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MORPHOMETRY ANALYSIS OF SITA RIVER BASIN, UDUPI DISTRICT, KARNATAKA

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ABSTRACT

The following paper documents the results and findings of morphometry analysis conducted on the Sita River basin as well as discuss the behaviour of the drainage network and the implications of the drainage behaviour on the surrounding landform, vegetation, activities, and population.

Keywords: Morphometry Analysis, river basin, GIS, remote sensing, geology, hydrology.

INTRODUCTION

Drainage basin analysis is important in any hydrological or geological study such as assessment of groundwater potential, groundwater management, environmental assessment, etc. Various hydrological phenomena can be correlated with physiographic characteristics of drainage basins such as size, shape, drainage density, slope of drainage area, etc.

Water and soil are basic and critical resources for the Udupi area in Karnataka, India. A sizable part of their economy is dependent on agriculture and fishing, food, and milk industry. Therefore, management and conservation of these resources is crucial for many reasons. An understanding of physical characteristics of watershed allows for soil and water conservation practices. The aim of this study is to quantify the morphometric characteristics of the Sita River sub-basin, which is the major source of water for the area.

Morphometric analysis is an important aspect of characterization of watersheds, involving computation of quantitative attributes of the landscape related to linear, aerial and relief aspects from elevation surface and drainage networks within a watershed *(Fenta, Yasuda, & Shimizu, 2017)*. As introduction and advancement of technology such as spatial technology, remote sensing and GIS computation happened, study of terrain and hydro morphometric characteristics were simplified.

For detailed morphometric analysis, SRTM data for preparing DEM map slope and aspect maps was acquired and used. GIS is used in evaluation of morphometric parameters. Using SRTM data, topographic maps and GIS techniques through QGIS is a fast, precise and inexpensive way for calculating morphometric analysis.

STUDY AREA

The area chosen for the purpose of morphometry analysis is the drainage network encompassing the Sita River in the Udupi district of Karnataka, India. The river is a major source of water for the area and facilitates the many operations and businesses as well as agriculture, in the area.

The Sita River basin is located in the Udupi district of Karnataka, India, between 13° 22’ 48” N 74° 42’ 00” E and 13° 30’ 00” N, 74° 51’ 00” E. The basin lies neighbouring to the city of Manipal and Udupi and has an area and perimeter of 63.8133 km^2 and 111.219 km, respectively. The study area is mostly known to be a tropical region that has excessive rainfall through most parts of the year.

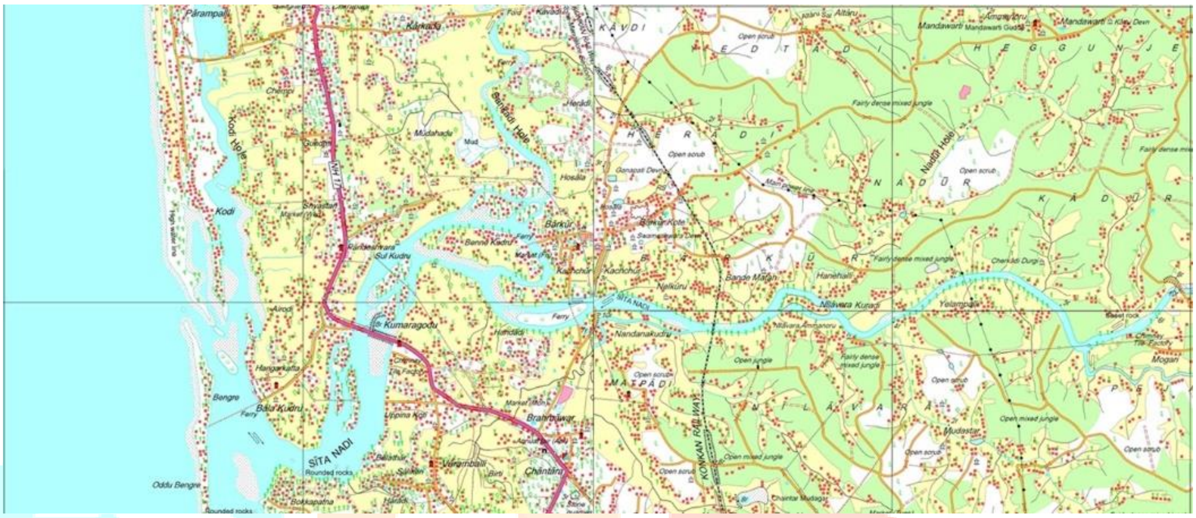

Figure 1: Open Street Map (OSM) view of the Sita River basin

METHODOLOGY

The principle behind conducting the morphometry analysis is to visualize the recorded remote sensing data (acquired through publicly available Digital Elevation Models) on top of the constructed topographic map (through topographic sheets acquired through Survey of India) and construct the drainage network to facilitate computation and analysis of the river basin, through the means of GIS software.

Through the above process the delineation of watershed is done to mark out the study area selected for the analysis. The Sita River basin has been classified into 28 sub-watersheds, all of which were considered due to having streams of at least 5 different orders.

The morphometry parameters derived from the analysis are classified into three aspect categories:

1. Linear aspects: These include stream order, stream length, mean stream length, bifurcation ratio, etc.
2. Aerial aspects: These are parameters that deal with area projected on a horizontal plane contributing overland flow to the segment of the channel of a given order. These include drainage density, drainage texture, stream frequency, form factor, circularity ratio, elongation ratio and length of overland flow.
3. Relief aspects: These include relief ratio, relative relief, and ruggedness number.

For the following study conducted in the Sita River basin area, the relevant morphometry parameters and the formulae associated with the respective parameters are tabulated below.

Formulae of Morphometry Parameters of Drainage Basin			
	Morphometry Parameter	Formula and/or Definition	Reference
Linear	Stream order	Hierarchical order	Strahler, 1964
	Stream length	Length of the stream	Horton, 1945
	Mean stream length	Lsm=Lu/Nu; Where, Lu=Mean stream length of a given order(km), Nu=Number of stream segment.	Horton, 1945
	Bifurcation ratio	Rb = Nu / Nu+1 Where, Nu=Number of stream segments present in the given order, Nu+1= Number of segments of the next higher order	Horton, 1945
Aerial	Drainage density (Dd)	Dd=L/A Where, L=Total length of stream, A= Area of basin.	Horton, 1945
	Stream frequency (Fs)	Fs=N/A Where, L=Total number of streams, A=Area of basin	Horton, 1945
	Texture Ratio (T)	T=N1/P Where, N1=Total number of first order stream, P=Perimeter of basin.	Horton, 1945
	Form Factor (Rf)	Rf=A/(Lb)2 Where, A=Area of basin, Lb=Basin length	Horton, 1945
	Circularity Ratio (Rc)	Rc=4πA/P2 Where A= Area of basin, π=3.14, P= Perimeter of basin	Miller, 1953
	Elongation Ratio (Re)	Re=√(Au/π)/ Lb Where, A=Area of basin, π=3.14, Lb=Basin length	Schumn, 1956
	Length of overland flow (Lg)	Lg=1/2Dd Where, Drainage density	Horton, 1945

Table 1: Formulae of Morphometry Parameters of Drainage Basin (Horton, 1945) (Strahler, 1964)

RESULTS AND DISCUSSION

The Sita River basin has a catchment area of 63.81 km^2 and a perimeter of 111.219 km, having largest stream length of 35.96 km. The elevation of the study area goes as low as 1m and has a maximum elevation of 56m. Generally, this low elevation could entail floods and other overland flow conditions, but due to the rainfall patterns and increasing elevation through the city, these situations seldom occur.

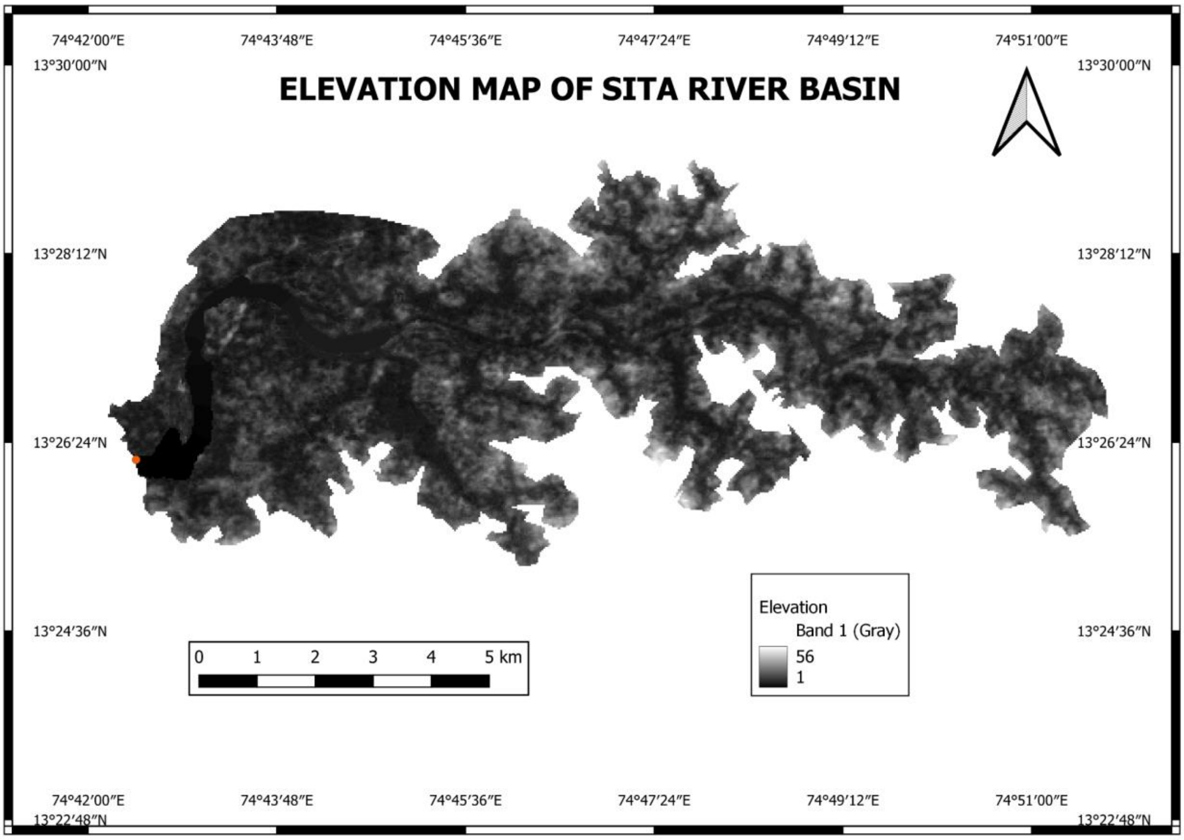

Figure 2: Elevation map of Sita River Basin

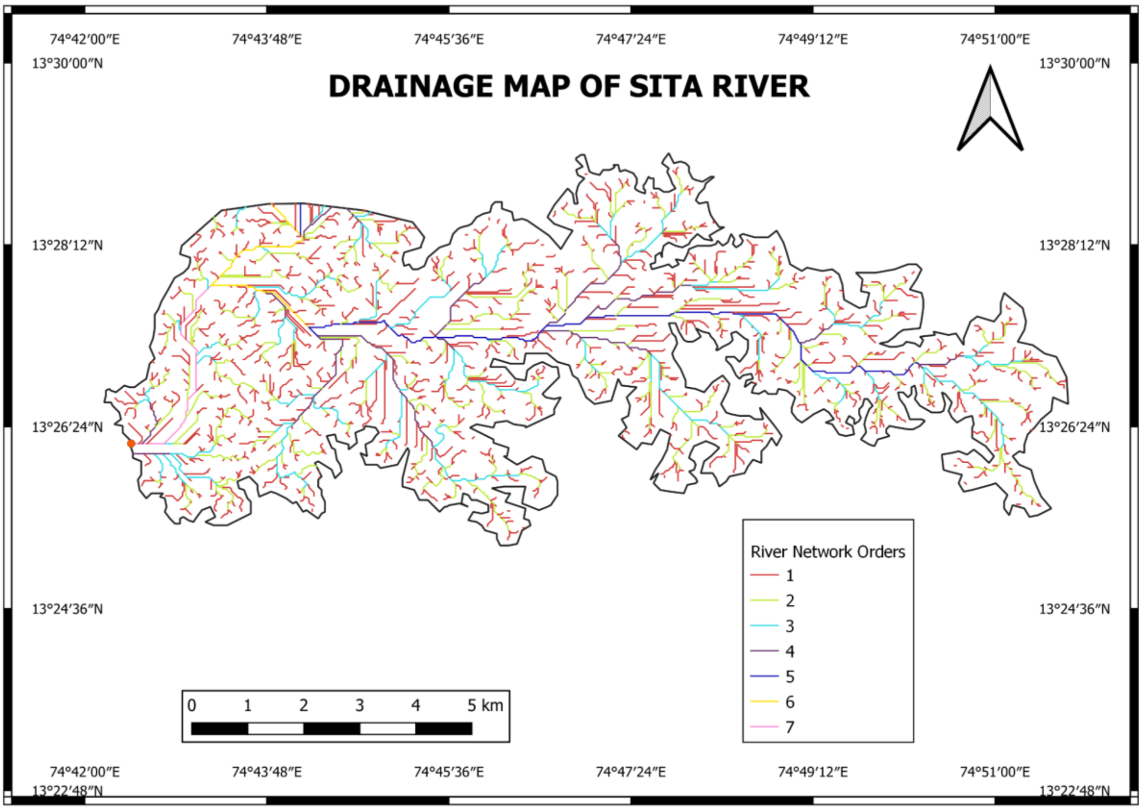

Figure 3: Drainage network of Sita River basin

In the following section the various morphometric parameters have been discussed regarding the derived cluster groups.

• **Drainage network:** Segmentation and hierarchical ordering of streams is necessary to address the hydrodynamic character of a drainage basin. Stream ordering has been done for Sita River basin following the hierarchical ranking proposed by Strahler. The total stream length of Sita River basin is 245.785km, of which the 1st and 2nd order streams constitute 79.14%. The stream length ratio varies from 0.11 to 0.53 and is high for 2nd and 3rd order streams in the Sita basin. With increasing stream order there is a decrease in stream number. With increasing stream order there is a decrease in stream number. The bifurcation ratio values for Sita basin ranges from 1.88-9.

• **Basin Geometry:** Basin shape is controlled by factors such as structure, lithology, precipitation, relief, etc. and varies from narrow elongated forms with irregular basin perimeter to circular or semi-circular forms. Circularity ratio of Sita basin ranges from 0.09 to 0.48, with high values in WS2, WS6, WS14, WS15, WS16, WS19, WS20, WS23 and low values in WS7, WS9, WS11, WS12, WS13, WS22, WS25 and WS27.

High values of form ratio and elongation ratio are found in WS1, WS2, WS3, WS6, WS9, WS11, WS13, WS16, and WS19 and low values in WS4, WS5, WS11, WS12, and WS25.

The relative spacing of channels in a drainage basin is expressed by texture ratio. The texture ratio values of Sita basin range from 0.34 to 3.50. High texture values are found in sub watersheds located in the upper reaches of the basin, whereas low texture values are found in sub watersheds located near the mouth of the basin.

• **Drainage Texture Analysis:** Texture indicates the amount of landscape dissection by a channel network and includes stream frequency, drainage density and length of overland flow. High values of stream frequency and drainage density are found in WS2, WS6, WS9 WS19, WS23, and WS24, whereas low values of stream frequency and drainage density are found in WS1, WS11, WS12, WS13, WS14, WS27 and WS28.

. The length of overland flow (*Lg*) values of Sita basin ranges from 0.0003 to 0. 0134.. Low *Lg* values are found in WS2, WS8, WS9, WS14, WS15, WS16, WS19, WS2 and WS24. Stream frequency and drainage density provide a numerical measurement of landscape dissection and run-off potential and bears a negative relationship with length of overland flow. The high values of stream frequency and drainage density in these sub-watersheds maybe due to high relief, steep slopes, and low permeability of the underlying rocks.

• **Relief Characteristics:** The relief properties in morphometric analysis bring into consideration the influence of aspect and height over a large basin area. Relief helps to indicate the erosion potential of the processes operating within a drainage basin. The total basin relief of Sita River basin is 55 m. The relief value of Sita basin ranges from 9m - 38m, with high values in WS1, WS3, WS5, WS12, WS13, WS14, WS15, WS16, WS18, WS24, and WS28, and low values in WS4, WS6, WS8, WS9, WS21, WS23, and WS25. Relief is related to the channel gradient and has a negative relationship with basin length.

Stream Order	Stream Number	Stream Length	Bifurcation Ratio (Rb)
1	1041	1890.803	2.1245
2	490	889.997	20.2481
3	242	43.9546	0.2262
4	107	194.3541	2.0981
5	51	92.6313	1.6449
6	31	56.3153	1.7225
7	18	32.6947	-

Table 2: Morphometry Parameters of Watershed

Sub watersheds	Area (Km^2)	Perimeter (Km)	Basin Length (Km)	Total basin relief (R)
SW1	3.0489	11.5545	2.0170	35.0000
SW2	0.1784	2.2481	0.5000	9.0000
SW3	0.8301	6.2643	1.3740	26.0000
SW4	0.5158	4.9251	1.4620	18.0000
SW5	0.9724	7.6582	1.6260	28.0000
SW6	0.2884	3.3439	0.6030	18.0000
SW7	1.0528	8.6231	1.8220	19.0000
SW8	0.6452	5.7136	1.2250	14.0000
SW9	0.7626	6.9271	1.0200	12.0000
SW10	0.3605	3.8931	0.8980	20.0000
SW11	5.6798	22.9756	3.2140	19.0000
SW12	3.8660	16.3042	4.6060	30.0000
SW13	4.0008	18.1557	2.4230	29.0000
SW14	3.2694	10.1479	2.1740	35.0000
SW15	1.3034	7.3562	1.7200	28.0000
SW16	0.4474	4.0775	0.6070	38.0000
SW17	1.5639	9.3069	1.5890	21.0000
SW18	1.4863	9.0571	1.8030	32.0000
SW19	0.2052	2.3094	0.4930	17.0000
SW20	0.4428	4.0709	0.8510	23.0000
SW21	0.5343	4.9263	1.0130	17.0000
SW22	1.1536	9.3086	1.7650	23.0000
SW23	0.2773	2.9856	0.7590	17.0000
SW24	0.3596	4.1352	0.8000	32.0000
SW25	2.1464	12.5125	2.4430	18.0000
SW26	0.6313	5.2924	1.1110	37.0000
SW27	6.6095	29.1832	4.2680	25.0000
SW28	0.4844	5.1147	0.8960	38.0000

Table 3: Linear morphometry parameters, per sub watershed

Sub watersheds	Length of Overland flow (Lo)	Drainage Density (Dd)	Stream Frequency (Nf)	Texture Ratio (Rt)	Circularity ratio (Rc)	Elongation Ratio (Re)	Form Factor (Rf)
SW1	0.0062	0.1180	481.4923	0.6829	0.2870	0.9768	0.7494
SW2	0.0004	2.0157	8227.9974	3.5096	0.4436	0.9532	0.7137
SW3	0.0017	0.4332	1768.4136	1.2595	0.2658	0.7482	0.4397
SW4	0.0010	0.6972	2845.9679	1.6020	0.2672	0.5543	0.2413
SW5	0.0020	0.3698	1509.6060	1.0303	0.2084	0.6843	0.3678
SW6	0.0006	1.2470	5090.2856	2.3596	0.3241	1.0049	0.7931
SW7	0.0021	0.3416	1394.3699	0.9150	0.1779	0.6354	0.3171
SW8	0.0013	0.5574	2275.1896	1.3809	0.2484	0.7399	0.4300
SW9	0.0016	0.4716	1925.0275	1.1390	0.1997	0.9660	0.7330
SW10	0.0007	0.9976	4072.1582	2.0266	0.2989	0.7544	0.4470

SW11	0.0116	0.0633	258.4616	0.3434	0.1352	0.8367	0.5498
SW12	0.0079	0.0930	379.7237	0.4839	0.1828	0.4817	0.1822
SW13	0.0081	0.0899	366.9295	0.4346	0.1525	0.9315	0.6815
SW14	0.0067	0.1100	449.0162	0.7775	0.3989	0.9385	0.6917
SW15	0.0027	0.2759	1126.2982	1.0726	0.3027	0.7490	0.4406
SW16	0.0009	0.8039	3281.3230	1.9350	0.3381	1.2434	0.9948
SW17	0.0032	0.2300	938.6711	0.8478	0.2269	0.8881	0.6194
SW18	0.0030	0.2420	987.7041	0.8711	0.2277	0.7630	0.4572
SW19	0.0004	1.7526	7153.9559	3.4164	0.4835	1.0368	0.8443
SW20	0.0009	0.8123	3315.6138	1.9381	0.3357	0.8823	0.6114
SW21	0.0011	0.6731	2747.6183	1.6016	0.2767	0.8142	0.5207
SW22	0.0023	0.3117	1272.5153	0.8476	0.1673	0.6867	0.3703
SW23	0.0006	1.2968	5293.5743	2.6427	0.3909	0.7829	0.4814
SW24	0.0007	1.0001	4082.3572	1.9080	0.2643	0.8458	0.5619
SW25	0.0044	0.1676	683.9478	0.6306	0.1723	0.6767	0.3596
SW26	0.0013	0.5697	2325.2818	1.4908	0.2832	0.8070	0.5115
SW27	0.0134	0.0544	222.1032	0.2704	0.0975	0.6797	0.3628
SW28	0.0010	0.7424	3030.5832	1.5426	0.2327	0.8765	0.6034

Table 4: Relief morphometry parameters, per sub watershed

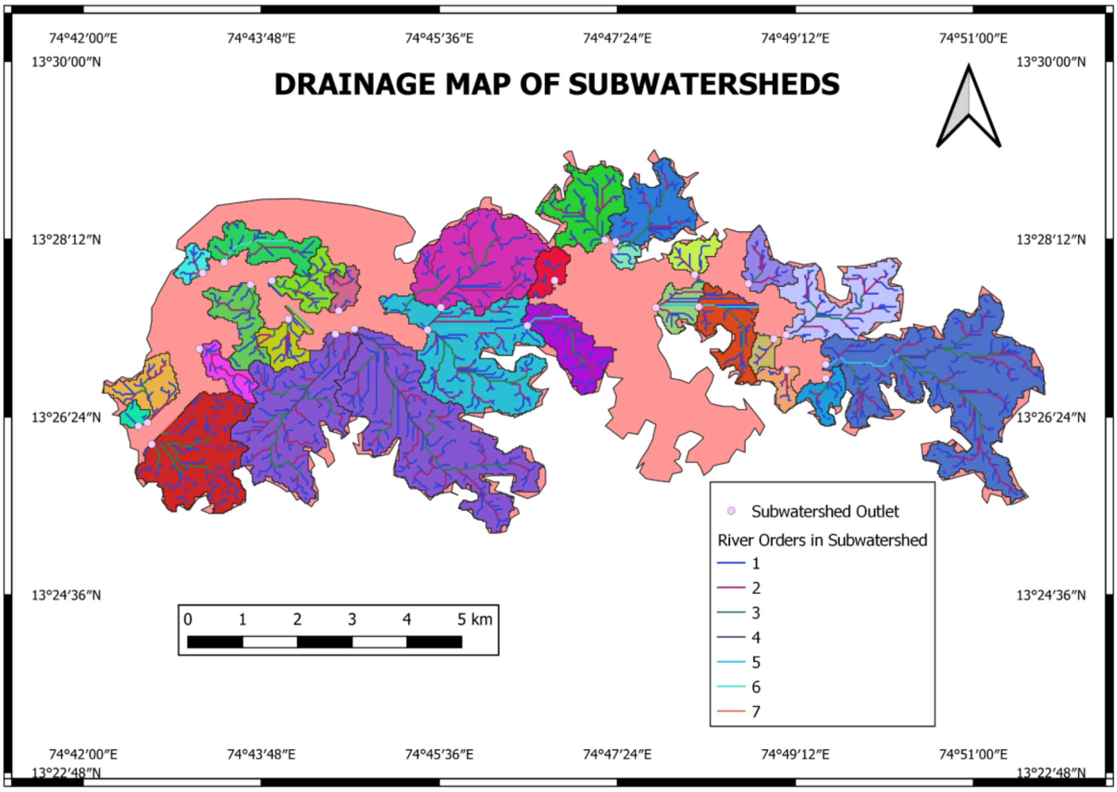

Figure 4: Drainage network classified by stream order in sub watersheds

Prioritisation was done with the help of Fuzzy analytic hierarchy process. For various criteria, the fuzzy analytic hierarchy process (AHP) shows to be a highly useful tool for making decisions in a fuzzy environment, which has found substantial applications in recent years. A crisp point estimate method, such as extent analysis or fuzzy preference programming (FPP) based nonlinear method for fuzzy AHP priority derivation, is used for the great majority of applications. The application of fuzzy AHP for multiple-criteria decision-making necessitates scientific techniques to weighting fuzzy pairwise comparison matrices. There are two types of fuzzy AHP weight derivation methods that are currently in use, one of them involves generating a set of fuzzy weights from a fuzzy pairwise comparison matrix., while the other one involves deriving a set of crisp weights from a fuzzy pairwise comparison matrix (*Wang & Chin, 2011)*. The first method was adopted for the prioritisation of sub watersheds. The geometric mean method was primarily used to derive fuzzy weights from fuzzy pairwise comparison matrices. After Fuzzy AHP was conducted, the results showed the high priority sub watersheds as SW27, SW11, SW2, SW12, SW13, SW19 and SW25 and the low priority watersheds as SW16, SW26, SW28, SW15, SW3, SW18 and SW24.

Basin	Priority	Priority Order
SW27	0.6010	1
SW11	0.5433	2
SW2	0.5376	3
SW12	0.4338	4
SW13	0.4016	5
SW19	0.3796	6
SW25	0.3763	7
SW9	0.3714	8
SW23	0.3564	9
SW8	0.3506	10
SW4	0.3395	11
SW6	0.3355	12
SW7	0.3303	13
SW10	0.3185	14
SW21	0.3156	15
SW14	0.3095	16
SW1	0.3080	17
SW22	0.3074	18
SW17	0.3026	19
SW20	0.2770	20
SW5	0.2744	21
SW24	0.2693	22
SW18	0.2679	23
SW3	0.2647	24
SW15	0.2638	25
SW28	0.2411	26
SW26	0.2325	27
SW16	0.2214	28

Table 5: Priority Order Assessment

CONCLUSION

Prioritization of the watershed is one of the most essential components of planning for the development and maintenance of the watershed. The current work highlights the utility of remote sensing and geographic information systems (GIS) for morphometric analysis and the prioritisation of sub-watersheds of Sita River in Udupi, Karnataka, India. Different sub-watersheds' morphometric characteristics help to reveal their relative qualities in terms of the watershed's hydrologic responsiveness. Sub-watersheds SW27 and SW11 have a very high priority and are more vulnerable to land degradation and soil erosion, as per the results after sub-watershed prioritisation. The basin's bifurcation ratio, length ratio, and stream order show that it's a seventh-order basin with a dendritic drainage pattern, homogenous nature, and no structural or tectonic influence. The research visual interpretation of the DEM shows little to no relief, indicating a very early mature stage of erosion development. The drainage basin's thorough morphometric analysis suggests that the offered area has an excellent groundwater potential. The findings suggest that analysing multiple morphometric characteristics in a GIS system can be used effectively for watershed prioritising, soil and water conservation, and natural resource management at the watershed level, as well.

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