Estimation among the Geomorphological Traits of Rapti River Basin Utilizing Geographic Technologies

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Abstract. This study used a combination of cutting-edge technology and tools, including remote sensing and geographic information systems (GIS), to ascertain the geomorphological features of the Rapti River basin. The watershed area, perimeter, stream order, basin length, mean stream length, bifurcation ratio, stream length ratio, form factor, drainage density, stream frequency, circularity ratio, elongation ratio, compactness coefficient, constant of channel maintenance, length of overland flow, etc. were among the various geomorphological characteristics found in the represent study. Studying geomorphology is crucial to comprehending how watersheds behave hydrologically. Measuring the drainage network's linear and shaped features as well as the contributing ground slopes can help with the morphometric study of a drainage basin and its stream system. Sub-watersheds could be prioritized using morphometric analysis by calculating linear and shape characteristics. The morphometric parameters of a watershed are useful in describing a watershed when there is a lack of extensive hydrological data. A basin's morphological feature reflects its characteristics, which can be used to combine hydrological response. When quantified and expressed in morphometric parameters, basin characteristics can be examined to see how they affect runoff. Surface runoff, infiltration, and erosion susceptibility within the basin can all be qualitatively assessed through the interpretation and quantitative analysis of five drainage parameters. We learned about the wide range of uses for geographic information systems, global positioning systems, remote sensing, and other instruments. GIS and remote sensing methods are widely used in NRM due to this application diversity. These approaches aren't used in case of Rapti basin which will help in better planning and management of resources of the basin.

Keywords: GIS, geomorphic studies, morphometric analysis, global positioning system, geospatial tools, watershed.

1 Introduction

Subsurface Water - The area from which rainfall-induced runoff is gathered and drained from a single outlet is known as a watershed. It is equivalent to a catchment region or drainage basin. A watershed might span hundreds of square kilometres for rivers, or just a few hectares for small ponds. There are smaller sub watersheds within every watershed. Many bodies of water, such as rivers, ponds, lakes, and the sea, gather the water that drains from the watershed. These bodies of water provide water for manufacturing, agriculture, and drinking, provides a habitat for a variety of flora and animals in addition to recreational activities. Each

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and every one of us depends on the water that flows through our watershed. For this reason, the watershed is essential to every human being's existence. [7,5]

The classification of watershed is given as below:

**Table 1. System of classification of watershed in India**

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Hydrologic Units Category</th>
<th>Size range ('000 ha)</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Water Resources Region</td>
<td>25-100</td>
<td>6</td>
</tr>
<tr>
<td>2</td>
<td>Basins</td>
<td>3-25</td>
<td>35</td>
</tr>
<tr>
<td>3</td>
<td>Catchments</td>
<td>1-3</td>
<td>112</td>
</tr>
<tr>
<td>4</td>
<td>Sub-catchments</td>
<td>0.2-1</td>
<td>500</td>
</tr>
<tr>
<td>5</td>
<td>Watersheds</td>
<td>0.050-0.2</td>
<td>3237</td>
</tr>
<tr>
<td>6</td>
<td>Sub-Watershed</td>
<td>0.010-0.050</td>
<td>12000</td>
</tr>
<tr>
<td>7</td>
<td>Mini-Watershed</td>
<td>0.001-0.010</td>
<td>72000</td>
</tr>
<tr>
<td>8</td>
<td>Micro-Watershed</td>
<td>0.0005-0.001</td>
<td>400000</td>
</tr>
</tbody>
</table>

Rainfall, which falls on the outermost layer of the planet and splits into various phases known as runoff, is the source of water. Runoff is greatly influenced by the characteristics of the watershed such as size, shape, slope, length, frequency, and type of soil, drainage density, and time of watershed concentration. Runoff is also influenced by other factors such as type of precipitation, intensity, duration, and distribution of rainfall. All of these elements are essential for managing watersheds because they enable a thorough grasp of the geometry of the basin. [7,11]

The programs' goals for watershed management are –

- To prevent harmful discharge.
- To control runoff and make use of it for beneficial purposes.
- To lessen the severity of floods in places downstream.
- When appropriate, to improve groundwater storage.
- Make sure that land resources are used appropriately and that resources for forests and fodder are developed.
- Watershed development presents a multitude of opportunities for the farmer's community and the following areas.
- Better conservation of natural resources; less flooding and water logging; appropriate use of rainwater, with excess water conserved for supplemental use.
- A steady supply of water for both industrial and residential use.
According to the 1971 National Commission on Agricultural Research, current water supplies, which come from big and small projects, cannot be used to irrigate significantly more than 40% of India's cultivable area. For the remaining 60% of the area, crop water may only be available from the monsoon rains. According to recent studies, crops can get one or two life-saving irrigations during dry spells, and the excess water collected as runoff during monsoon seasons can significantly boost crop yield. This calls for the creation of a water collection method that could be used in a tiny watershed. If appropriate steps for conserving water and soil are taken and new practice packages are implemented, this watershed area ought to have a high level of production potential. In order to maximize productivity while minimizing risks to natural resources, effective management of a watershed requires the usage of a variety of factors, including land, water, soil, land cover, and natural resources. In order to investigate the geomorphological features of a chosen watershed, gathering data is a crucial aspect of the research process. The typical technique of collecting data is time-consuming, labour-intensive, and not cost-effective. The traditional approach to gathering data is likewise skewed and yields results slowly. Digitizers and computer programs like GIS (Geographic Information System) are utilized these days to determine features. Modern geospatial technology is crucial to the management of watersheds. The science of obtaining data about an object via measurements taken without the sensor actually coming into contact with it is known as remote sensing. The sensor, which records the energy reflected from the object on Earth as electromagnetic waves across the whole spectrum, could be cameras or another type of energy measurement device. Due to the item's distinctive spectral response, it has its own "signature" within a specific spectral bandwidth. Therefore, the degree of confidence in recognition can be significantly increased by separating this number of spectral bands and obtaining the signature uniqueness and response individually. The sensors are fixed to a satellite or an airplane. Because satellites are repeating, they offer multi-spectral and synoptic coverage in the form of sequential images, allowing us to assess natural resource management strategies for maximum effectiveness. It also assists us in keeping track of and assessing the development initiatives that have been or will be implemented in the watershed. Over the past three decades, one of the most exciting things to study has become the science of remote sensing. It has been of significant scientific value to extract data regarding geophysical characteristics from the satellite seen field using suitable models. Earth observation research has risen to the forefront of scientific endeavours thanks to geospatial tools like the Geographic Information System (GIS), sophisticated image processing techniques, the Global Positioning System (GPS), and robust computing systems. In order to determine landscape attributes, it is crucial to use the Digital Elevation Model (DEM). A GIS database's ability to incorporate ground truth data can save money, time, and enhance the amount of precise information obtained for soil surveys. [7.3, 7.6]

Studying geomorphology is crucial to comprehending how watersheds behave hydrologically. Measuring the drainage network's linear and shaped features as well as the contributing ground slopes can help with the morphometric study of a drainage basin and its stream system. Sub watersheds could be prioritized using morphometric analysis, which computes linear and shape characteristics. When describing a watershed in the lack of extensive hydrological data, the morphometric parameters of the watershed are useful. A basin's morphological feature embodies its characteristics, which can be utilized to combine hydrological response. The impact of basin characteristics on runoff can be investigated when quantified and expressed in morphometric parameters. Therefore, a straightforward and practical method to mimic the hydrologic behaviour of different basins can be developed by connecting the morphologic factors with the hydrological features of the basin. Surface runoff, infiltration, and erosion susceptibility within the basin can all be
qualitatively assessed through the interpretation and quantitative analysis of different drainage parameters. [7.9]

The following goal guides the morphometric research of the Rapti basin in the previously described context:

Utilizing geospatial technologies to ascertain the Rapti River Basin's geomorphological features

2 LITERATURE REVIEW

Narendra Kumar Rana studies on Flood plain management in Rapti River Basin in (Jan 2015) Floodplains are extremely valuable resources. They are the lowlands that border lakes, seas, and other bodies of water, as well as the channels of rivers, streams, and other watercourses. Four broad categories of operations make up the common framework for managing floodplains: reducing floods, reducing susceptibility to flooding, reducing the effect of flooding, and maintaining the floodplains' advantageous and natural functions. After providing an overview, this chapter examines the problems associated with managing the floodplain of the Rapti River, which flows through eastern Uttar Pradesh. The Rapti River Basin is notable for its frequent flooding, both in general and in specific areas where exceptional flooding occurs. The report recommends using performance metrics to assess floodplain control initiatives' effectiveness and progress.

Rocky Talchabhadel, Hajime Nakagawa Kenji Kawaike, Rajaram Prajapati studies on Numerical simulation of inundation process of a heavy precipitation event: A case study of August 2014 in west Rapti river basin Nepal in (Aug 2020) In these isolated areas, there is a gap of more than one kilometer between two neighboring spot heights. Based on a shallow water equation, the flood simulation model (Talchabhadel, Nakagawa, Kawaike, Yamanoi, et al. 2020) is a two-dimensional unsteady flow model. Next, we employed a distinct DEM for every instance. The calibrated inundation propagation model was finally simulated (Talchabhadel, Nakagawa, Kawaike, Yamanoi, et al. 2020).

Buddhi Raj Shrestha Raj Kumar Rai saroj Marasini studies review of flood hazards in Nepal in (Jan 2021) in Nepal, flooding is a recurrent event that is mostly caused by water during the monsoon season. Along with having a negative influence on the country's essential infrastructure, it results in several deaths and injuries. This study examines journal articles from both domestic and foreign publications that discuss mapping flood hazards in Nepal. Nepal's Bagmati and Province 2 are more affected than other provinces, according to the Desinventar database from 1971 to 2016. Here, we examine earlier research on flood disasters on a regional and national scale. The findings indicate that the majority of the studies focus more on hazard analysis than vulnerability and risk assessment, with a steady flow model serving as the foundation for inundation mapping.

Rocky Talchabhadel, Hajime Nakagawa Kenji Kawaike, Rajaram Prajapati studies Appraising the potential of using satellite-based rainfall estimate for evaluating extreme precipitation: A case study of August 2014 event across the west Rapti river basin, Nepal in (Aug 2021) Every year, Nepal has heavy precipitation events that have an
impact on life and property, particularly during the summer monsoon season (June to September). We looked into an August 2014 severe (heavy) precipitation event that occurred across Nepal's West Rapti River (WRR) Basin. First, we used hourly rainfall data from nine stations that were gauged and ground-based to build a rainfall-runoff model. Second, we verified against the hourly water level at a WRR Basin outflow. The effectiveness of various satellite-based rainfall estimates (SRES) in capturing an extreme precipitation event was then assessed in this study. We took into consideration the use of hourly data from PERSIANN with a spatial resolution of 25 km and PERSIANN-CCS with a spatial resolution of 4 km, as well as half-hourly data from IMERG (Early, Late, and Final versions) with a spatial resolution of 10 km. Additionally, we employed 3-hour real-time (3B42RT) TMPA product data with a 25-kilometer geographical resolution. Overall, the gauge data on a daily scale revealed a similar pattern of extreme precipitation for all of the examined SRES. On a sub-daily scale, we discover that these items could not precisely replicate. All things considered, IMERG and TMPA outperformed PERSIANN and PERSIANN-CCS. Lastly, we used the information from well-performed SRES to fill in data gaps for gauge rainfall and rectified poorly-performed SRES in relation to gauge data. Our research shows that using SRES for high-temporal resolution local flood modeling in Nepal is a significant problem.

NAT HAZARDS, Amrit P Sharma, Xudong Fu, Kattle studies Is there a progressive flood risk management in Nepal? A synthesis based on the perspective of a half century (1971–2020) flood outlook in (Jun 2023) Floods are one of the most frequent and dangerous natural disasters. In many mountainous areas, anthropogenic climate change has made them more severe, which has affected socioeconomic situations in the twenty-first century. The study compiled flood loss data from the previous 50 years (1971–2020), created spatial maps of flood loss by district, and investigated any gaps in flood loss mitigation due to Nepal Himalaya's varied topography through literature reviews. In Nepal, over 300 families have been impacted by disasters on a daily basis over the past 50 years, with an average of two deaths per day from them altogether. Just the flood catastrophe component revealed 11.43% of flood incidents, 9.33% of fatalities, 38.42% of missing persons, 0.75% of injuries, 61.60% of suffering for families, and 10.16% of property damages. In the post-2000 era, the frequency of floods has climbed to over six times the amount that occurred in the 1970s, resulting in four times as many fatalities as before. Although the flood loss acknowledges the increase in population, the incremental rate has been determined to have decreased to nearly half. District-specific spatial maps of flood loss show that Jhapa has seen the greatest number of flood events, while the districts of Sarlahi, Surkhet, Chitwan, Mahottari, Sunsari, and Bardiya have seen the greatest numbers of fatalities, injuries, and suffering among families, as well as full and partial damages to privately owned homes. Despite the implementation of proactive laws, our research revealed no improvement in flood loss, suggesting that Nepal's comprehensive flood risk management has not advanced.
3 STUDY AREA & COLLECTIONS

3.1 STUDY AREA

The West Rapti, also known as the Kuwano, is a river that drains the Rapti Zone in the Mid-Western Region of Nepal, the Awadh and Purvanchal regions of the state of Uttar Pradesh, and ultimately India. It flows into the Ghaghara. It is a major Ganges left bank tributary and is sometimes called the Karnali inside Nepal. We shall be searching only the Gorakhpur area of this river for these projects. I conduct study on the Rapti River segment that passes through Gorakhpur. To determine the geomorphology of the river, I utilize a Graphical Information System (GIS) to evaluate both recent and historical data from that research location. In the Purvanchal area of the state of Uttar Pradesh, the city of Gorakhpur is located on the banks of the Rapti River. [7.1, 7.13]
3.2 DATA COLLECTION

The study's foundational data came from publicly available sources. To prepare the base map, two Digital Elevation Models (DEMs) were taken from the website Bhuvan.nrsc.gov.in, which was hosted on a Cartosat-1 satellite.

The basic data for the study were obtained from publicly accessible sources. Two Digital Elevation Models (DEMs) were acquired from http://bhuvan.nrsc.gov.in, which was housed on a Cartosat-1 satellite, in order to build the base map. [7.9]

4 METHODOLOGY

Watershed geometry and motion system are characterized using morphological analysis, a rigorous technique that quantifies the drainage community, linear features, expansive qualities, and cozy factors. Either directly or indirectly, the physical characteristics represent the entire watershed. The size, shape, slope, comfort, range of streams, vegetation, islands, and majority community of each watershed have all been measured and recorded. These features make it possible to evaluate a watershed's potential for producing runoff, which is useful for setting priorities for improvements to the watershed and determining which watersheds should be given priority when applying various remedies meant to lower runoff and soil loss by using appropriate preservation techniques. [7.2]

5 DATA ANALYSIS
Understanding the behavior of a watershed requires an understanding of its geomorphological features. Hence, GIS software is used to extract significant geomorphological features. Stream qualities, form properties, drainage network characteristics, and slope characteristics are the categories under which the geomorphological features are analyzed.

### Table 2. Data Analysis

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Data</th>
<th>Data Source</th>
<th>Objective</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The Digital Elevation Model (DEM) of Cartosat-1)</td>
<td><a href="http://bhuvan.nrsc.gov.in">http://bhuvan.nrsc.gov.in</a>.</td>
<td>In order to create a thematic layer, delineate the boundaries of the watershed and investigate its characteristics, slope maps, flow path maps, and flow accumulation maps must be prepared.</td>
</tr>
<tr>
<td>2</td>
<td>G-Map</td>
<td>Google Earth Pro</td>
<td>To determine the basin's point of outlet.</td>
</tr>
<tr>
<td>3</td>
<td>Working platform</td>
<td>ArcGIS 10.7.1</td>
<td>To analyze the DEM files so as to gather the spatial parameters.</td>
</tr>
</tbody>
</table>

![Flowchart of Methodology](image)

**Figure 1. Flowchart of Methodology**

Understanding the behavior of a watershed requires an understanding of its geomorphological features. Hence, GIS software is used to extract significant geomorphological features. Stream qualities, form properties, drainage network characteristics, and slope characteristics are the categories under which the geomorphological features are analyzed.
features of a watershed are categorized. For analysis, three main aspects—Linear, Areal, and Relief—have been described. The basin length, stream order, stream number, stream length, and bifurcation ratio are the characteristics of the linear aspect in morphometry. The areal aspect depicts the features of the catchment region and explains the ways in which the catchment area modifies and governs the hydrological behaviour. The catchment’s topographical configuration and features are defined by the relief aspect. [7.4, 7.14]

5.1 Linear aspect

The word—linear aspect—withinside the context of basin-drainage morphometry refers to diverse homes associated with the period and association of channels inside a drainage basin. Linear functions of morphometric evaluation consist of move order, bifurcation ratio, suggest move period, move period ratio, and move period in a region.

Basin area (Ab)
A watershed's basin area is a crucial component.

Stream order (Nu)
Determining the stream's hierarchical position in relation drainage basin is known as the stream order.

Stream length (Lu)
Measured from the stream's mouth to the drainage divide, the total length of streams in a given order represents the length of the drainage network in the region. ArcGIS software was used to determine the total length of streams using the stream order relation.

\[ Y = -910.33U + 4238.3 \]
Where,
\[ Y = \text{stream length of order } U, \text{ km} \]

Stream numbers (N)
The relationship between the two parameters is described by the following regression equation with a R^2 value of 0.99. The stream number is the number of streams with different orders and is inversely proportional to the stream order.

\[ Nu = 3815.3e^{-0.671U} \]
Where,
\[ Nu = \text{Number of streams of order } U. \]

Bifurcation ratio (Rb)
It can be described as the proportion of a given number of streams in order to the next lowest number of streams in the order.
5.2 Areal aspects

Drainage density, stream frequency, texture ratio, form factors, stream discharge and basin area is made much easier with the help of circulatory ratio, length of overland flow, and consistent channel this analysis maintenance are all included in this analysis. Finding the link between

Drainage density (Dd)
It is the proportion of a stream's overall length to its entire drainage area. It is a crucial component for indicating the basin's peak runoff potential and landscape segmentation.

**Stream frequency (NF)**
The drainage frequency is another name for the stream frequency. The calculation involves dividing the entire amount area based on the quantity of streams (Horton 1932). It mostly depends on the region's physiography and rainfall.

**Form factor (FF)**
It is the ratio of the greatest basin length to the basin area squared. It primarily depicts the dimensions and form of the basin only.

**Circulatory ratio (CR)**
The hydraulic radius is another name for the circulatory ratio. It ranges from zero for an extended basin to one for a circular basin and is helpful for measuring basin form.

**Elongation ratio (ER)**
The definition of elongation ratio is the ratio between the greatest basin length and the diameter of a circle with the same area as the basin (Schum, 1956).

**Compactness coefficient or Compactness constant (CC)**
The ratio of the catchment's perimeter to that of the circle whose area is the basin is known as the compactness constant. It is primarily dependent on the slope and unaffected by the watershed's size.

**Length of over land flow or extension of the surface route (LOLF)**
The first mechanism of surface flow is known as overland flow, and it is defined as the length of the flow path across the ground before it is focused into a specific stream network and is primarily seen in small watersheds. [7.7]
Fig. 8. Basin Area

Fig. 8. Stream order
5.3 Relief aspects

It refers to the characteristics related to the landscape of specific areas. These features are not related to the pattern of drainage involving water channels. Instead, they focus on the highest and lowest elevation points in a particular region. The relief aspects include relief, relief ratio.

Relief ratio (RR)

It is the ratio of the basin's overall relief to its longest basin length, as determined by running the major drainage line across it (Schumm 1956).

The low degree of slope and hard rock are the causes of the low relief value. High relief and a steep slope are indicated by the highest value.

Ruggedness number (RN)

Ruggedness number for a selected basin is the result of basin relief and drainage density (Stahhler, 1968). Regarding the drainage network's slope and steepness, this analysis is quite helpful. [7.8, 7.10]
6 RESULT AND CONCLUSION

Features of Rapti River Basin Watershed's Geomorphology

To define the Rapti river basin, one employed the Digital Elevation Model. The Rapti River covers 900 km² in total. The watershed's perimeter is 254 kilometres.

6.1 Linear aspects

6.1.1 Stream order

The most crucial stage in the quantitative examination of the basin is stream arrangement. Horton (1952) first introduced stream ordering, although Strahler (1952) later improved his approach. A measure of stream branching in a watershed is called stream ordering. A tributary created by two or more streams of order (N1) and streams of lower order is generally referred to as a Nth order stream. According to Horton's law of stream ordering, the number of stream segments reduces as the stream order increases. It provides information on the drainage area, runoff, and stream size, and the extent is closely correlated with the size. Table 4.1 lists the streams in a watershed in order. The Rapti River Basin has been identified as a VI order. (5)

6.1.2 Stream number (Nu)

Stream numbers are the total number of stream segments in order of order. "Number of stream segments of each order form an inverse geometric sequence with order number," according to Horton (1945). Stream number is the total number of streams in a particular watershed of each order. Stream order and stream number are inversely correlated. Figure 4.2 makes a similar suggestion. Each order's number of streams creates an inverse geometric sequence.
against stream order, according to the law of stream order (Horton, 1945). The physiographical, geomorphological, and geological conditions of the area have a major impact on the variation in stream order and tributary basin size (P. K. Rai et al., 2014). The quantity and hierarchy of streams, overall duration of the bedrock and the formation are permeable. Mean stream length, according to Strahler (1964), characterizes the typical size of stream network components. A given order's mean stream length is shorter than that of the order above it. On the other hand, as stream order increases, total stream length drops from its maximum in first order. (12)

Table 4. Graph between stream no. and stream order

![Graph between stream no. and stream order](image)

Table 5. Data from software

<table>
<thead>
<tr>
<th>Stream order</th>
<th>No of streams ( Nu)</th>
<th>Length(km) (Lu)</th>
<th>Average Length (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st order</td>
<td>6284</td>
<td>764</td>
<td>0.121</td>
</tr>
<tr>
<td>2nd order</td>
<td>3483</td>
<td>431</td>
<td>0.123</td>
</tr>
<tr>
<td>3rd order</td>
<td>1502</td>
<td>214</td>
<td>0.142</td>
</tr>
<tr>
<td>4th order</td>
<td>556</td>
<td>62</td>
<td>0.115</td>
</tr>
<tr>
<td>5th order</td>
<td>413</td>
<td>49</td>
<td>0.118</td>
</tr>
<tr>
<td>6th order</td>
<td>405</td>
<td>64.34</td>
<td>0.158</td>
</tr>
</tbody>
</table>
6.1.3 **Bifurcation ratio (Rb)**

When we compare the number of stream segments of a particular order \( N_u \) to the number of streams in the next higher order \( N_{u+1} \), we get the bifurcation ratio (Rb). As per Strahler's (1957) findings, the bifurcation ratio exhibits minimal fluctuations across diverse geographies and environments, with the exception of areas where strong geological influence is predominant. The drainage basin's lithological and geological evolution is primarily responsible for the order-wise irregularity in Rb. A high bifurcation ratio value indicates a high possibility for flash flooding during an extreme rainfall event, as well as high overland flow and an early hydrograph peak. Less structural disruptions are indicated by a lower value of Rb (Strahler, 1964). In the Rapti Basin, the highest Rb value strongly suggests that the drainage pattern is subject to physically strong structural. (10)

**Table 6. Bifurcation Ratio**

<table>
<thead>
<tr>
<th>Bifurcation Ratio</th>
<th>Mean value for whole watershed</th>
</tr>
</thead>
<tbody>
<tr>
<td>( R_b (1-2) )</td>
<td>1.804</td>
</tr>
<tr>
<td>( R_b (2-3) )</td>
<td>2.318</td>
</tr>
<tr>
<td>( R_b (3-4) )</td>
<td>2.701</td>
</tr>
<tr>
<td>( R_b (4-5) )</td>
<td>1.346</td>
</tr>
<tr>
<td>( R_b (5-6) )</td>
<td>1.019</td>
</tr>
<tr>
<td><strong>Mean ( R_b ) of Rapti Basin</strong></td>
<td>1.837</td>
</tr>
</tbody>
</table>

6.1.4 **Stream length (Lu)**

Using a geographic information system (GIS), the mean and total stream length for each order is calculated and shown in Table 4.3 displays how the stream segments have developed as well as the features of surface runoff. Streams with comparatively shorter lengths suggest that the terrain is hilly. A flatter gradient can be inferred from longer streams. Stream length is a measure of the hydrological characteristics of bedrock and the area of drainage (47) In a well-drained watershed, just a few comparatively longer streams occur wherever. (4)
The Rapti River Basin's mean RL of 1.016 further demonstrates the diversity in stream length ratios between streams of varying orders caused by topographical and slope variations. This suggests that the streams within the research region are in the late youth stage of geomorphic development. According to Horton's stream length law from 1945, the mean stream length segments of each of the basin's subsequent orders tend to resemble a straight geometric series as stream length increases toward higher order streams. (7)

**Table 8. Stream length Ratio**

<table>
<thead>
<tr>
<th>Stream Length Ratio</th>
<th>Rapti basin</th>
</tr>
</thead>
<tbody>
<tr>
<td>RL (2-1)</td>
<td>1.016</td>
</tr>
<tr>
<td>RL (3-2)</td>
<td>1.154</td>
</tr>
<tr>
<td>RL (4-3)</td>
<td>0.781</td>
</tr>
<tr>
<td>RL (5-4)</td>
<td>1.063</td>
</tr>
<tr>
<td>RL (6-5)</td>
<td>1.338</td>
</tr>
<tr>
<td>Mean for RL Kasari basin</td>
<td>1.070</td>
</tr>
</tbody>
</table>
6.1.6 Basin Length (Lb.)

The basin duration is the longest measurement of the parallel to the principal drainage line (Schumm, 1956). The Rapti watershed’s expected basin duration is sixty-five km. The watershed’s shape and form elements are being impacted through Lb.

6.2. Areal aspects

6.2.1 Drainage density (Dd)

The length of a stream per unit area in a region is known as its drainage density (Dd) (Horton, 1945, Strahler, 1952). Studying the landscape's dissection, rainfall intensity, potential for runoff, the land's ability to absorb water, the basin's climate, and its vegetation cover are all essential components of drainage morphometry. The Rapti Basin has a somewhat high average Dd of 1.760 km/km², which is indicative of its sparse vegetation and rugged topographical features. It is acknowledged that drainage density has a role in influencing how long water takes to move (Schumm, 1956). Each subbasin is given a weight based on the impact of drainage density on soil erosion. (2)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drainage density (km/km²)</td>
<td>Dd</td>
<td>1.760</td>
</tr>
<tr>
<td>Stream frequency (km²)</td>
<td>Sf</td>
<td>14.047</td>
</tr>
<tr>
<td>Length of overland flow</td>
<td>Lo</td>
<td>0.284</td>
</tr>
<tr>
<td>Constant channel maintenance</td>
<td>C</td>
<td>0.568</td>
</tr>
<tr>
<td>Form factor</td>
<td>Ff</td>
<td>0.213</td>
</tr>
<tr>
<td>Compactness coefficient</td>
<td>Cc</td>
<td>71.652</td>
</tr>
<tr>
<td>Circularity ratio</td>
<td>Rc</td>
<td>0.175</td>
</tr>
<tr>
<td>Shape Index</td>
<td>Sw</td>
<td>4.694</td>
</tr>
<tr>
<td>Drainage Intensity</td>
<td>Di</td>
<td>0.125</td>
</tr>
</tbody>
</table>

Table 9. Areal Aspect
6.2.2 **Stream frequency (Sf)**

The term "Stream frequency," which refers to the total number of stream segments of all orders per unit area, was first used by Horton (1932). High relief, sparse vegetation, impermeable subsurface material, and low infiltration capacity are all associated with high stream frequency (Pawar-Patil et al., 2013). Low relief and very permeable geology are indicated by low stream frequency. The Rapti River Basin's Sf of 14.047 numbers per km² shows that the watershed has little surface runoff. This suggests low potential runoff as well. There are fewer streams available when the minimum stream frequency is reached. It is mostly reliant on the basin's lithology. Consequently, it depicts the drainage network's texture. In particular, channel frequency density in relation to stream orders and their characteristics provide data which can throw light even on the order in which relief developments occurred and the extent of ruggedness in the area (Singh, 1980). An effective technique for determining the erosion process at work over a region is channel frequency density.

6.2.3 **Length of overland flow (Lo)**

The significant independent characteristic influencing the development of hydrologic watersheds and hydrologic flow has an inverse relationship with the length of overland flow. Strong relief and steep land slopes are typically connected with values between 0.6 and 0.8. A region with low relief is indicated by a number approaching 1. The watershed of the Rapti River Basin has a L0 value of 0.284. The river basin of Rapti. The watershed exhibits a mature stream network and a late juvenile stage of geomorphic formation.

6.2.4 **Constant of channel maintenance (C)**

The shape of a basin determines how floods originate and travel. It is commonly recognized that in round basins rather than elongated ones, floods develop and spread more swiftly. In addition, floods in the former type of basins are stronger, move faster, and have a larger capacity for erosion and transport. Because tributaries flow into the main stream at longer intervals in both time and space, an extended design tends to reduce floods. The channel maintenance constant is equal to 0.568. It indicates how many square feet of surface area in watersheds are needed to support one linear foot of channel. Therefore, 0.568 square feet of space in the Rapti River Basin are needed to support one foot of the channel.

6.2.5 **Form factor (Ff)**

According to Horton (1932), the form factor is a dimensionless ratio of a drainage basin's area (A) to the square of its greatest length (Lb). Simple dimensionless ratios of the three fundamental measurements—area, perimeter, and length—can be used to index the geometry of a basin (Singh, 1998). Form factor is a measure of the degree of erosion, the creation and movement of floods, and the ability of a watershed to convey its sediment load. The Rapti River Basin's Ff value is 0.213. From 0 (a greatly elongated shape) to unity, or 1, (a perfect
circular shape), the value of Ff varies. Rapti watershed has a lower value of Ff, indicating that its shape is relatively elongated and that its flow lasts longer. Compared to circular basins, elongated basin flood flows are simpler to control.

6.2.6Compactness coefficient (Cc)

The compacting coefficient, which is the product of the circumference of the circular region and the measurements of the watershed's perimeter, can be used to determine the size of a watershed (Gravelius, 1914). It just depends on the slope and is unaffected by the size of the watershed. With a circularity ratio (Re) of 71.652, the situation is as follows. Miller (1953) defined the circularity ratio as the area (A) of the basin divided by the circumference of a circle whose periphery is similar to the basin's. The ratio is equal to one when the basin is shaped like a perfect circle; it ranges from 0.4 to 0.5 when its basins is shaped like a significantly extended, highly permeable homogeneous geologic material. The sustainability ratio can be affected by the slope, surface vegetation, and relief geologic structure of the basin. The river basin's great length, low runoff flow, as well as elevated subsurface susceptibility are represented by its Cc value of 0.175.

6.2.7Elongation ratio (Re)

The elongations ratio can be defined as the diameter of a circle with the same area as the basin divided by the basin's strongest length (Schunmm, 1956). It is an important index to look at the form of the basin. Higher elongation ratio values are indicative of good infiltration capacity and little drainage, according to extension ratio evaluation. When it comes to runoff discharge, an elongated basin is less efficient than a circular basin (Singh and Singh, 1997).

52 Five categories—less elongated (0.7-0.8), elongated (0.5-0.7), circular (0.9-1.0), oval (0.80.9), and more elongated (<0.5)—were established by Strahler (1964) for the elongation ratio.

6.2.8Shape index (Sw)

Shape index is the reciprocal of form factor and is a dimensionless quantity. The value of the Rapti river basin is 4.694. Greater basin elongation and weaker flood discharge are associated with higher form index values.

4.2.10 Intensity of Drainage (Di) The ratio of the stream frequency to the drainage density of the corresponding basin is known as the drainage intensity (Di) (Faniran, 1968). The Rapti watershed is exhibiting extremely low drainage intensity, 1.760, which suggests that stream frequency and drainage density have insufficient effects on how much the surface has been depressed by denudation agents.

6.3. Relief aspects

6.3.1Relief (H)

The difference between the highest point and the basin relief in the the lowest point and the watershed on the valley floor. Relief from a basin is among the main factors that significantly
increases the runoff in the basin. The distance that separates between the furthest point and the watershed outlet is 81 meters.

6.3.2 Relief ratio (RH)

It is a gauge of the degree of erosion occurring on 53 of the drainage basin’s slopes and assesses the total steepness of a drainage basin by taking into account the significant elevation differential. The relief ratio is the ratio of the horizontal distance on which relief was measured (H) to the relief.

6.3.3 Relative Relief Ratio (Rhb)

The formula developed by Melton (1957) is used to calculate the relative relief ratio. The primary Rapti watershed has a Rhb of 31.889.

6.3.4 Ruggedness Number (Rn)

The drainage density multiplied by the basin relief yields the ruggedness number (Rn). Rapti Basin has a toughness value of 142.56. The area is somewhat prone to soil erosion, as indicated by the moderate value of Rg. The relief ruggedness in the basin is specifically represented by the Melton's roughness number. This gives a sense of the water's general roughness.

<table>
<thead>
<tr>
<th>Table 10. Ruggedness Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameter</td>
</tr>
<tr>
<td>-----------------------------</td>
</tr>
<tr>
<td>Ruggedness Number</td>
</tr>
<tr>
<td>Relative Relief Ratio</td>
</tr>
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</table>
6.4. Result obtained

The Rapti River Basin, located in Uttar Pradesh's Gorakhpur District, is the project's study region. It was discovered that the Rapti River Basin covered 900 km². The basin has a 254 km perimeter. The elevation is 42 to 123 meters overall. The region is situated in latitude 27° - 51' N and longitude 81° - 49' E. The watershed's mean bifurcation ratio (Rb) is 1.837, indicating a structurally strong physical control over the drainage pattern. The Rapti River Basin's mean stream length ratio (R) is 0.128, indicating that the study area's streams are in the late youth stage of geomorphic development. With a moderate average drainage density (Dd) of 1.760 km/km², the Rapti River Basin is characterized by steep terrain features and scant vegetation. The Rapti River Basin's stream frequency (Sf) is 14.047 per km², indicating a low level of surface runoff throughout the watershed. This suggests low potential runoff as well. Overland flow (Lo) in the watershed of the Rapti River Basin is 0.284. The Rapti River Basin's form factor (Ff) is 0.213. The Rapti watershed has a lower value of Ff, indicating that its shape is fairly elongated and that its flow lasts longer. The Rapti River Basin's Circularity Ratio (Rc) value of 0.175 indicates its extreme length, low runoff discharge, and high subsurface permeability. The form index value for the Rapti river basin is 4.694. A longer basin and a weaker flood discharge period are indicated by a higher form index. The Rapti River Basin's compactness coefficient (Cc) value is 71.652. Where the result we can conclude are the current study locates and pinpoints the largely unexplored water resource potential in the Rapti river basin, thanks to its intricate physiography. Farmers make up the majority of the population in this area. Leveraging the area's irrigation potential could be facilitated by the study. Furthermore, due to the area's potential for floods. Marking and locating the mouths of various streams could be helpful in order to construct small check dams in various subbasin locations, which would help lessen the issue of flooding. The outer and inner Tarai, slopes of plains suitable for settlement and agriculture, and tall mountains make up the entire basin's topography.

REFERENCE


5 Khan OA, Skinner R (Editors). Geographic Information Systems and Health Applications.


