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(SCIENCE & TECHNOLOGY)

VADODARA

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Prof. C. N. MURTHY

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UTILIZING GEOSPATIAL TECHNOLOGY FOR ASSESSING LINEAR CHARACTERISTICS OF THE SHASTRI RIVER BASIN MORPHOMETRY TO ENHANCE SUSTAINABILITY IN WATERSHED MANAGEMENT

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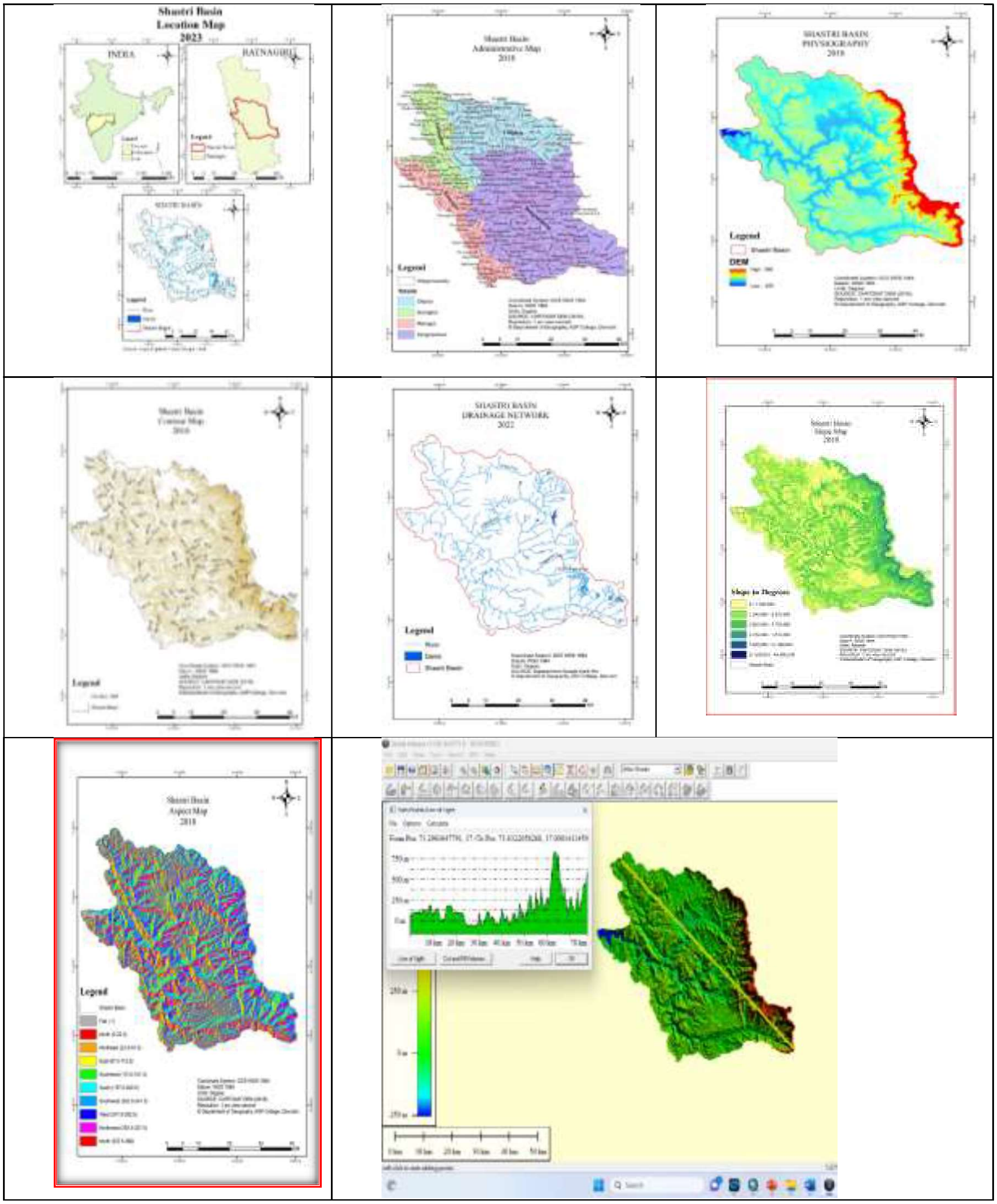
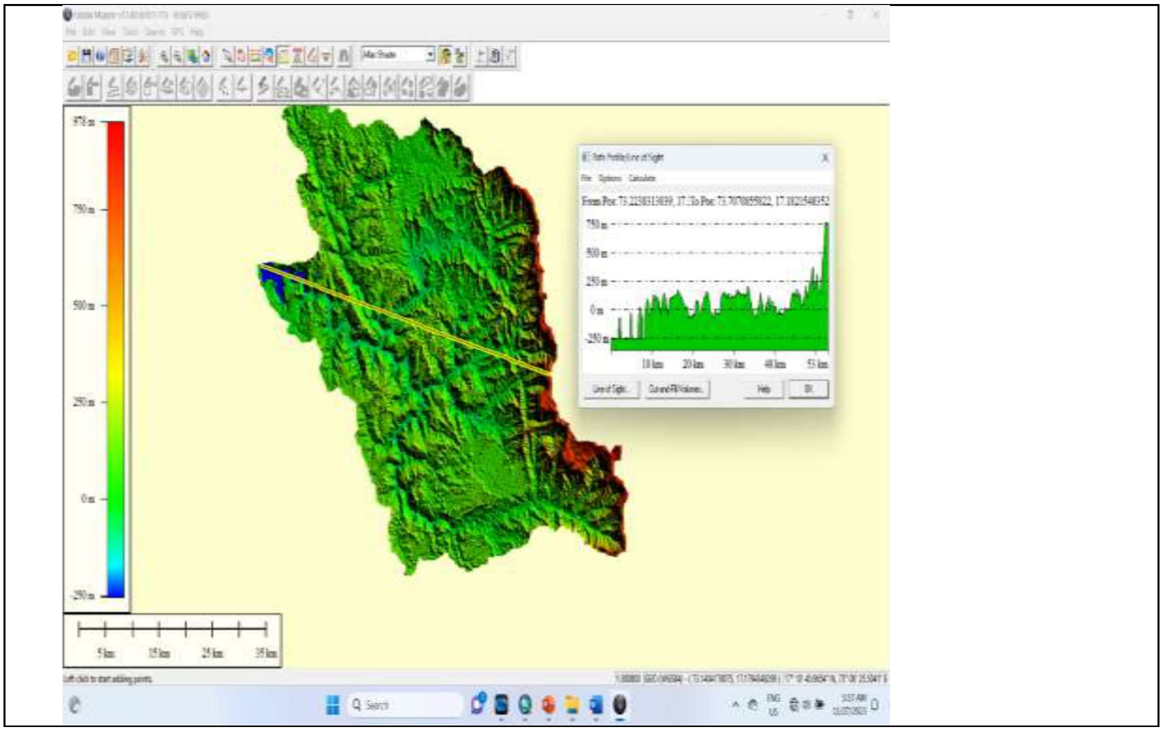
Abstract: In geomorphology 'morphometry may be defined as the measurement and mathematical analysis of the configuration of the earth's surface and the shape and dimensions of its landforms'. It incorporates the quantitative study of the area, altitude, volume, slope, profiles of the land, and drainage basin characteristics of the area concerned. The morphometric characteristics of a river basin widely control watershed management and its sustainability. The main objective of the present research is to analyse the linear aspects of the Shastri River Basin and investigate its correlation with watershed management sustainability. The overall analysis of the linear aspects of the Shastri Basin verifies that the influence of topographical variation is found in the basin. Stream orders (Up to level 6), bifurcation ratio (Mean: 3.44), stream numbers (Average 3.43), stream length (Mean length 6.43 km), length ratio (ranges between 0.93 and 13.02), deviation of the observed path from the expected (SI – 1.62), etc. are an outcome of the undulating topography and the geology of the region. It plays a crucial role in the watershed management sustainability.
Keywords: Basin Morphometry, Stream Order, Bifurcation Ratio, Sinuosity Index, Stream length and length ration, watershed management sustainability

Introduction: The linear aspects of the basin are an important segment of the river basin morphometry. It is correlated with the channel patterns of the drainage network(S. Patil, 2014) (Singh, 1998). The drainage network consists of stream junctions that act as points and streams that connect the points to become links or lines, and the number of all segments is counted, their hierarchical orders are measured, and their various interrelationships are studied(Ali1 & Khan2, 2013; Bloom, 1979; Różycka & Migoń, 2021; Sharma et al., 1986). The nature of flow paths in terms of sinuosity is equally important in the study of the linear aspect of the drainage basin(Prakash et al., 2017). The linear aspect includes the discussion and analysis of stream order, bifurcation ratio, stream length, length ratio, and sinuosity index(Singh, 1998). The researchers attempted to analyze the linear aspects of the river basin morphometry of the Shastri Basin using ArcGIS software. The details are given below.

Study region: For the present research work, the Shastri basin is selected as the study region. It is located in the north-south centre of Konkan. The latitudinal extent of the Shastri basin is 16.9551^{O} N to 17.4923^{O} N and the longitudinal extension of the region is 73.2205^{O} E to 73.8458^{O} E (Google

Earth, 2022). As calculated by the researchers' using shapefiles in GIS, the Shastri basin covers an area of 2158.06 square kilometres and it is spread over five tehsils, such as Sangammeshwar (1090.85 Sq. Km), Chiplun (483.95 Sq. Km.), Ratnagiri (261.18 Sq. Km.), Guhagar (238.23 Sq. Km.) and Lanja (0.23 Sq. Km.) of the Ratnagiri district. The basin is bounded by the Vashishti Basin in the north, the Kajali Basin in the south, and the Krishna Basin in the East.



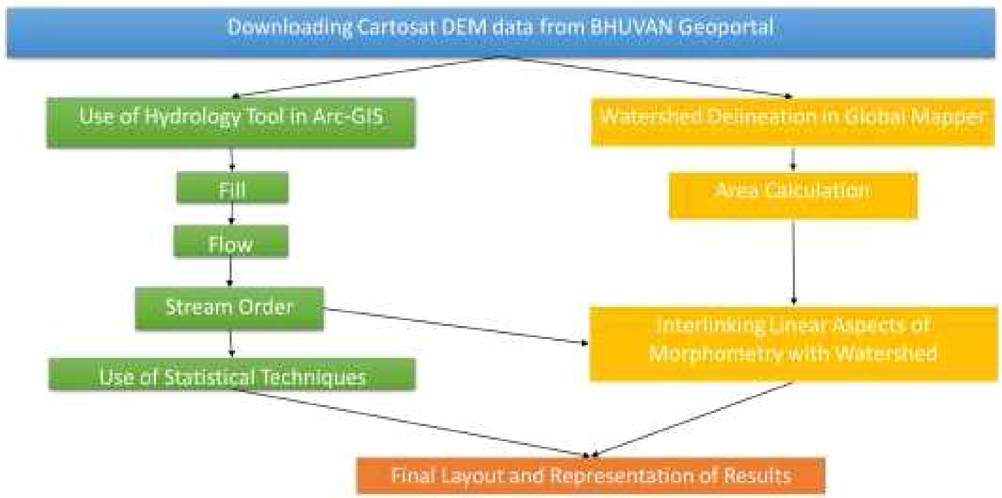


Review of literature: Conducting a thorough literature review is a crucial preliminary step in research, providing a systematic overview of prior studies relevant to the chosen topic. This review is indispensable for identifying research gaps and laying the foundation for further investigation. Scholars have extensively explored the morphometry of drainage basins over the years, with a notable shift in emphasis following R.E. Horton's influential paper in 1945. Key contributors include R.L. Singh, B. Ghose, and Renu Srivastava, who conducted comprehensive studies, contributing significantly to the understanding of terrain and basin morphometry (Singh, 1998). In the 21st century, the advent of remote sensing and GIS technology has revolutionized morphometric analysis. Recent studies, exemplified by Garud S.B. and Kumari et al., leverage these technologies to explore river basins like Rangavali and Sabarmati, shedding light on physical settings, morphometry, and drainage patterns. Additionally, scholars such as Lokare Pavan utilize GIS approaches to identify geomorphological characteristics, emphasizing the evolving landscape of morphometric analysis (Garud, 2021) (Kumari et al., 2021) (Lokare et al., 2021). While these advancements mark a transformative era, some studies, like those by Surajit Singh and B.R. Thakur (2011), exhibit limitations in detailing research methodologies and objectives. This underscores the need for comprehensive approaches in basin morphometry analysis to ensure a robust foundation for sustainable watershed management practices (Lama & Maiti, 2019) (Das & Pardeshi, 2018) (Patil, 2014) (Singh & Thakur, 2011).

Research gaps: Researchers worldwide, particularly post-2000, have extensively explored morphometric analysis using advanced technologies like remote sensing and GIS. Notably, Sardar Ananda Patil (2014) focused on Linear Aspects of Basin Morphometry in the Saplingi Basin. Research gaps identified include the absence of studies on the Shastri Basin and the unexplored link between linear morphometry and watershed management sustainability.

Objective: The main objective of the present research is to analyse the linear aspects of the Shastri River Basin and investigate its correlation with watershed management sustainability.

Methodology: The present research work is based on primary as well as secondary data. The following flowchart provides an insight into the research methodology employed in the investigation of the subject.



Discussion and analysis: Stream ordering: Stream ordering refers to the determination of the hierarchical position of a stream within a drainage basin. A river basin consists of several branches having different positions in the basin area, they have their Morphometric characteristics, and therefore, it becomes necessary to locate the position of a segment in the basin, so that the hierarchical organization of stream segments is visualized(S. Patil, 2014).

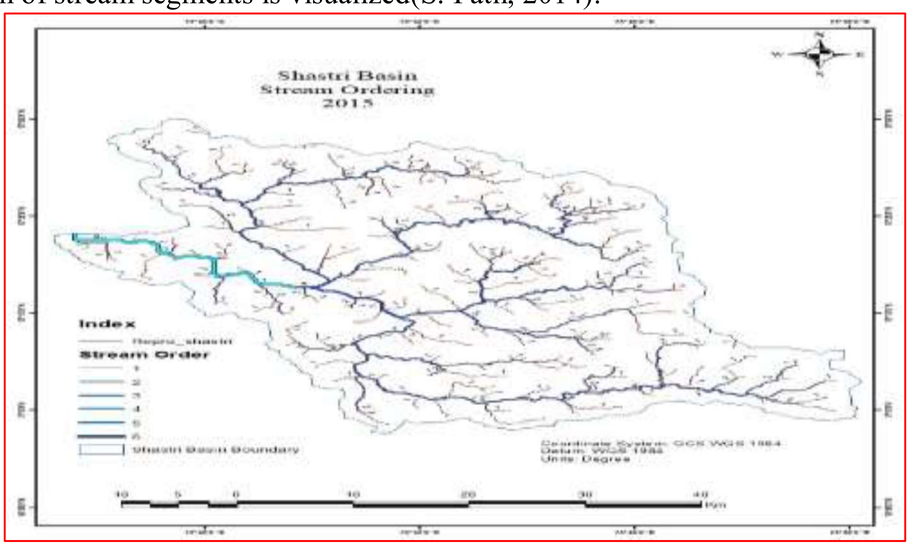


Fig. 2
Source: (National Remote Sensing Centre & Indian Space Research Organisation, 2022)

Here an attempt is made to analyze the stream order of the Basin by using Strahler's method of Stream ordering. It is observed that in the study region, stream orders are up to the sixth level. A total of 206, 87, 60, 31, 7, and 1 segments of streams are observed from the first to the sixth level of stream order, respectively. Fig. No. 2 depicts the stream ordering in the study region based on CARTOSAT DEM of 1.0 arc view second resolution.

Bifurcation ratio: Bifurcation ratio (R_b) which is related to the branching pattern of the drainage network, is defined as a ratio of the number of streams of a given order (Nμ) to the number of streams of the next higher order (Nμ+1)(Singh, 1998) and is expressed in terms of the following equation-

$$R_b = \frac{N\mu}{N\mu + 1}$$

Where,
Nμ = number of streams of a given order
Nμ+1 = the number of streams of the next higher order

Table 1. The Shastri River Basin- Bifurcation Ratio

Sr. No.	Stream order (μ)	Number of streams (Nμ)	Bifurcation ratio (R_b)
1	1	306	2.37
2	2	127	1.45
3	3	60	1.94
4	4	31	4.43
5	5	7	7.00
6	6	1	-

Source: Attribute Data of Stream Ordering in Arc-GIS (National Remote Sensing Centre & Indian Space Research Organisation, 2022)

The mean bifurcation ratio of the study region is 3.44. It is observed that the bifurcation ratio of the Shastri Basin is 2.37 for the first order. The Bifurcation ratio for the second, third, fourth, and fifth order is 1.45, 1.93, 4.43, and 7.00 respectively (S. A. Patil et al., 2022). The Bifurcation ratio of Shastri Basin is controlled by the Physiography, drainage density, stream entrance angles, lithological characteristics, basin shapes, and basin area. Initially, bifurcation ratio from first order to second order is decreased, and after that, it increases with an increase in stream order. It is also observed that number of streams decreases with increasing stream order. Figure 3 denotes changing linear pattern of Bifurcation Ratio in basin.

Law of stream numbers: The law of stream numbers relates to the definite relationship between the orders of the basins and stream numbers. R. E. Horton's law of stream numbers states (1945) 'that the number of stream segments of successively lower orders in a given basin tends to form a geometric series beginning with the single segment of the highest order and increasing according to constant bifurcation ratio' (Bloom, 1979; S. Patil, 2014; Sharma et al., 1986; Singh, 1998). In the present research work, the following equation given by R. E. Horton (Singh, 1998) is used

$$N\mu = R_b^{(k-\mu)}$$

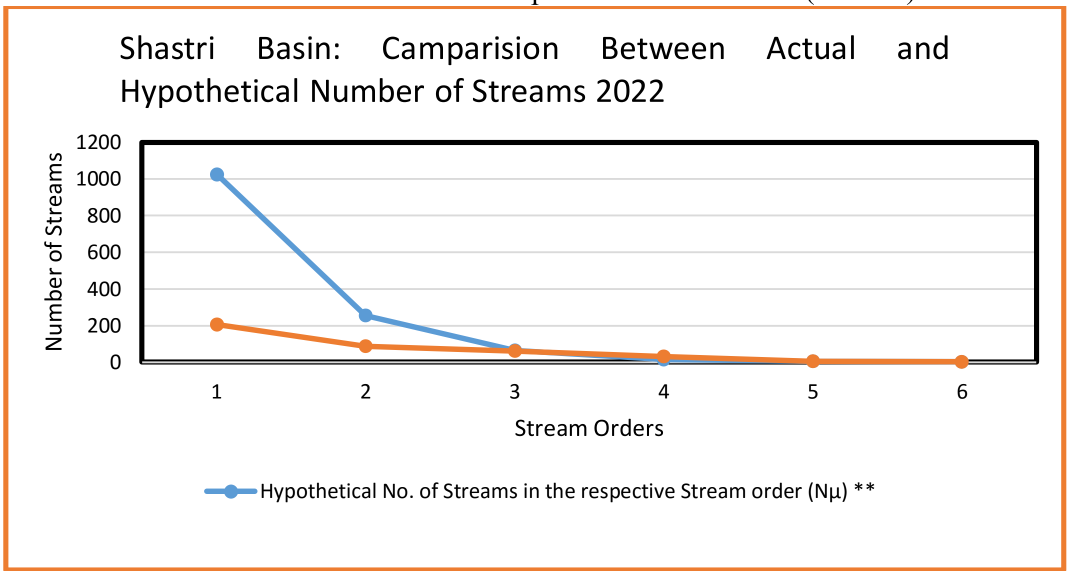
Where,
$N\mu$ = number of stream segments of a given order
R_b = constant bifurcation ratio
μ = basin order
k = highest order of the basin

Table 2 Shastri River Basin -Law of Stream Numbers

Sr. No.	Stream order (μ)	Hypothetical No. of Streams in the respective Stream order (Nμ) **	Actual No. of Streams in the respective Stream order (Nμ)*	Actual Bifurcation ratio (R_b) *	Constant Bifurcation ratio (R_b) **
1	1	1024	206	2.37	4
2	2	256	87	1.45	4
3	3	64	60	1.94	4
4	4	16	31	4.43	4
5	5	4	7	7.00	4
6	6	1	1		4

Source:
1. * (S. A. Patil et al., 2022)
2. ** (Singh, 1998)

The analysis based on R. E. Horton's equation shows that the stream numbers of The Shastri Basin are more or less in geometric series. Fig. 4 compares the actual stream numbers observed in the study region with the hypothetical stream numbers given by R. E. Horton. It is interesting to note that the law of stream numbers is best fitted except for the first and second order. The hilly area with heavy slopes at the origin of streams and the short length of the main basin as compared to the rivers in the rest of India and the world is responsible for the same. (Table 2).



Length ratio and law of stream length: The proportion of the increase in mean length of stream segments of two successive basin orders is defined as length ratio (R_L). In present research work, following equation given by Singh Savindra (Singh, 1998) is used to calculate the length ratio (R_L).

$$RL = \frac{\overline{L\mu}}{\overline{L\mu} - 1}$$

Where, $\overline{L\mu} = \frac{\sum L\mu}{N\mu}$

Where,
R_L = Length Ratio.
$\overline{L\mu}$ = is the mean length of all stream segments given order.
ΣLμ= is the sum of the length of all stream segments of a given order.
Nμ = is the number of stream segments of a given order

Table 3 Shastri River Basin- Length Ratio

Sr.No.	Stream order	Total No. of Streams in respective Stream order (Nμ)	Total Length of respective Stream order in km (ΣLμ)	Cumulative length of the stream orders	Mean Length of respective stream order in km(Lμ)	Length Ratio (RL)
1	1	206	452.16	452.16	2.19	-
2	2	87	219.89	672.05	2.53	1.15
3	3	60	139.85	811.9	2.33	0.92
4	4	31	71.95	883.85	2.32	1.00
5	5	7	14.58	898.43	2.08	0.90
6	6	1	27.12	925.55	27.12	13.02

Source: (S. A. Patil et al., 2022)

Sr.No.	Name of the River	Length of Observed Path	Length of Expected Path	Sinuosity Index
1	Shastri	72.13	51.69	1.40
2	Kapsi	51.37	24.45	2.10
3	Gad	52.46	30.52	1.72
4	Gadgadi	19.97	12.82	1.56
5	Sonavi	11.74	8.92	1.32
6	Bav	71.07	38.16	1.86
7	Saptlingi	23.68	16.89	1.40
	Average Sinuosity Index			1.62

Table 4 Shastri River Basin- Sinuosity Index Source: (S. A. Patil et al., 2022)

The total stream length of Shastri Basin is 925.55 km. The mean length of all streams is 6.43 km. Table 3.3 and Fig. 3.4 give an idea about law of stream length and length ratio. There is a negative correlation between mean length of streams and stream order, except first to orders. It means mean length of the streams is decreasing with increasing stream order. Initially, length ratio decreased up to the third order and afterward it increased and highest ratio i.e. 13.02 is recorded at sixth order.

Sinuosity index: The shape of the open link in terms of the geometric structure of the drainage line involves the calculation of deviation of the observed path (O_L) from the expected path- almost a straight line (E_L) of a river from the source to the mouth (Bloom, 1979; Jose et al., 2019; Kumari et al., 2021a, 2021b; S. Patil, 2014; Sharma et al., 1986; Singh, 1998; Thomas et al., 2012). For the calculation of the sinuosity index, the following equation given by S. A. Schumm is used.

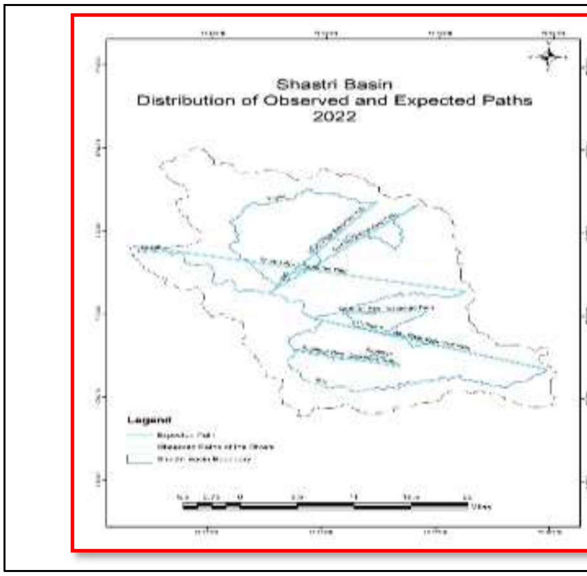
$$CS = \frac{O_L}{E_L}$$

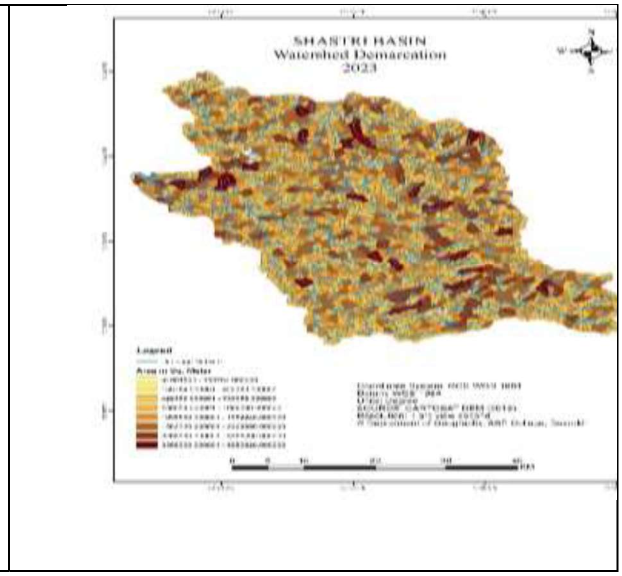
Where,
CS = Channel sinuosity
O_L = Observed path of the stream
EL = Expected straight path of a stream

Table 4 provides details about the length of the observed path and the expected path. Whereas Fig. 3.5 provides information about the deviations from the expected paths.

It is interesting to put on record that the physiographic variations in the region have affected deviations between observed and expected paths. The average sinuosity index for the Shastri basin is 1.62. The highest sinuosity index is observed in the Kapsi subbasin (2.10) whereas the lowest sinuosity index is recorded in the Sonavi subbasin (1.32). All the subbasins have a sinuosity index of more than 1.40, except the river Sonavi.

Watershed management: Linear morphometric parameters provide insights into the connectivity of a watershed. Sustainable watershed management involves preserving natural connectivity to ensure the free movement of water, nutrients, and aquatic species. This approach helps maintain biodiversity, support fisheries, and enhance the overall ecological integrity of the watershed. Understanding the linear aspects of river morphometry is crucial for effective floodplain management. Analyzing channel width, depth, and meander patterns aids in predicting flood behavior and implementing measures to mitigate flood risks. Sustainable watershed management includes the development of floodplain zoning regulations, infrastructure planning, and early warning systems to minimize the impact of floods on communities and ecosystems.





Conclusion and suggestions: The overall analysis of the linear aspects of the Shastri Basin verifies that the influence of topographical variation is found in the basin. Stream orders, bifurcation ratio, stream numbers, stream length, length ratio, deviation of the observed path from the expected, etc. are an outcome of the undulating topography and the geology of the region. The linear aspects of river morphometry are integral to sustainable watershed management. By analyzing stream length, sinuosity, channel slope, watershed connectivity, and floodplain characteristics, stakeholders can make informed decisions to preserve water resources, prevent erosion, and protect ecosystems. Incorporating these morphometric considerations into watershed management strategies is essential for achieving a harmonious balance between human activities and the natural environment.

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