to determine the characteristics that are most sensitive. The study places a strong emphasis on the sub-watersheds' prioritisation based on morphometric analysis. According to the threat of erosion, the total score for all nine sub-watersheds is determined. However, the sub-watershed with the lowest value of the compound parameter was given top priority (Chandniha & Kansal, 2017).

CHAPTER-3: STUDY AREA

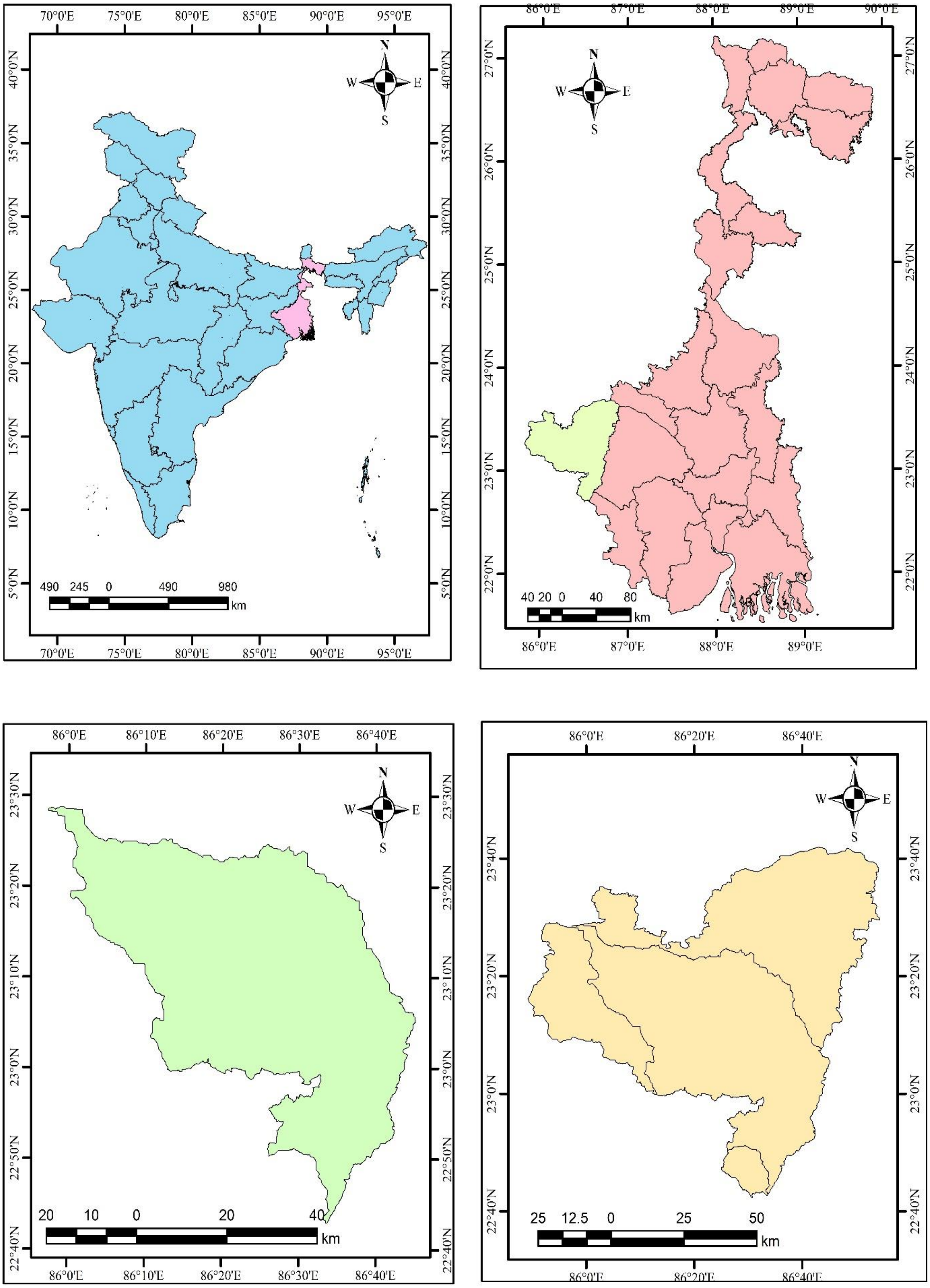
Kangsabati (also variously known as the Kasai, Kansai, and Cossye) a non-perennial alluvial river, originates at an altitude of approx 403 mt. from "Jahar Pahar" (part of Chhotanagpur Plateau) of Jhalda-II C.D. block of Purulia District and flowing over the Jhalda-II, Joypur, Arsha, Purulia-I, Purulia-II, Puncha and Manbazar-I C.D. and meets the Kumari River, a major right-hand tributary of kangsabti at its south-eastern flow towards Mukutmonipur of Bankura District, West Bengal. The Kangsabati River includes three distinct sections, The upper course is started from Jhalda and extended upto Sarenga, middle course lies between Sarenga to Mohanpur and lower course extended between Mohanpur to Bandar near Ghatal (Rupnaryan branch). The upper kangsabati basin, the core study area, extended from 23°28′24.75″N latitude to 22°42′59.81″N latitude and 85°57′15.16″E longitude to 86°33′29.61″ of "Chhotanagpur Granitic or Granite Gneiss Complex (CGGC)" (Bhattacharya, 2018).

GEOLOGY

The geology of the study area is made up of a variety of stratigraphic units, from the ancient Archaeans (pre-Cambrian) to the more recent Tertiary-Quaternary formations (Mukhopadhyay, 1992). Achaeans comprise granitic rocks, meta-sedimentaries, calc-granulites and metabasics. The granitic rocks include gray banded biotite-granite gneiss, pink granite, porphyritic granite gneiss. All these granitic rocks, older schist and gneisses and basic rocks have been intruded by pegmatites and quartz veins. The major part of the study area falls under Chhotanagpur gneissic complex and the most common Archaean rock of the upper kangsabati area is gneiss.

LITHOLOGY

The whole northern, north-eastern and north-western part the upper kangsabati basin have the abundance of granitic gneiss. Whereas southern part of the basin has riched with mica schist with hornblende schist. There are some other lithologic units found dispersedly over the entire basin are hornblende schist, amphibolite, meta ultrabasite, phyllite, dolerite, tuff, tuffaceous psammo-pelite, unclassified soil and alluvium.



Study Area Map

GEOMORPHOLOGY

Almost 90% area of the basin has denudational landforms within it there are vast network of fluvial origin. Denudational hills are made up of jointed and fractured gneisses and granites and are the result of different weathering and erosion processes. Topographic cuts, joints, and fractures present make groundwater infiltration is feasible, but as the slope increases, the likelihood of runoff also rises, restricting the process of groundwater recharging (Ezung et al., n.d.). Only the eastern pocket of the basin has some anthropogenic landforms and in western and southern part there are some structural origins.

CLIMATE

The tropical rainfed river "Kangsabati," which causes floods and droughts in its basin every year, inspired the basin's name. The summers months are exceptionally dry due to the oppressive temperatures and high levels of evaporation, which also hastens the groundwater's rapid depletion (Alharbi et al., 2022). The summers are extremely humid and frequently hot, with daytime highs of around 40°C. November through February is *considered* winter which characterised by a moderately cold winter, with overnight lows of around 10°C. The start of summer is announced in late March, and it lasts until June when it reaches its uncomfortable peak (Ezung et al., n.d.).

Annual rainfall averages between 1100 and 1500 mm in the upper catchment of kangsabati basin. Since the area's rainfall is not consistent from year to year but rather irregular and scarce, the Kharif crops fail and a drought occurs. July through September is the monsoon season. The South-West monsoon, which is responsible for 80% of the district's total rainfall, is the predominant precipitation source. In the monsoon season, the relative humidity is high, ranging from 75% to 85%. However, during the summer, it drops to 25% to 35%. Summer winds in the district are dry and hot, with velocities between 5 and 6 km/h (Ezung et al., n.d.).

DRAINAGE

This alluvial river basin has follows dendritic to sub-dendritic drainage or radial pattern. The main perennial rivers that drain the basin are the river Kasai, which runs through the basin's centre along with the Damodar, Subarnarekha. The largest river of the watershed as well as in Purulia is the Kasai, which is joined by Kumari, one of its major tributaries. Generally, the streams within the basin run either easterly or southerly. Small areas in the basin's northeastern and eastern halves are drained by the Darakeswar and Silai or Silabati rivers, respectively (Ezung et al., n.d.).

SOIL

The majority of the basin's soils are of the residual variety, which are a direct result of the weathering of Achaean granites, gneisses, and schists. In contrast to the lowlands, where reddish clay loam or white to reddish clay are more common, lateral soil predominates in the uplands. There are many different textural classes to choose from, including sandy loam, reddish loam, white or reddish stiff clay, etc. The topography is undulating; therefore, the soil is typically gravelly and has a thin soil cover. Jhalda, Arsa, Bagmundi, Barabazar, Para, Kashipur, Hura, and Santuri's gently sloping to undulating plains have witnessed deep, well-drained to moderately drained, sandy loamy soil. Whereas shallow, well-drained, gravelly loamy soils have been found in the undulating plains of Joypur, Purulia I, Purulia II, Barabazar, Manbazar, and Para, as well as the gently sloping ridges of Bagmundi and subdued ridges of Jhalda. The entire catchment's soil is discovered to be acidic in nature. The soil typically has 0.04% nitrogen, 0.005% P_2O_5, and 0.01% K_2O content. The soil has a maximum nitrogen level of 0.87% and a lowest nitrogen content of 0.036%. Due to the soils' low levels of organic matter, with the exception of river alluvium and valley fills, fertility is likewise low (Ezung et al., n.d.).

CHAPTER-4: METHODOLOGY

The first and foremost thing to escalating the topic of watershed prioritization is to delineate the basin area with a proper manner. For this purpose, six topographical sheets have been superimposed with each other namely 73E/14, 73E/15, 73E/16, 73E/17, 73I/3, 73I/4 with a RF of 1:50,000 which covers the entire upper kangsabati basin of Purulia district. These six topographical maps have been downloaded from official website of Survey of India (SOI) (https://www.surveyofindia.gov.in/) from the edition of 1961.

For preparation of basic physiographic map such as geology, geomorphology and lithological map of upper kangsabati basin of Purulia district, we have been used the online open-source website of Geological Survey of India, named BHUKOSH (https://bhukosh.gsi.gov.in/Bhukosh/Public). To properly portray the underlying lithologic units or geologic features or the geomorphic divisions we have collected map from the year 2020 with a scale of 1: 2,50,000.

To elucidate the vast variety of land use/land cover characteristics of the basin we have choosen satellite image from Landsat-9 which have a spatial resolution of 30 mt. downloaded from United States Geological Survey (USGS) (https://earthexplorer.usgs.gov/). Landsat-9 have two instruments in it, one is Operational Land Imager (OLI-2) and Thermal Infrared Sensor (TIRS-2) with eleven spectral bands where there are two thermal bands (Band 10 and Band 11) and the satellite image was captured on early April, 2023, basically a pre-monsoon image from which we could finely differentiate and categorized LULC classes.

For analyzing the prioritization of sub-watershed slope map, basin relief map, dissection map, lineament map, drainage density map, topographic wetness index map, stream power map etc. are the most important. These maps have been prepared with the help Digital Elevation Model (DEM) data and the whole SRTM (Shuttle Radar Topographic Mission) data has been downloaded from the official website of USGS (https://earthexplorer.usgs.gov/). This SRTM-DEM has a spatial resolution of 30 mt. with allotted path-row of 54-08 respectively. The DEM data was also a pre-monsoonal image captured on early April, 2023.

GEOSPATIAL TOOL USED

We have used two geospatial tools namely (i) Arc Hydro Tools and (ii) Arc Morphometry Tools.

(i) **Arc Hydro Tools:** This tool basically used to perfectly delineate the drainage pattern of the vast basin area through which we can easily make drainage related all maps within a short period of time. We have installed ArcHydroTools_x64 version from google and then add this tool on ArcGIS for the analysis.

(ii) **Arc Morphometry Tools:** This tool also used for easily get the information about the various morphometric features (linear, areal, relief parameters) of the basin just doing few steps. We have downloaded Morphometric_tool from google and add on this tool on ArcGIS for further analyzation.

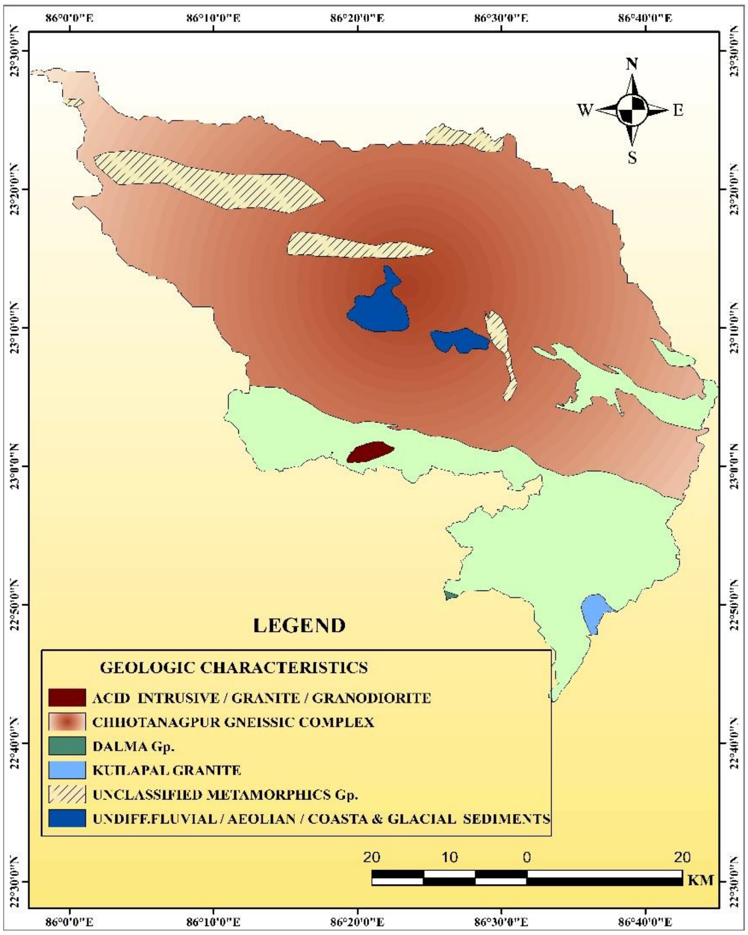
DIGITAL IMAGE PROCESSING

The term "digital image processing" describes the use of a computer to perform a series of processing operations on an image. The goals that are intended to be achieved by the processing are determined by the precise type of processing activities that are selected to be performed to the image. demonstrating that there is a particular application-oriented flavor to digital image processing (Hunt, 1983). Here, prior for my dissertation work, to delineate the watershed map, the topographical information was taken from the Geographical Review of India and the Indian Parliament, corrected, and digitalized using ArcGIS programming (version 10.8) (S. Ghosh et al., 2023). Morphological structure related map like geology, geomorphology, lithology maps have been downloaded from BHUKOSH website. To properly clip these maps in the shape the study area we have selected vector to vector “geoprocessing tools”. Another maps like slope map, relief maps, drainage related maps, TWI map, stream power map have been prepared based on SRTM data. These DEM data then have been processed through Inverse Distance Weighting (IDW) interpolation method. This method requires an algorithm to determine how many points are closest to the x point because the user can specify how many points around the x point will be utilized in the computation. In the second, the algorithm must choose several sampling locations that are located within the user-specified radius from point x. Cross validation approach, which was previously described, can be used to determine the procedure for creating an ideal P value by determining the smallest RMSE between the interpolation result and real values. The ArcGIS software's Geostatistics Analyst will automatically try to choose an ideal value if you're using it (XXXXX, n.d.).

CHAPTER-5: DISCUSSION

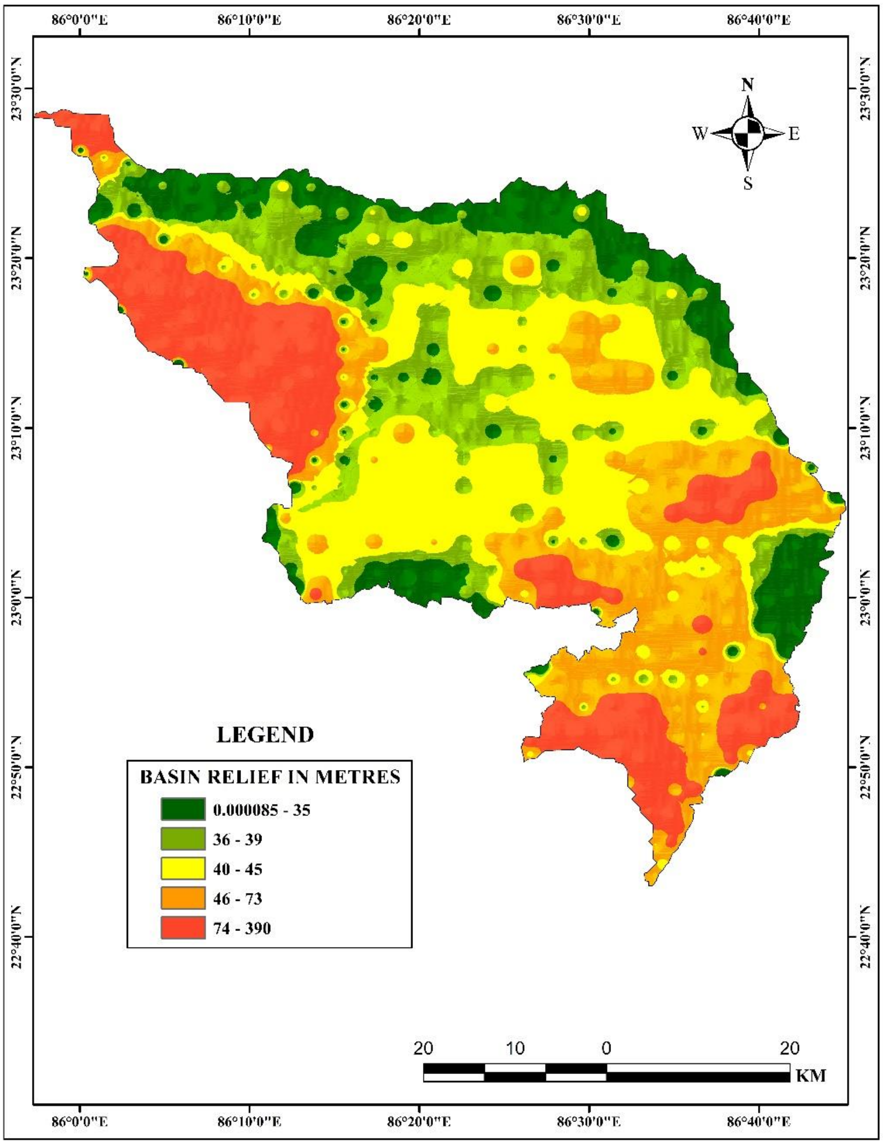
GEOLOGY

Geology affects drainage basins in several ways. The type of rock and soil in the drainage basin can affect the rate of erosion and the amount of sediment that is carried by the water. For example, rock that is quick to erode forms dendritic patterns in the drainage basin. The topography of the land also affects drainage basins. Steep slopes can cause water to flow quickly and create deep channels, while flat areas can cause water to flow more slowly and create shallow channels. If we observed the basin area specifically then we see that the greater part of the basin covered by the Chhotanagpur Gneissic Complex rock structure. Above 70% area covered by Chhotanagpur Gneissic Complex type of rock structure. Whereas the southern part of the basin cover by the Dalma Gp. Rock type which is the second most important type of rock of that river basin. Some northern parts of are covered by Unclassified Metamorphic Gp. Very less parts of the basin covered by Acid Intrusive/Granite/Granodiorite rock structure. Some minimal parts of the river basin covered by Undiff.Fluvial/Aeolian/Costal & Glacial Sediment rock types (in central parts of basin) and Kuilapal Granite.



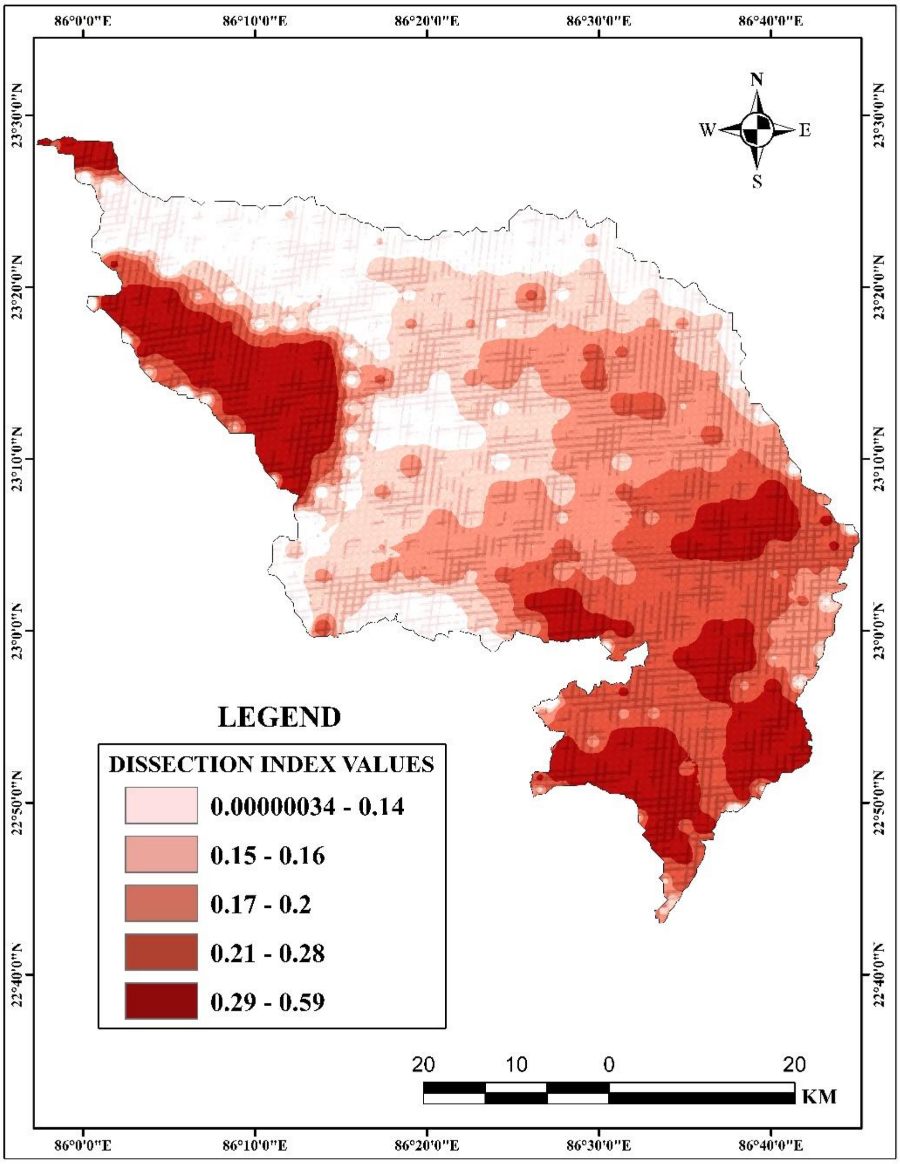
BASIN RELIEF

Basin relief represents the elevation difference between the highest point on the drainage divide and the outlet point of the subbasin. Relief Ratio (RR) is an index of the relief characteristics of a drainage basin. It is expressed as $Rh = H / L$, where H is the difference in height between the highest and lowest points in the basin and L is the horizontal distance along the longest dimension of the basin parallel to the main stream line. If we observed the basin area specifically then we see that the north-western part of the basin is the highest part of that basin and the north, north-eastern parts are the lowest. In southern part we observe some higher area where in south most part have height of above 100 metres. Also, the north-western part has a height above 74 metres. The middle part of the basin has a moderate height which is 40 to 45 metres. The lowest height of the basin area is less than 35 metres. So, if we observe the basin relief component then we see that the trend of the relief slope is mainly west to eastward.



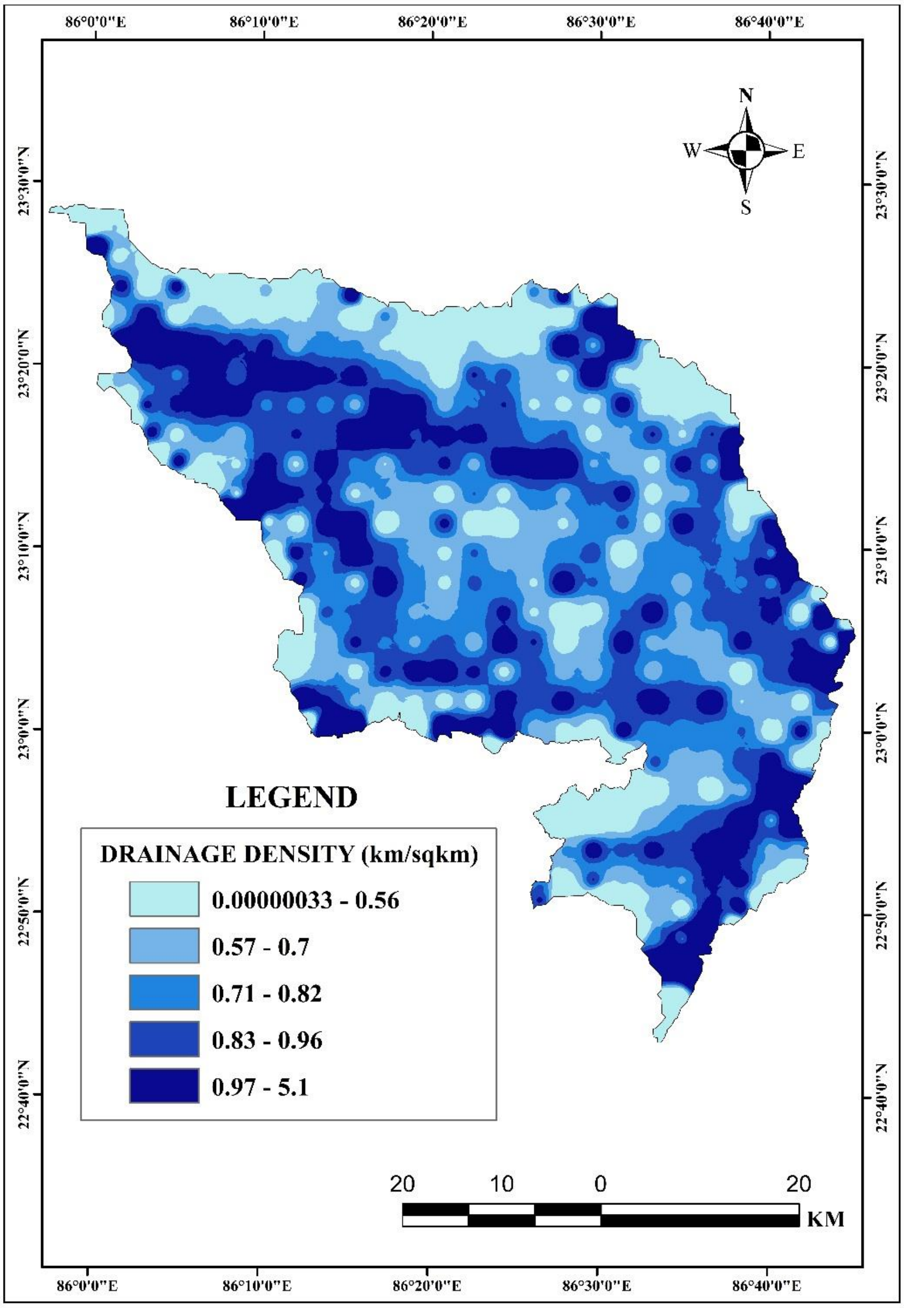
DISSECTION INDEX

Dissection index (DI) is a morphometric indicator of the nature and magnitude of dissection of terrain. It is expressed as the ratio of the maximum relative relief to maximum absolute relief. The value of DI varies from zero (complete absence of dissection) to one (vertical cliff). Dissection index is a quantitative description of drainage basin geometry that helps understand the slope, structural controls, geological and geomorphic history of the drainage basin. It is defined as the ratio of the difference between the maximum and minimum elevations of the basin to its maximum length. If we observed the basin area specifically then we see that the north-western and southern part of the basin have higher dissection index value which is higher than 0.21 and some area have very high value (greater than 0.5). Northern area has very less dissection index value which is less than 0.14. The greater most area of the basin have a value which varies 0.15 to 0.2.



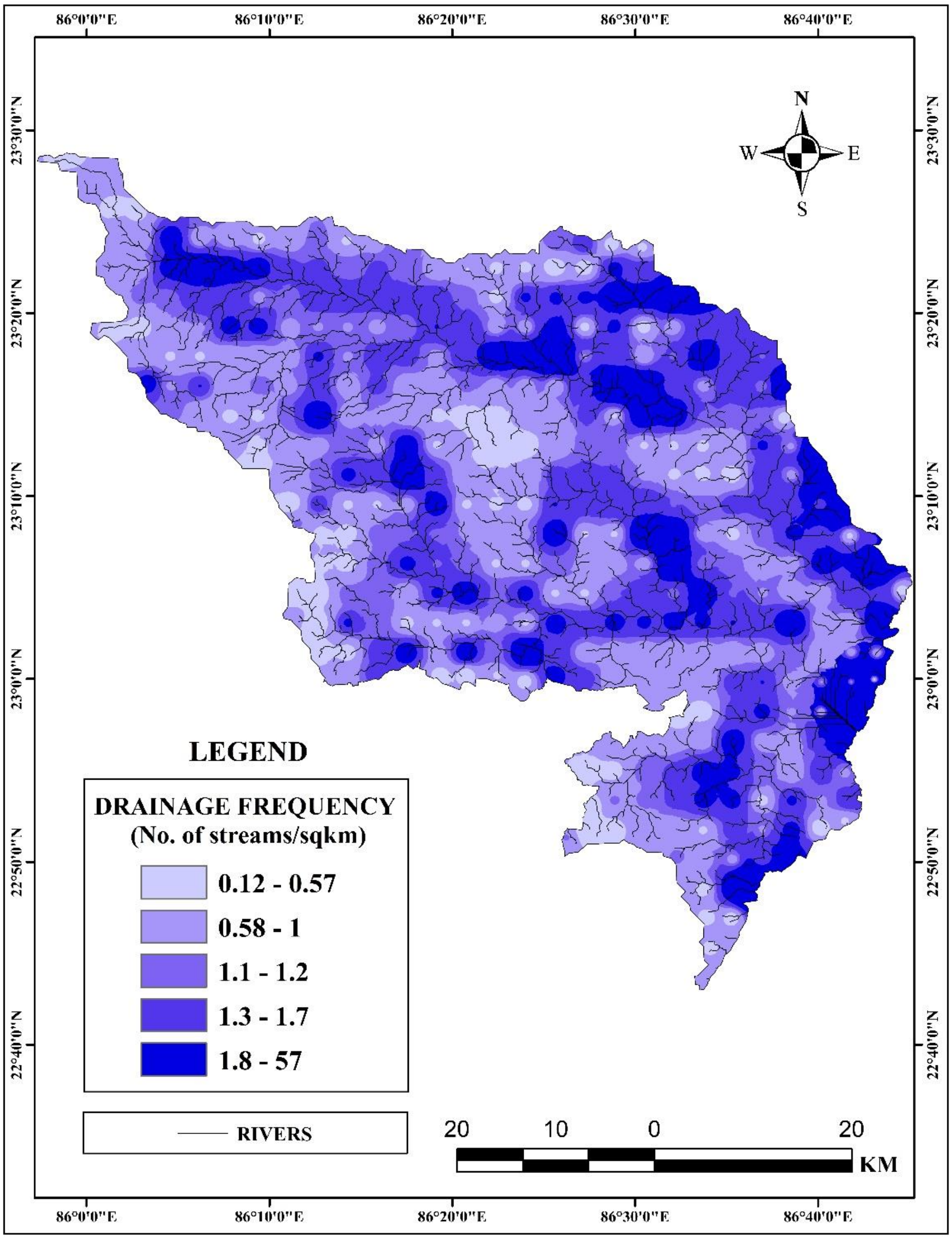
DRAINAGE DENSITY

Drainage density is the total length of channel in a drainage basin divided by the total area. It is indicative of infiltration and permeability of a drainage basin, as well as relating to the shape of the hydrograph. High drainage densities also mean a high bifurcation ratio. The unit of drainage density is usually meters per square meter. If we observed the basin area specifically then we see that the north-western and south-eastern area of the drainage basin have highest drainage density which is above 0.80. The density value of the middle part of the basin is varies from 0.57 to 0.82. Whereas, some vast northmost part of the basin has very low drainage density which was less than 0.55.



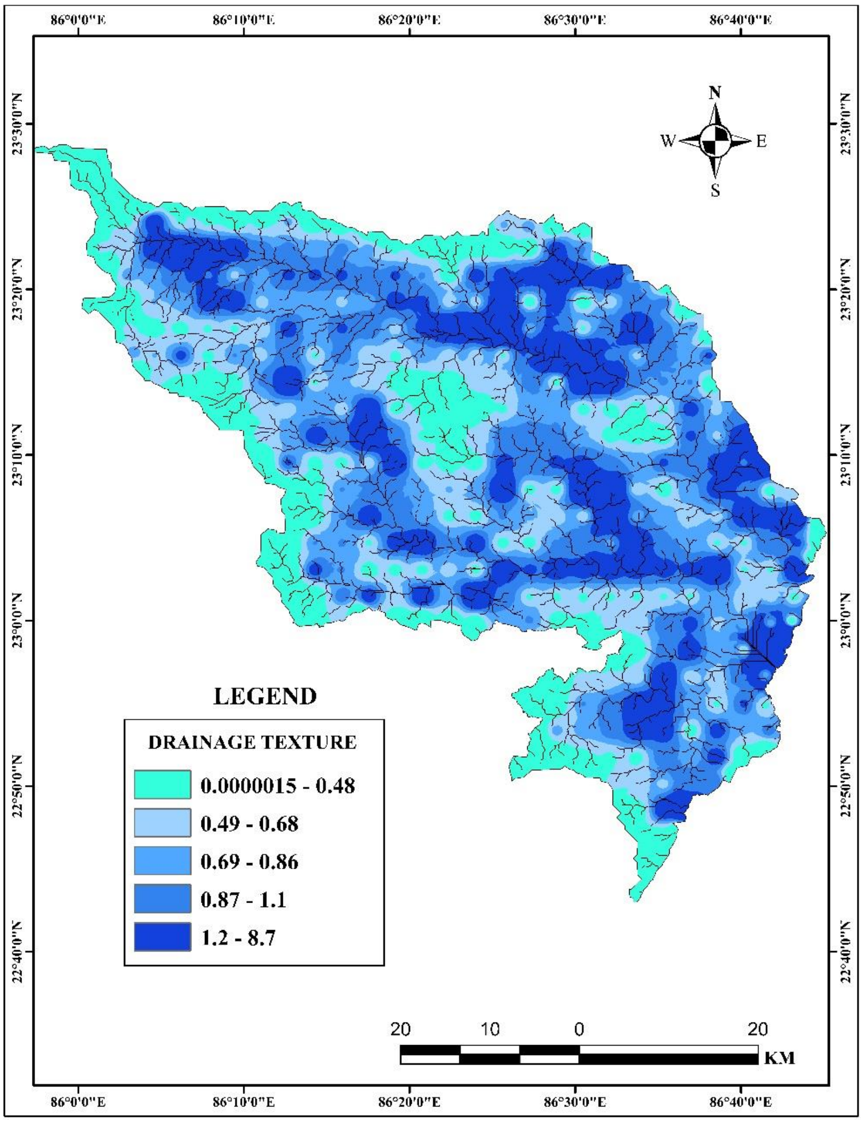
DRAINAGE FREQUENCY

Drainage frequency is the measure of the number of streams per kilometre area. The frequency of drainage depends on the climate and physical characteristics of the drainage basin. If we observed the basin area specifically then we see that the eastern and south-eastern part of the basin have highest drainage frequency which is above 1.8 or near 2 number of stream/per sqkm. The Drainage frequency reduced from eastern to western region in that basin area. We observe that in the north and north-western area of the basin have less than 1 number of stream/per sqkm. Also, in the mid part of the basin we observe same pattern of that parameter.



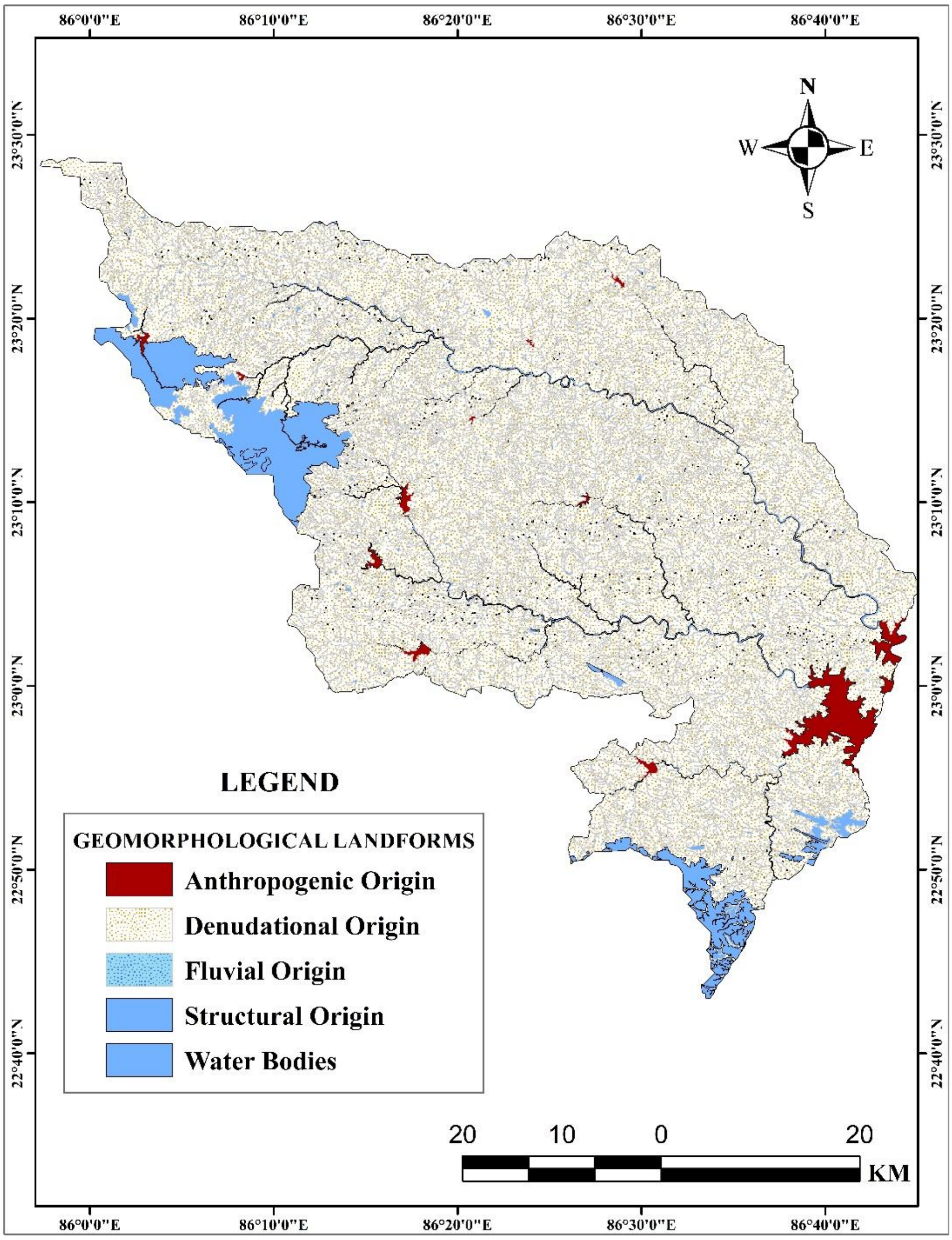
DRAINAGE TEXTURE

Drainage texture is the total number of stream segments of all order in a river basin to the perimeter of the basin. It depends on a variety of factors and can provide information on underlying materials and indirectly on structure. The unit of drainage texture is km-1. The classification of drainage density is based on the number of stream segments per unit area. Researchers have classified five different drainage textures related to various drainage densities as very coarse (below 2), coarse (2 -4), moderate (4 - 6), fine (6 -8) and very fine (8 and above). Now, if we observed the basin area specifically then we see that the eastern and south-eastern part of the basin have highest drainage texture which is above 0.87 or near 2. The Drainage texture reduced from eastern to western region in that basin area. We observe that in the north and north-western area of the basin have less than 0.5. Also, in the mid part of the basin we observe same pattern of that parameter.



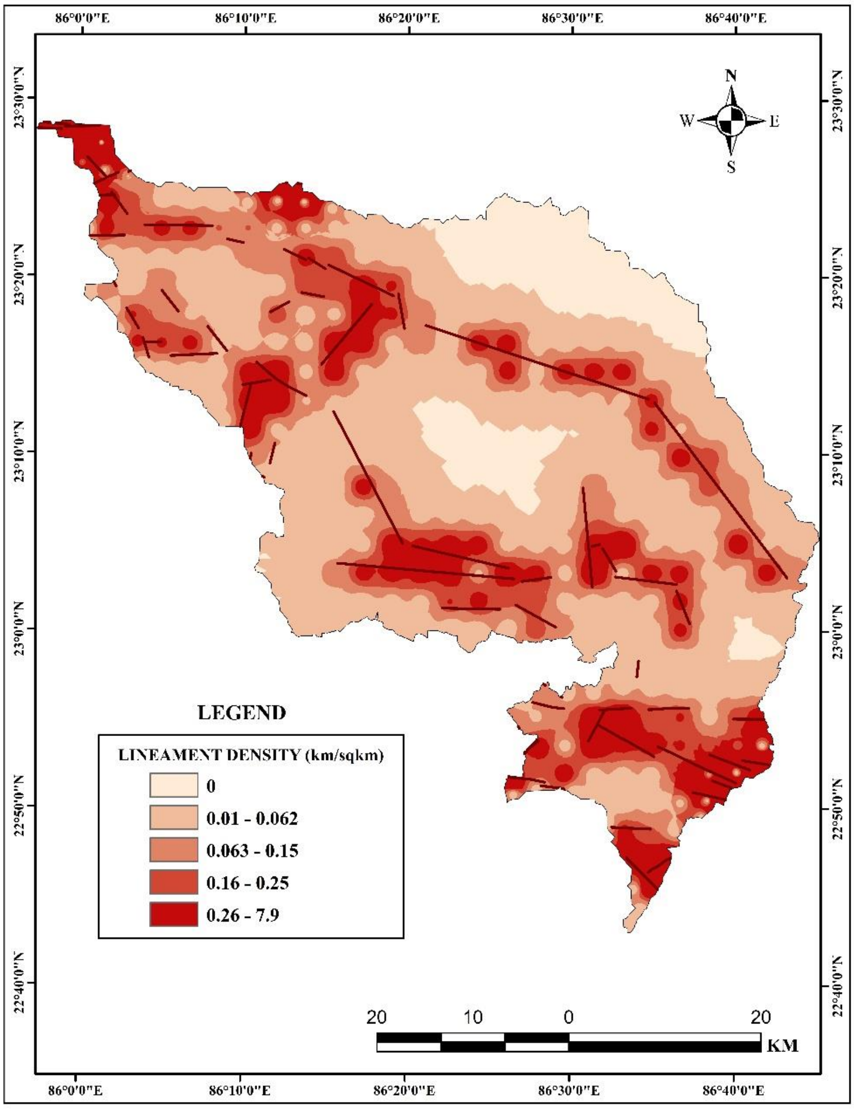
GEOMORPHOLOGY

Geomorphological landforms of a river basin include the drainage basin or watershed which is a fundamental landscape unit in fluvial geomorphology. A drainage basin contains a primary, or trunk, river and its tributaries. Watersheds are separated from their neighbours by a divide; a highpoint where water flows in different directions on either side. Other landforms include glacial and fluvial landforms. Now, if we observed the geomorphological landforms of the basin area specifically then we see that the 85% area covered by Denudational & Fluvial Origin. In some minimal area of eastern region of the basin covered by Anthropogenic Origin. Other than the Rivers and Water bodies (some parts of western and southern part of the basin) covered the basin area.



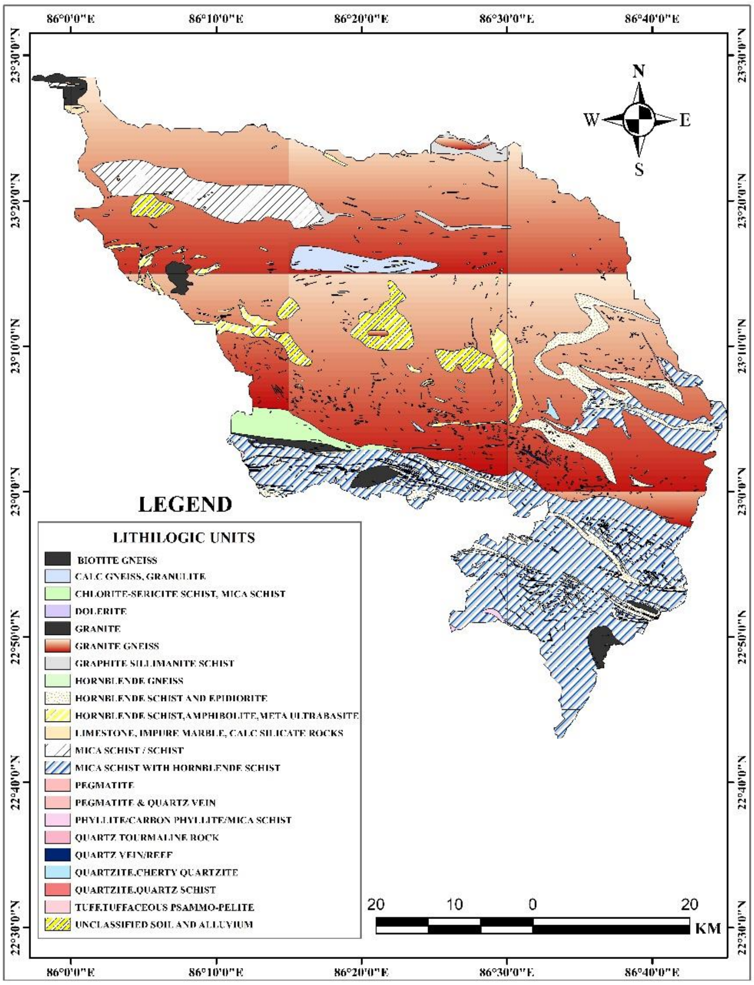
LINEAMENT DENSITY

Lineament density is a measure of the density of lineaments in an area. The presence of lineaments usually denotes a permeable zone, and areas with high lineament density are good for groundwater potential zones. Lineament density can be calculated by dividing the total length of lineaments in a grid by the area of the grid, and then plotting the values on a lineament density map using GIS software. For instance, in one study, lineament density was found to be directly proportional to groundwater potential. Areas having a lineament density between 0.2 and 0.25 km/km2 were considered as excellent groundwater prospect zone covering about 3.49% of the landscape. We observe highest lineament density in north-western and south-eastern part of the drainage basin which is greater than 0.15 km/sqkm. The north-east area and some area of the middle part of the basin of the basin show lowest lineament density which is near of 0. We recognize the densest areas as a most groundwater potential area.



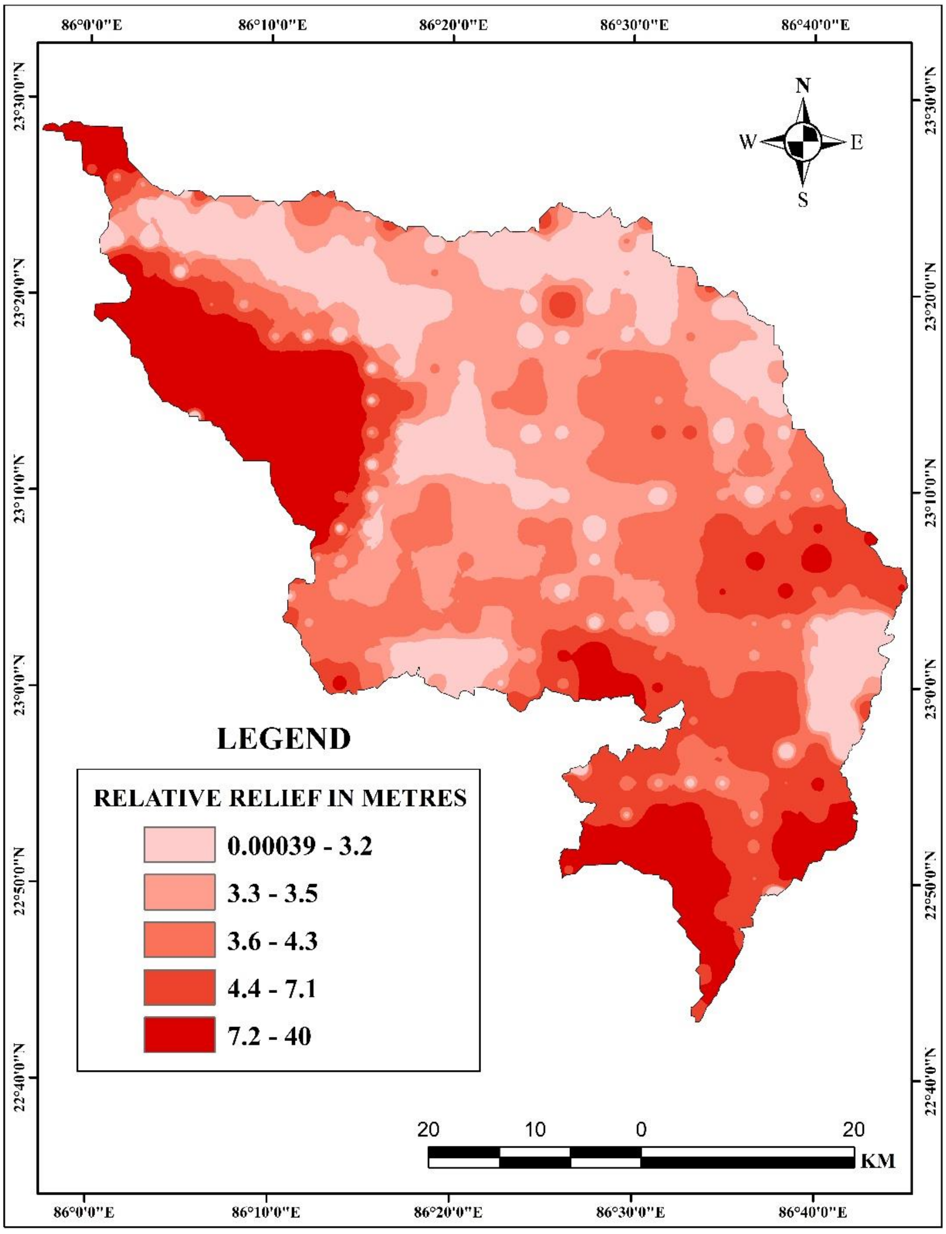
LITHOLOGY

Lithology is a branch of earth sciences that describes the **physical characteristics** of a unit of a rock on Earth's crust, such as colour, texture, grain size, and composition. Lithology is different from geology, which is the study of the structure, history, and processes of the Earth. Lithology is important for mapping and correlating rock sequences, as well as understanding their permeability and water absorption. So, if we observe the basin area, we see that the most of the area of the basin was made by Granite Gneiss rock. That Granite Gneiss cover more than 50% area of that basin. In southern part of the basin, we mainly observe the Mica Schist with Hornblende Schist. Also, in southern part we observe some Granite, Hornblende Schist and Epidiorite. In north-western part of the basin, we observe Mica Schist/Schist, Biotite Gneiss in a vast area. We observe Hornblende Schist, Amphibolite, Meta Ultrabasite and Calc Gneiss, Granulite and Unclassified Soil, Alluvium rock type in central area of the basin. Some smaller areas are covered by different types of Quartz and Quartzite in the basin. Some smaller areas of northern part of the basin are covered by Graphite Sillimanite Schist.



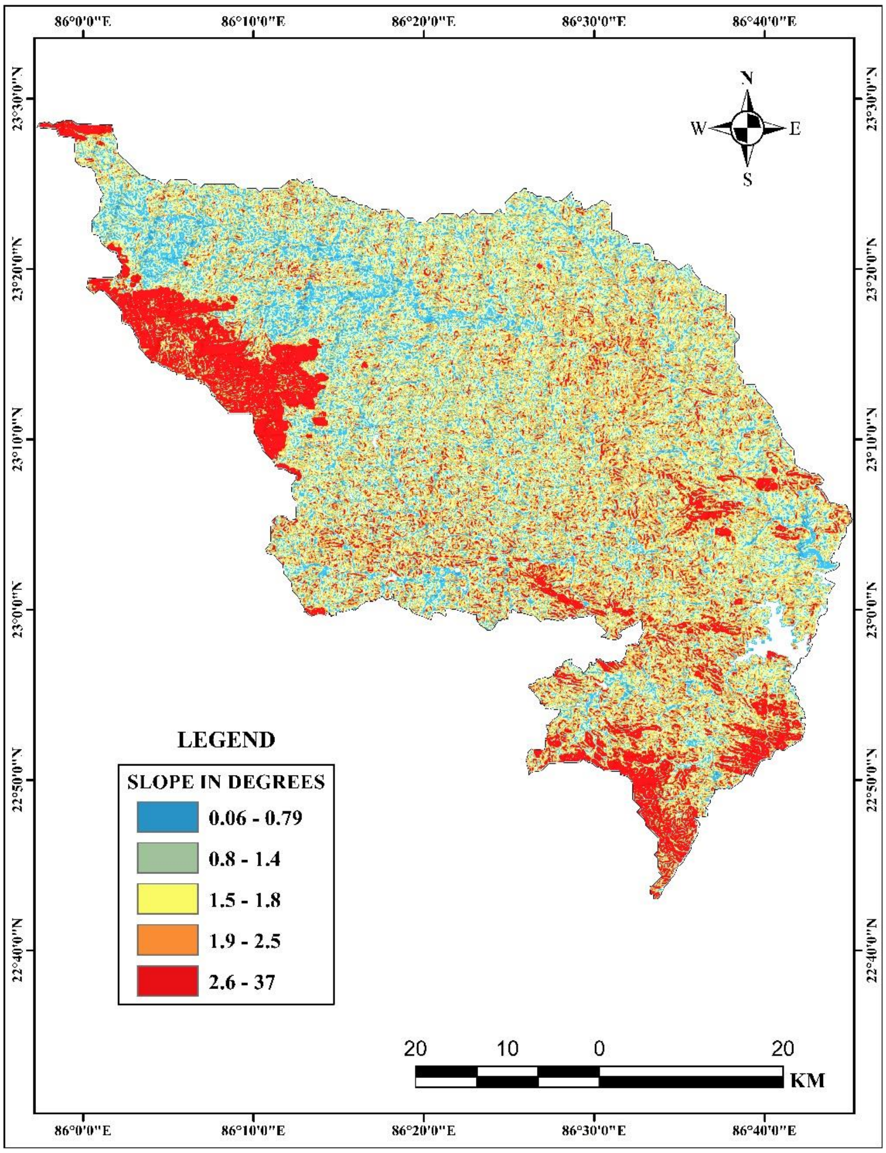
RELATIVE RELIEF

Relative relief is the actual variation of altitude in a unit area with respect to its local base level. It represents the difference in height between the highest and the lowest points in a determined surface grid area. Relative relief is a measure of the difference in elevation between the highest and lowest points in a given area. It is calculated by subtracting the lowest elevation from the highest elevation and dividing the result by the area of the region. The formula for relative relief is: relative relief = (highest elevation - lowest elevation) / area. In that drainage basin we observe that the north-western and south, southern-eastern area have higher relative relief ratio which is much than 7 metres. So, we observe the relative relief reducing from west to north, north-east region of the basin.



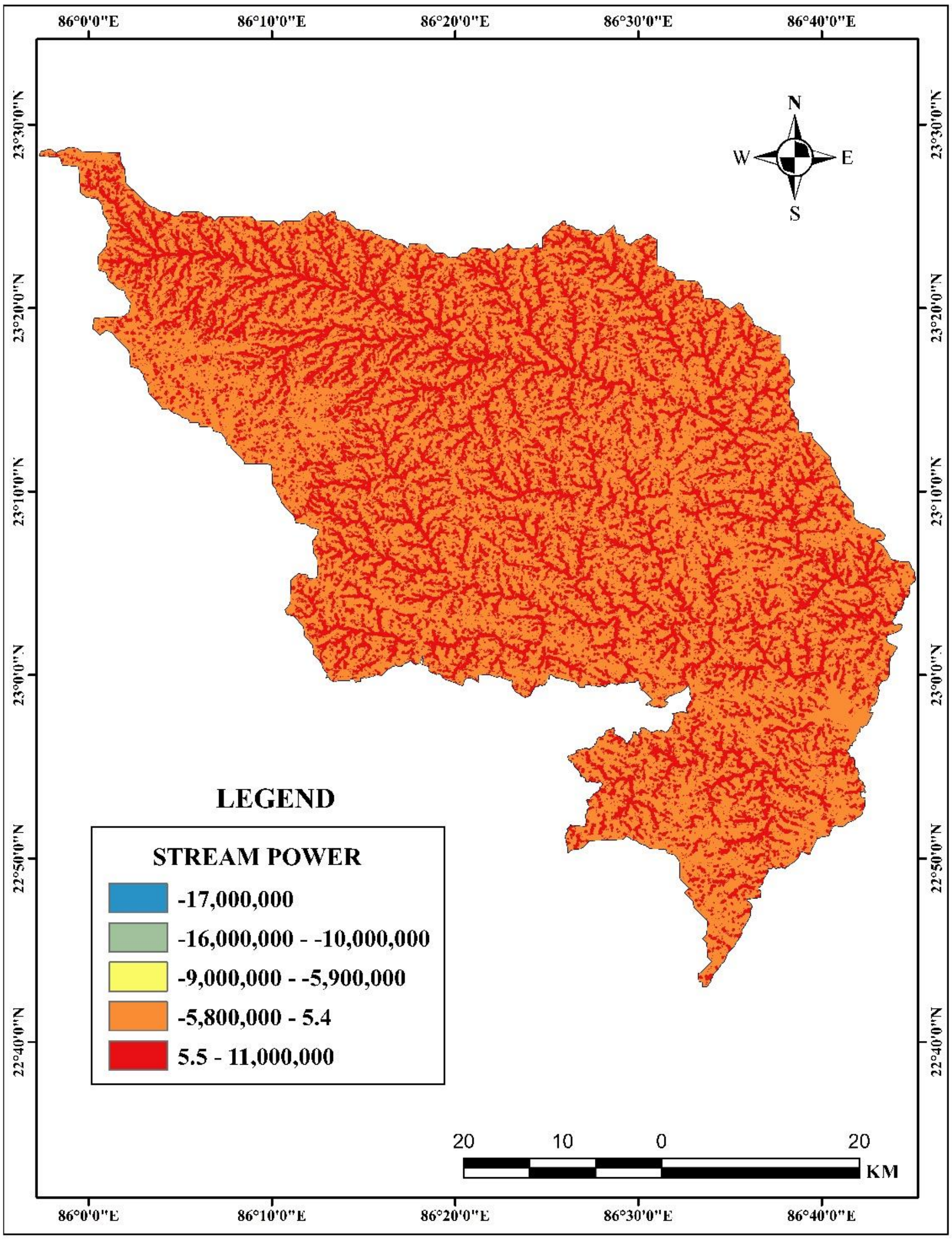
SLOPE

The slope of a drainage basin depends on the type of surface or pipe and the desired flow rate. For paved surfaces, a slope of one percent is fine, but for yards, a slope of two percent is recommended. For drain or sewer lines, a slope of 1/4 inch per foot or two percent is recommended, as too flat or too steep slopes can cause clogs. For French drains, a slope of 1/8 inch per foot or one percent is usually enough. Wentworth's method of slope analysis is a technique used to determine the average slope of any region. It was given by Wentworth C.K. in 1922. The method involves dividing the area into a number of equal parts and then calculating the slope of each part. The average slope is then calculated by adding up all the slopes and dividing by the number of parts. In that drainage basin we observe that the north-western and south, southern-eastern area have higher degrees of slope which is much than 2.5 degrees. That indicates, those areas of the basin are highland regions.



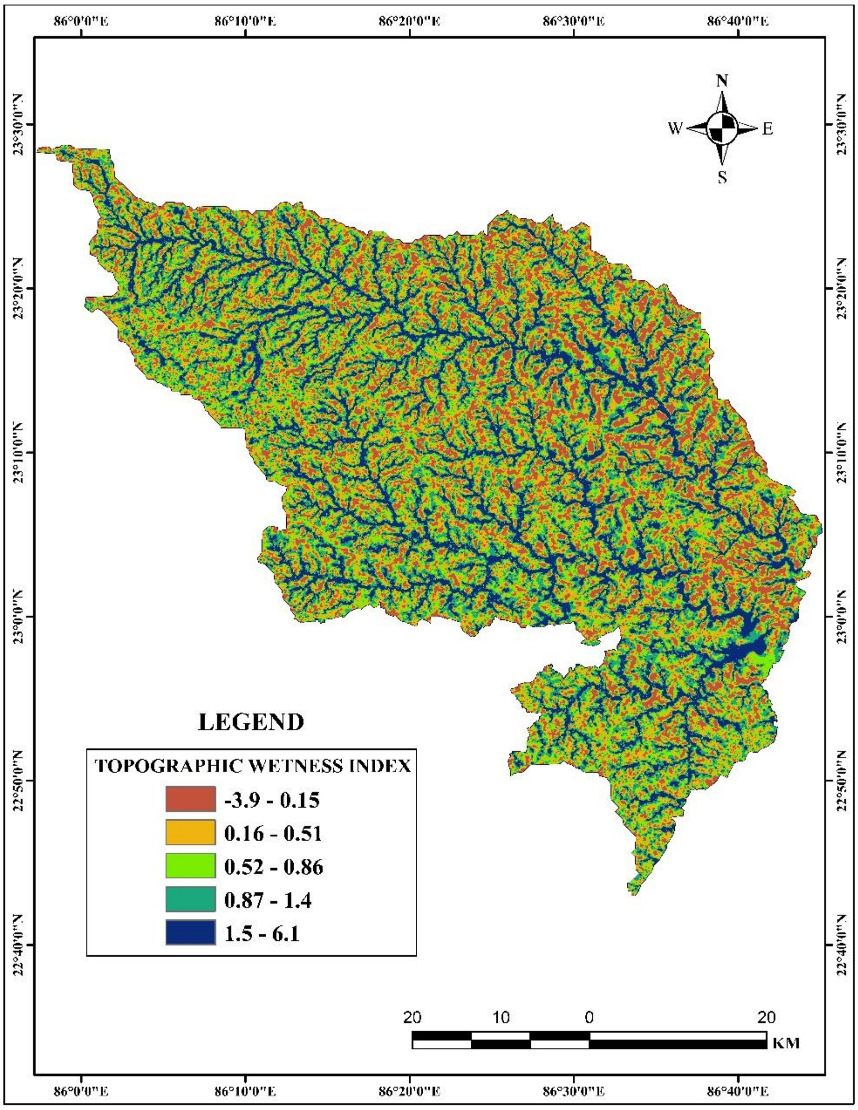
STREAM POWER

Stream power is the rate of energy expended by a river per unit of channel length. It is calculated as the product of the water discharge and the slope of the stream channel. The drainage basin is the area from which a stream receives runoff, throughflow, and its saturated equivalent, groundwater flow. Stream power is the rate of energy dissipation against the bed and banks of a river or stream per unit downstream length. It is given by the equation: $\Omega = \rho g Q S$, where Ω is the stream power, ρ is the density of water (1000 kg/m^3), g is acceleration due to gravity (9.8 m/s^2), Q is discharge (m^3/s), and S is the channel slope.



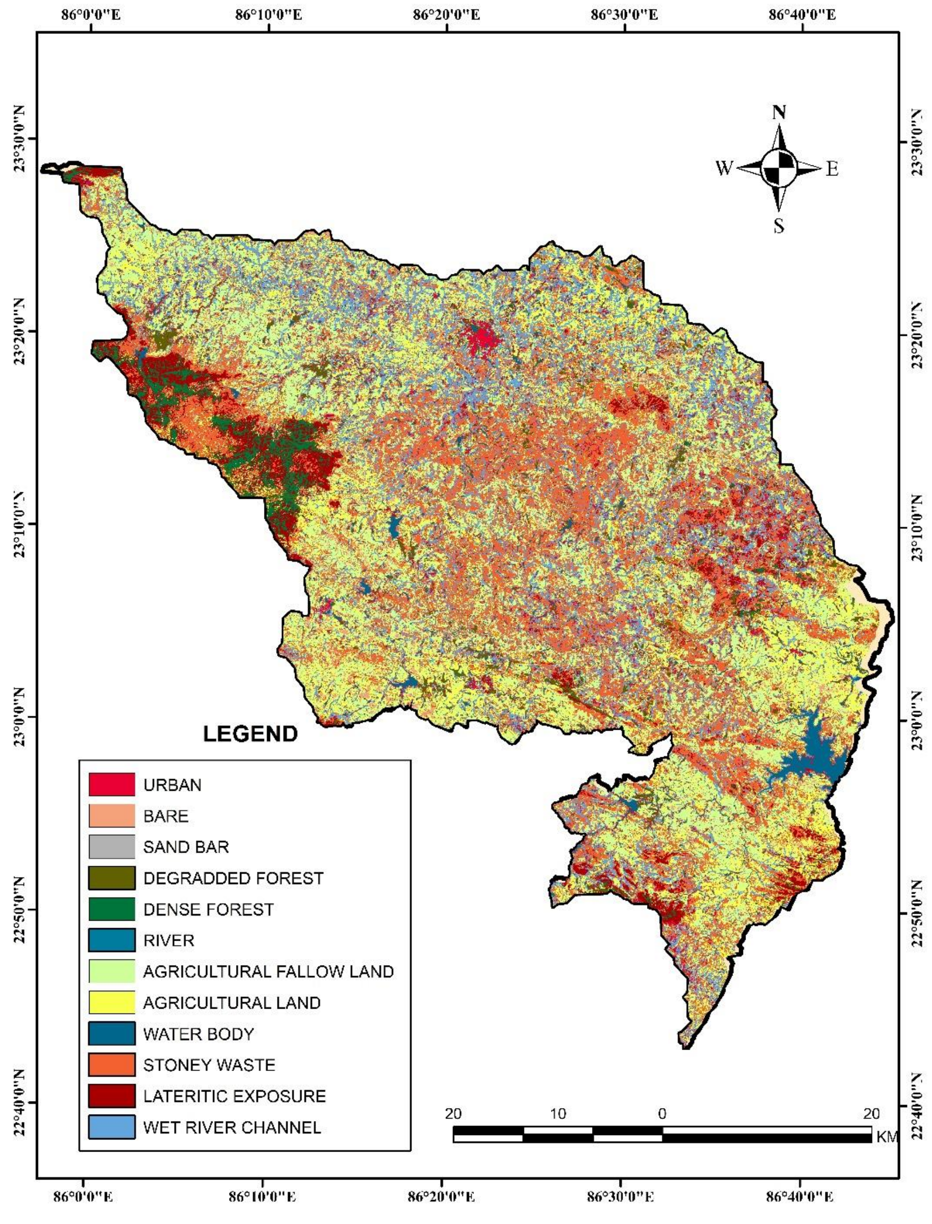
TOPOGRAPHIC WETNESS INDEX

The topographic wetness index (TWI) is a steady state wetness index that quantifies topographic control on hydrological processes. It is a function of both the slope and the upstream contributing area per unit width orthogonal to the flow direction. It describes the tendency of an area to accumulate water. Concave, low gradient areas have low TWI values, whereas steep, convex areas have high TWI values. To calculate the TWI from the digital terrain model, terrain sinks and flat pixels should be removed first, and then total catchment area, flow width and slope for each pixel should be calculated. Here we observe higher topographic wetness index value from there where the rivers and streams flows. The waterbodies have higher wetness index value which are above 1.5. The drier regions have negative value of wetness index. River and stream valleys show high index scenario. If we north, north-east part of the basin we see that part is much drier than south, north-west areas of the basin.



LAND USE AND LAND COVER

Land use and land cover mapping is a process of identifying, analysing and classifying the land surface into different categories based on various factors such as vegetation cover, soil type, water bodies, etc. It is an important tool for natural resource management and planning. A land use and land cover map of a drainage basin is a map that shows the different types of land use and land cover in a particular drainage basin. It can be used to identify areas that are vulnerable to soil erosion, sedimentation, and other environmental problems. The map can also be used to identify areas that are suitable for different types of land use such as agriculture, forestry, or urban development.



CHAPTER-6: ANALYSIS AND RESULTS

- ## ANALYSIS OF MORPHOMETRIC PARAMETERS

- **LINEAR OARAMETER**

i) **Stream order (U) and Stream number (N):** The stream order is a measure of degree of stream branching within a watershed. In the study area the highest order obtained is 6th order and hence designated as 6th order watershed. Each segment of the stream was numbered starting from the first order to the maximum order present in each of the sub-basins. After numbering, the drainage-network elements are assigned their order numbers, the segments of each order are counted to yield the number Nu of segments of the given order u.

ii) **Main Stream length (Lu):** Length of the stream is an indicator of the area contribution to the watershed, steepness of the drainage watershed as well as the degree of drainage. Steep and well drained areas generally have numerous small tributaries; whereas, in plains, where soils are deep and permeable, only relatively long tributaries (generally perennial streams) will be in existence. Thus, this factor gives an idea of the efficiency of the drainage network. Generally, the total length of the stream segments decreases with stream order. Deviation from its general behavior indicates that the terrain is characterized by high relief and /or moderately steep slopes, underlying by varying lithology and probable uplift across the watershed.

iii) **Length of over land flow (Lg):** Length of overland flow is the flow of water over the surface before it becomes concentrated in definite stream channels. The length of overland flow is a measure of erodibility and is one of the independent variables affecting both the hydrologic and physiographic development of the drainage watershed. Horton (1945) defined the length of overland flow as the length of flow path, projected to a horizontal plane of the rain flow from a point on the drainage divide to a point on the adjacent stream channel. The shorter the length of overland flow, the quicker the surface runoff from the streams.

iv) **Bifurcation ratio (Rb):** This is the universal value for maturely dissected drainage basins (Rao and Babu, 1995). The number of stream segments of any given order will be fewer than for the next lower order but more numerous than for the next higher order. According to Strahler (1957), in a region of uniform climate and stage of development, the Rb tends to remain constant from one order to next order. The irregularities of the drainage watershed depend upon lithological and geological development, leading to changes in the values from one order to the next. An elongated watershed has higher Rb than the circular watershed.

Linear Morphometry –

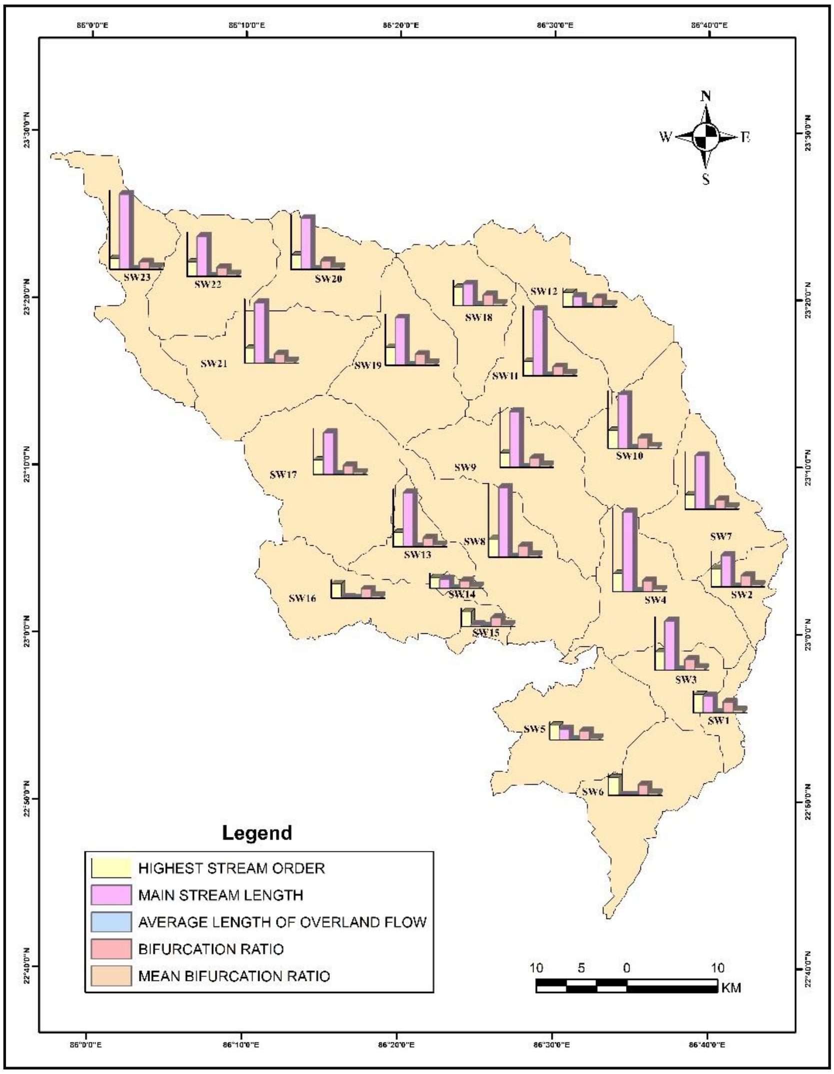
Highest Stream Order – Here we observe Highest Stream Order in SW1,2,3,4,6,8,10,18,19 which is 5 number of streams and lowest in SW14,23 which is 3 number of streams.

Main Stream Length – In that basin we observe highest Main Stream Length in SW4 which is 22.11 kms and lowest in SW6 which is 0.06 kms.

Average Length of Overland Flow – In that basin we observe highest Average Length of Overland Flow in SW17 which is 0.0488 kms and lowest in SW14 which is 0.0022 kms.

Bifurcation Ratio – In that basin we observe highest Bifurcation Ratio in SW1,2,3,4,6,8,10,18,19 which is 3.0 and lowest in SW14,23 which is 2.0.

Mean Bifurcation Ratio – In that basin we observe highest Mean Bifurcation Ratio in SW1,2,3,4,6,8,10,18,19 which is 0.6775 and lowest in SW14,23 which is 0.58.



- **AREAL PARAMETERS**

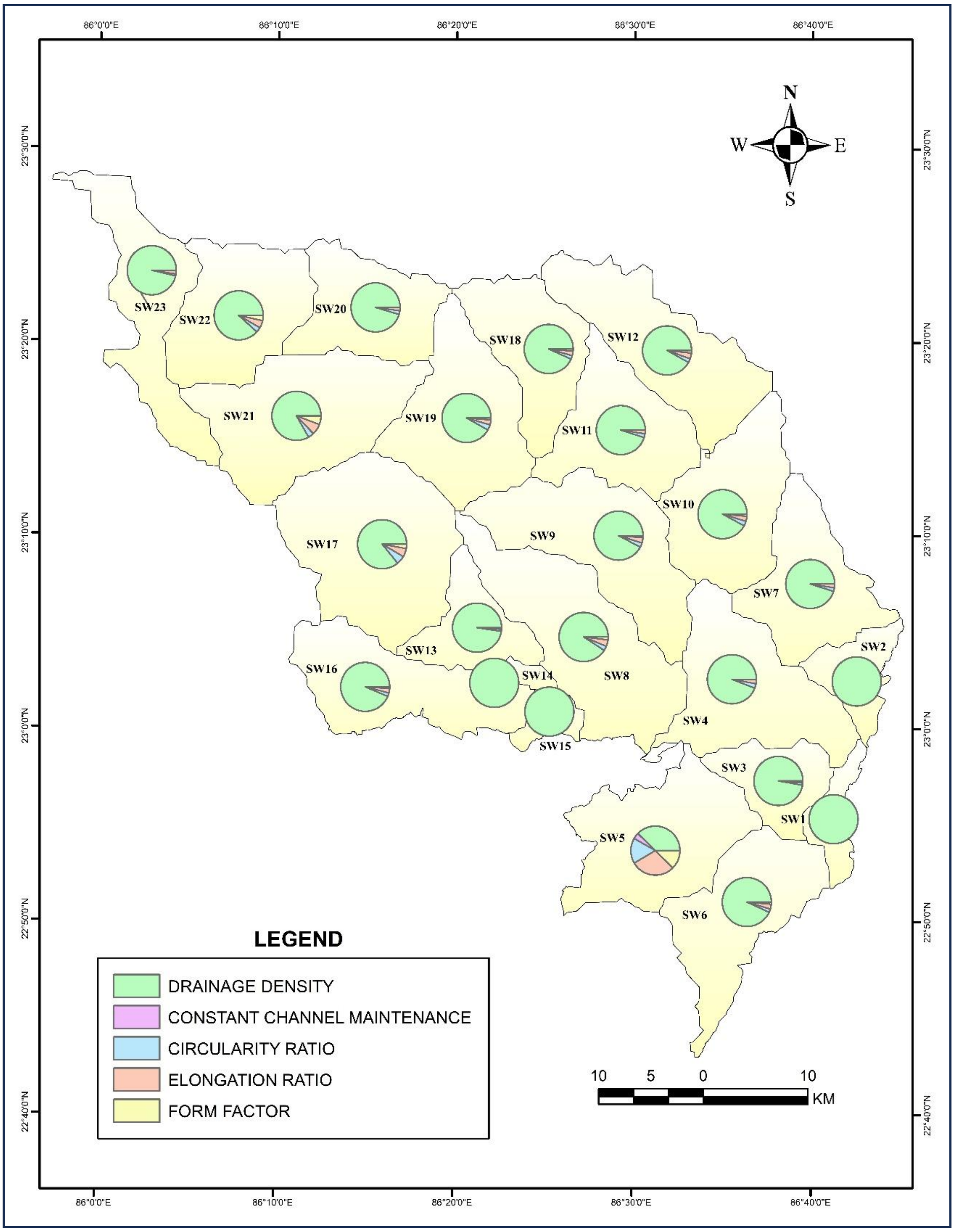
i) **Form factor (Ff):** The value of form factor would always be greater than 0.78 for a near perfect circular watershed. Smaller the value of the form factor, more elongated will be the watershed.

ii) **Circularity ratio (Rc):** Greater the value more is the circularity ratio. It is the significant ratio which indicates the stage of dissection in the study region. Its low, medium and high values are correlated with youth, mature and old stage of the cycle of the tributary watershed of the region. The Rc value of 0.4 and below indicates basin is elongated and values greater than 0.75 indicate circular basin. Rc values in 0.4-0.75 indicate intermediate shape of basin. Miller (1953) has described the basin of the circularity ratios range 0.4 to 0.5, indicates highly permeable homogenous geologic materials present in the area. The circularity ratio value (0.44) of the watershed corroborates the Miller's range, which indicates that the watershed is elongated in shape, low discharge of runoff and highly permeability of the subsoil condition.

iii) **Drainage density (Dd):** Dd is the other element of drainage analysis which provides a better quantitative expression to the dissection and analysis of land forms, although a function of climate, lithology, structures and relief history of the region and can ultimately be used as an indirect indicator to explain those variables, as well as the morphogenesis of landform. Drainage density is defined as the total length of streams of all orders to total drainage area. The drainage density, which is expressed as km/km2, indicates a quantitative measure of the average length of the overland flow, and therefore, provides at least some indication of the drainage efficiency of the Low drainage density generally results in the areas of highly resistant or permeable sub-soil material, dense vegetation and low relief. High drainage density is the result of weak or impermeable sub-surface material, sparse vegetation and mountainous relief. Low density leads to coarse drainage texture while high drainage density leads to fine drainage texture. The low value of drainage density influences greater infiltration and hence the wells in this region will have good water potential leading to higher specific capacity of wells. In the areas of higher drainage density, the infiltration is less and surface runoff is more. The drainage density can also indirectly indicate groundwater potential of an area, due to its surface runoff and permeability.

iv) **Constant of channel maintenance (Cm):** It indicates the number of Sq.km of watershed required to sustain one linear km of channel. It not only depends on rock type permeability, climatic regime, vegetation, relief but also as the duration of erosion and climatic history. The constant is extremely low in areas of close dissection.

v) **Elongation ratio (Re):** Lesser the value more is the elongation of the watershed. Strahler (1952) states that the ratio of Re runs between 0.6-1 over a wide variety of climatic and geologic types. Re Value of 1 are found in typical regions of low relief, while values from 0.6- 0.8 are generally associated with strong relief and steep ground slopes.



Areal Morphometry –

Drainage Density – Here we observe highest Drainage Density in SW14 (Sub Watershed) which is 218.65 km/sqkm and lowest in SW5 which is 0.70 km/sqkm.

Constant of Channel Maintenance – In that basin we observe highest Constant of Channel Maintenance in SW17 which is 0.097 sqkm/km and lowest in SW14 which is 0.004 sqkm/km.

Circularity Ratio – In that basin we observe highest Circularity Ratio in SW17 which is 0.68 and lowest in SW23 which is 0.23.

Elongation Ratio – Here we observe highest Elongation Ratio in SW21 which is 1.01 and lowest in SW1 and SW13 which is 0.34.

Form Factor – In that basin we observe highest Form Factor in SW21 which is 0.80 and lowest in SW1 and SW13 which is 0.09.

- **RELIEF PARAMETERS**

i) **Relief ratio (Rf):** Rf is the ratio of maximum watershed relief to the horizontal distance along the longest dimension of the watershed parallel to the principal drainage line (Schumm, 1956). It measures the overall steepness of a watershed and is an indicator of the intensity of erosion processes operating on slopes of the watershed.

ii) **Relative relief Ratio (Rp):** The relative relief is the ratio of basin relief (H) to the length of the perimeter (P). It is an indicator of general steepness of the basin from summit to mouth.

iii) **Total relief (H):** Total relief (H) is the maximum vertical distance between the lowest (outlet) and the highest (divide) points in the watershed. Relief is an indicative of the potential energy of a given watershed above a specified datum available to move water and sediment down slope.

iv) **Ruggedness number (Rn):** High values of the Rn in the watershed are because both the variables like relief and drainage density are enlarged. Extensively high value of ruggedness number occurs for a high relief region with high stream density.

Relief Morphology –

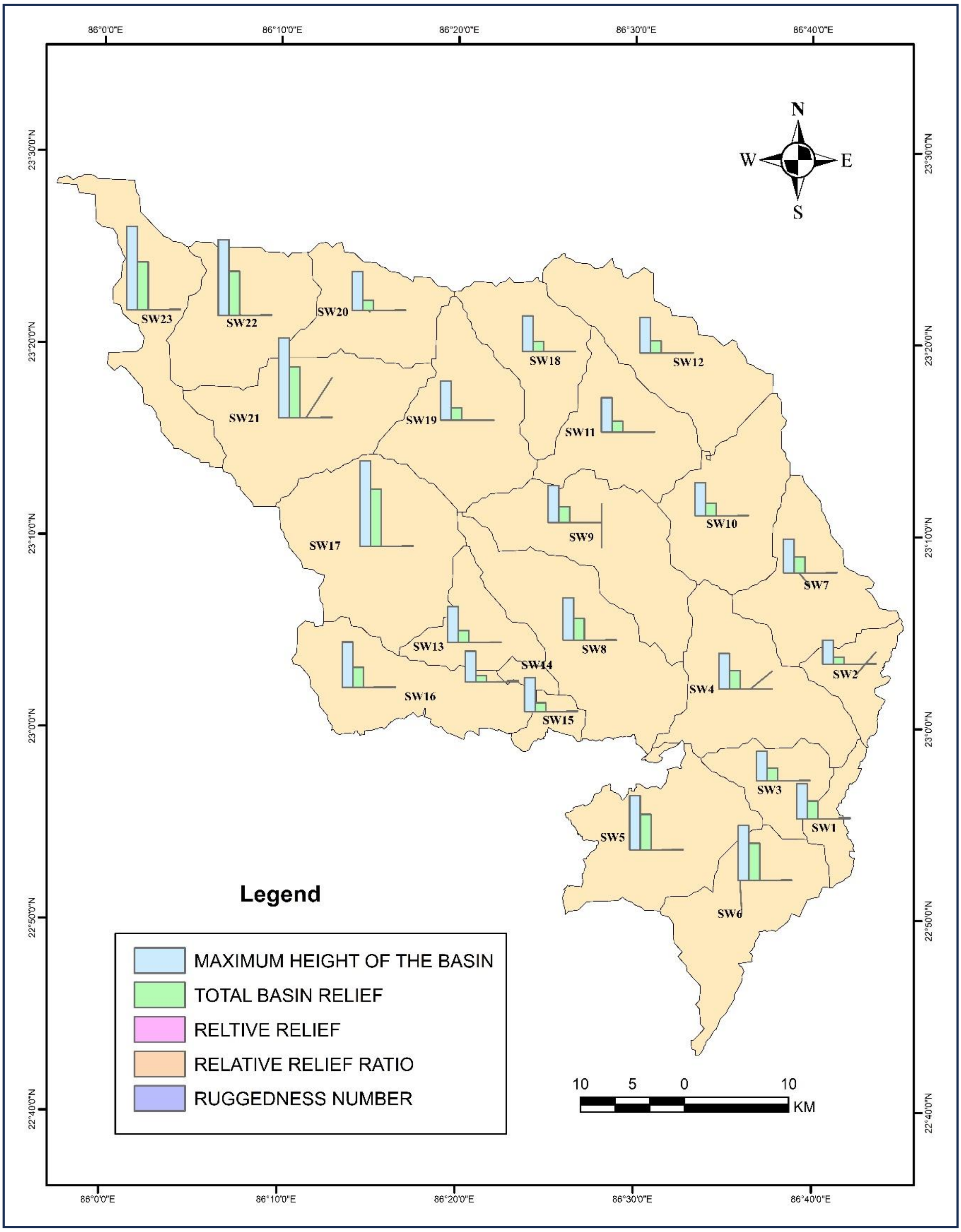
Maximum Height of the Basin – In that basin we observe highest Maximum Height of the Basin in SW17 which is 656 meters and lowest in SW2 which is 185 meters.

Total Basin Relief – Here we observe highest Total Basin Relief in SW17 which is 440 meters and lowest in SW14 which is 49 meters.

Relief Ratio – In that basin we observe highest Relief Ratio in SW21 which is 0.0249 and lowest in SW11,20 which is 0.0030.

Relative Relief Ratio – Here we observe highest Relative Relief Ratio in SW17 which is 0.68 and lowest in SW2,12 which is 0.13.

Ruggedness Number – In that basin we observe highest Ruggedness Number in SW14 which is 10.71 and lowest in SW12 which is 1.31.



CHAPTER-6: CONCLUSION

Morphometric analysis of River Basin is one of the most important aspects and study for watershed management. Dendritic Drainage pattern are found in both Kumari-chaka and Kumari-hanumata watersheds of Kumari River Basin. Calculation of bifurcation ratio is a good indicator of the structural development of drainage pattern. The higher value of bifurcation ratio of the study area indicates the structural disturbances to the drainage basin. The bifurcation ratio of the study area between 2 to 5 which indicates that the drainage network of the study area is well developed. The present study demonstrates the utility of Remote Sensing and GIS techniques in morphometric analysis and the significance of morphometric analysis in the geomorphological study.

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