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Ken river basin morphometric characterization by employing G.I.S and remote sensing techniques

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Abstract

Water resource management required morphometric characteristics to be evaluated in order to better understand the aspects that could contribute to the impact of big floods caused by inadequate water disposal management. The basin's inadequate channel design and drainage make it especially vulnerable to floods. An elongated shape is indicated by a significantly lower form factor value for the Ken river basin. The vulnerability to water erosion in the Ken River Basin, which results from inadequate drainage infrastructure for the secure removal of surplus water, is one of the primary causes of concern. An analysis of the relief variables showed that the basin experienced severe flood characteristics at times of excessive rainfall. It might be helpful to examine a basin's features and manage water resources sustainably by using remote sensing and GIS techniques for assessment. This entails constructing runoff-controlling structures and modifying conventional water-saving methods to boost infiltration rates while lowering surface runoff and erosion.

Keywords: Remote sensing, watershed, GIS and morphometric parameters

Introduction

The amount of water available in different river basins is impacted by the dramatic changes in natural cycles brought about by climate change. Morphometric analysis of a river basin is useful to assess seasonal changes in drainage basin characteristics, understand groundwater potential, and address issues related to managing soil erosion caused by flash floods during high flows (Pophare *et al.* 2014, Arabameri *et al.* 2020) ^[16, 1]. Morphometric parameter analysis may be used to characterize the watershed's hydrological response behavior (Rai *et al.* 2017 ^[17] By assessing the channel network's linear, aerial, relief, and gradient characteristics as well as the ground slope that contributes to the basin, the morphometric aspects of the watershed may be identified (Sreedevi *et al.* 2009) ^[21]. The physical characteristics of the soil, the processes that produce landforms, and the erosional characteristics of watersheds are all impacted by drainage morphometry, making its study crucial.

An assessment of the watershed's morphometric features can provide insight into the evolution of land surface processes that impact the watershed's hydrologic response (Magesh *et al.* 2013) ^[8]. Basin management and other hydrological studies benefit from the extraction of river basins and their drainage networks. Using the watershed's geomorphic characteristics, morphometric parameters may be utilized to predict surface runoff and drainage system flow intensity (Ozdemir and Bird 2009) ^[14]. Understanding the impact of drainage morphometry on landforms and their features is made easier by the evaluation of morphometric parameters utilizing remote sensing and a GIS methodology. For different river basins, several researchers have conducted morphometric investigations, including Biswas *et al.* (1999) ^[3], Nag and Chakraborty (2003) ^[11], Narendra and Nageswara Rao, (2006) ^[12], John Wilson, and Magesh and Chandrasekar (2012b) ^[7].

For the management of river basins, the spatial data evaluated with remote sensing and GIS tools is essential. For ridgeline delineation, characterization, priority evaluation, problem identification, erosion-prone area identification, developing water conservation strategies for building check dams and reservoirs, etc., remote sensing data can be combined with traditional data (Somashekar, Paulinus *et al.* 2016) ^[15].

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The use of remote sensing and GIS techniques provides an appropriate setting for identifying, analyzing, and interpreting spatial data pertaining to river basins. Combining the two methods aids in examining a drainage basin's hydrological response for determining its groundwater potential as well as its geographic and geomorphic features. The goal of the current study was to examine the Ken river basin's morphometric features, which include its linear, aerial, and relief features.

Study area description at the Ken River

The Ken River is a significant tributary of the Yamuna River, which rises in the Jabalpur region of Madhya Pradesh, close to the village of Ahirgawan. In the central Indian area of Bundelkhand, it is one among the main rivers. The basin is between longitudes 78°30' and 80°32' E and latitudes 23°20' and 25°20' N. The whole catchment area of the 427-kilometer river is 28,058 square kilometers, of which Madhya Pradesh and Uttar Pradesh account for 24,472 square kilometers and the remaining portion, respectively.

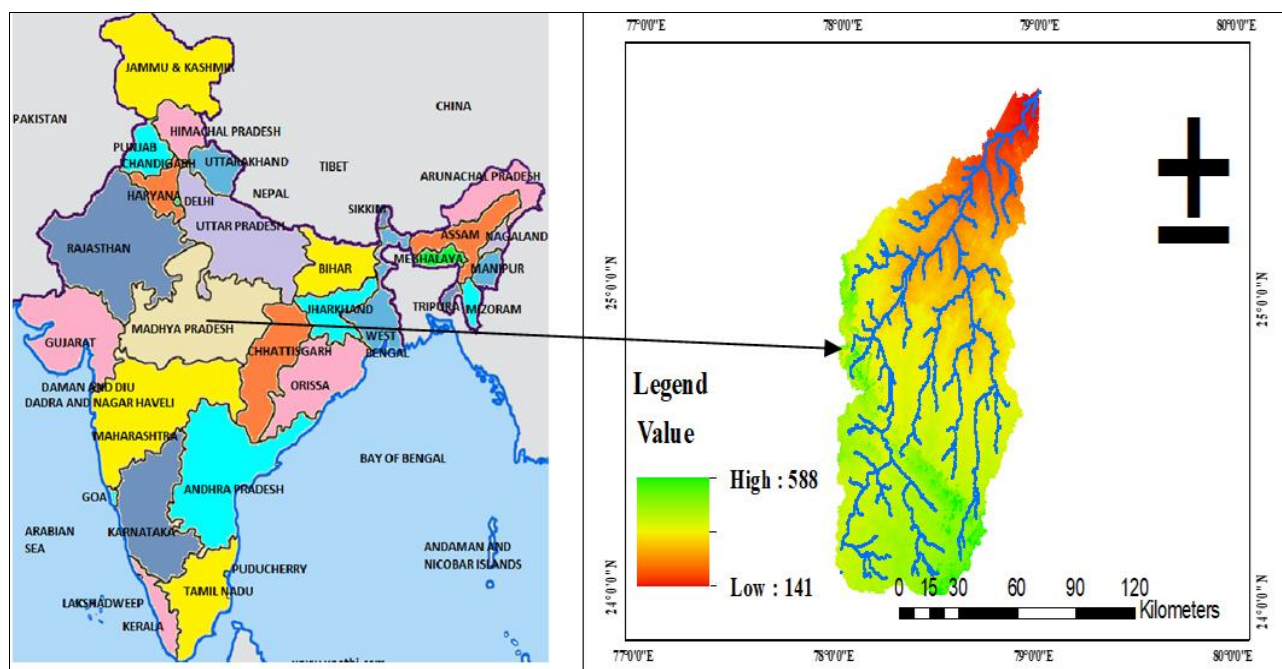


Fig 1: Study area location Map

Methodology

The key factor influencing the effectiveness of management planning for the use of water resources is the morphometric analysis of watershed characteristics. Information regarding the rock formation's hydrological response that was discovered inside the drainage basin is helpful. Figure 2 displays the Ken River Basin's digital elevation model (DEM). Information on

permeability, storage within rock formation, and yield from the basin can be efficiently evaluated by evaluating drainage metrics such as bifurcation ratio, length of over flow etc. A number of geoprocessing methods, such as fill, flow direction, flow accumulation, and pour point detection in ArcGIS, were employed to assist in defining the watershed boundary using DEM.

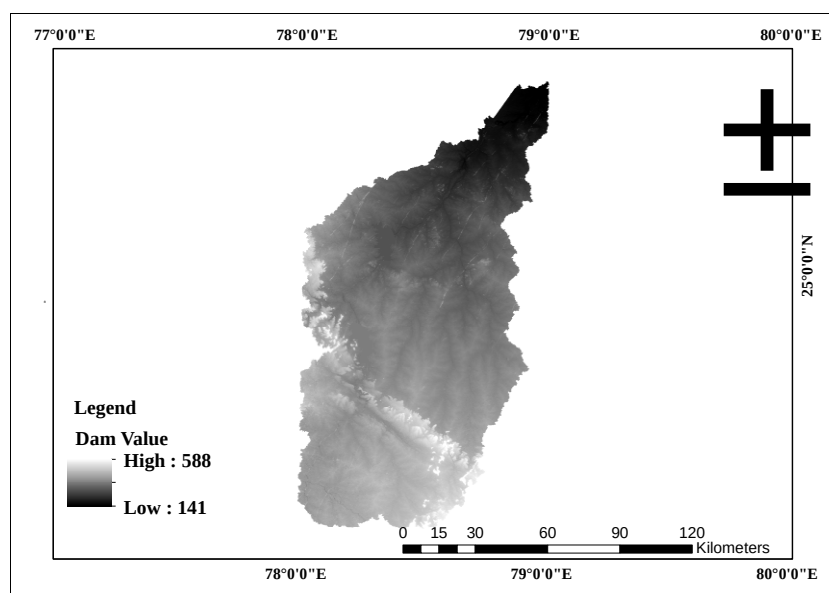


Fig 2: Model for the digital elevation of study area

Results and Discussion

Linear aspects

Stream order and Stream number

Stream order, number, length, mean length, and bifurcation ratio are all evaluated as part of the Ken River basin's linear morphometric characteristics. According to Leopold *et al.* (1964) and Strahler (1957) ^[22], stream order (U) is a measurement of a stream's location, size, and drainage area. The fourth-order drainage basin is the Ken River basin. According to Horton (1945) ^[4], the number of streams in each order that is inversely proportional to stream order is known as the stream

number (Nu). A total of 129 streams of various orders are discovered in the research region. The number of streams with varying orders is listed in Table 2. Streams of various orders in the Ken River Basin are seen in Figure 3.

Table 2: Different order of Number of stream

Parameter	Stream order				Total
	1 st	2 nd	3 rd	4 th	
Number of streams	105	20	3	1	129

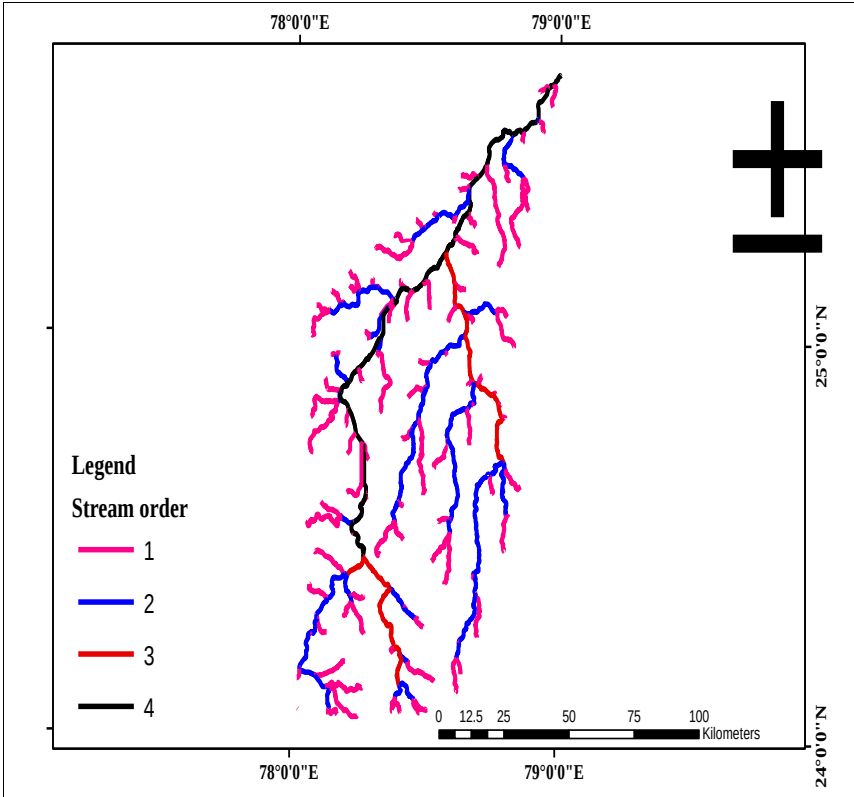


Fig 3: Different order streams in the area of study

Bifurcation Ratio (Rb)

The bifurcation ratio is a dimensionless feature that is calculated by dividing the number of stream segments of one level by the number of segments of the next higher order. The current study's bifurcation ratio spans from 3 to 6.67, with an average of 3.73. this implies that the drainage pattern has less channel creation with homogeneous geology and is unaffected by structural disturbances.

Stream length

Measured stream lengths for each sequence are listed in Table 3. It aids in highlighting the features of surface runoff that are most prevalent in the river basin.

Table 3: Stream length of each order

Stream order	1 st	2 nd	3 rd	4 th
Stream Number	105	20	3	1
Length of stream (km)	863	480	139	208

Areal aspects of drainage basin

Form factor

According to Horton (1932), form factor is the drainage basin's size (A) divided by its maximum length (Lb) squared. A longer,

elongated basin with a high sediment transport capacity was indicated by the research region's form factor value of 0.17. This is because groundwater percolates and a saturation zone is created when streams enter the mainstream at larger intervals and spaces. This creates a condition similar to flooding as water pours across the ground surface at a rapid speed.

Compactness coefficient

It was discovered that the compactness coefficient, which is a ratio of catchment's perimeter to the circle perimeter with an area equal to the basin's, was 2.46. A higher number indicates that the catchment is more vulnerable to erosion because of increased runoff.

Circulatory ratio

Miller (1935) defined the circulatory ratio as a ratio area of the catchment to the circle with the same perimeter as the catchment, to describe the basin form. With its homogeneous geologic structure and medium to low relief, the drainage basin has a longer form, according to the calculated circulatory ratio value of 0.16.

Elongation ratio

The elongation ratio, which is the ratio of the diameter of a

circle with the same area as the drainage basin to the maximum basin length, is used as an index to assist disclose the drainage basin's form (Kumar 2011) ^[6]. Strahler (1964) ^[23] divided elongation ratios into five classifications according to their shape: less elongated (0.7-0.8), elongated (0.5-0.7), round (0.9-1.0), oval (0.8-0.9), and more elongated (<0.5). A more extended basin form with a moderate slope is indicated by the elongation ratio of 0.45.

Drainage density

The drainage density of a basin is defined as the ratio of its area to the total length of its streams across all orders. A low drainage density under heavy vegetation cover suggests that the subsurface material is reasonably permeable. The basin's low terrain, dense vegetation, and permeable subsurface material contribute to its drainage density of 0.1352 km/km².

Stream frequency

The number of stream segments per unit basin area is known as the stream frequency. High stream frequency, sparse vegetation, high relief, and limited infiltration capacity are generally associated with impermeable underlying material, and vice versa. A poor drainage network is indicated by a lower stream frequency value. The watershed's stream frequency is 0.0111/Km², which is extremely low and suggests low slope, poor drainage, poorer permeability, and less relief.

Drainage texture

According to Horton (1945) ^[4], it is the total number of stream segments of all kinds per area's perimeter. Horton's research identifies infiltration capacity as the only significant variable that affects drainage texture, texture ratio, and drainage density and stream frequency. Drainage density was divided into five different textures by Smith (1950) ^[20]: very coarse (<2), coarse (2-4), moderate (4-6), fine (6-8) and very fine (>8). Peak runoff occurred after a lengthy period of time, as shown by the watershed's drainage texture of 0.31, which is highly coarse and suggests a substantial basin lag time.

Relief aspects of the drainage network:

Basin relief

One important feature of the topography is the basin relief aspect, which is the elevation difference between the basin outflow and the highest point inside the basin's boundary. The basin relief value of 346 m indicates mountainous areas with higher erosion and runoff velocity.

Relative relief

The ratio of the highest basin relief (H) to the basin perimeter (P) is how Melton (1958) ^[10] defined relative relief. Watersheds with a relative relief of 0.034 have a significant risk for erosion and runoff.

Relief ratio

The results show that the relative relief and relief ratio are 0.034 and 0.00128, respectively. The watershed has to be corrected using soil and water conservation techniques since there is evidence of erosion.

Ruggedness number

In the same unit, the ruggedness number, which is an important parameter, is defined by the product of basin relief and drainage density (Strahler, 1957; Melton, 1958) ^[23, 10]. The toughness value of 48.2 has been considered for the present study. The watershed had the highest roughness value.

Slope

Any region's Morphoclimatic processes, which are influenced by the resistance of the rock surface, determine the slope (θ), a crucial morphometric parameter. Knowing the kind of slope in a specific location is important since it influences the infiltration-runoff connection. Infiltration capacity and slope are inversely related. The upper portions of the Ken basin were characterized by a relatively high slope ($> 40^\circ$), which suggests limited infiltration linked to high drainage density and frequency. Additionally, it identifies the fundamental phases of geomorphic development. But when Ken moves into foothill plain areas, the slope drastically drops. Intense flood features and particular geomorphic landforms, such as alluvial fans, were formed by this distinctive slope characteristic. The slope features that are prevalent in the area are shown in Figure 4.

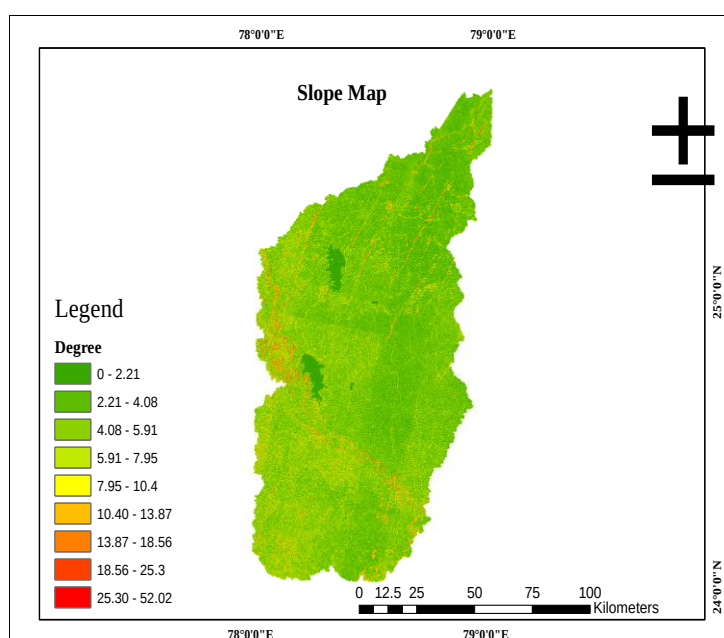


Fig 4: Slope (in degree) which prevails in the Ken basin

Conclusion

For the construction of basin levels and flood management planning, morphometry is essential. This study aims to identify the morphological and hydrological characteristics of the Ken River Basin by assessing a number of morphometric factors. Because the steep slope structure results in less permeable rock formation, the regions experience large overland flow and discharges. Given the Ken basin's more elongated shape and great capacity for sediment movement, flooding is likely to occur. The watershed's very coarse drainage texture points to a significant basin lag time, which means peak runoff occurred after a protracted period of time. Construction of suitable buildings helps to develop groundwater, and soil and water conservation structures are crucial to minimizing the losses caused by surface runoff.

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