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Geospatial technique for sub-watershed prioritization

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ABSTRACT

Watershed priority and drainage network description are quantified by morphometric analysis. The present study was conducted for the Upper Godavari river basin, which is about 8,927.25 km^2 in size and is situated in Maharashtra, India. Sub-watersheds of Upper Godavari river basin were prioritized using two different methods viz. LULC and Morphological analysis. The main challenges of geomorphological study include complexity of natural landscapes, data limitations and integration of multiple systems, technological constraints, interpretation subjectivity, and resource or funding issues. Geomorphological analysis has contributed significantly to understanding Earth's surface processes, landform evolution, environmental management, and hazard assessment through advances in theory, technology, and application. The seventh-order river basin was the Upper Godavari river basin sub-watersheds. All sub-watershed in Upper Godavari river basin had an elongated to circular shape, according to all morphometric criteria, including the circularity ratio (0.24–0.43), elongation ratio (0.76-0.89) and form factor (0.46-0.79). Sub-watersheds SW1 and SW2 were classified as low priority, SW4 and SW5 as moderate priority, and SW3 as higher priority based on morphological studies. Sub-watersheds SW2 and SW5 were classified as low priority, SW3 and SW4 as moderate priority, and SW1 as higher priority based on the LULC study. According to the sub-watershed's final prioritization, SW2 was categorized as low priority, SW4 and SW5 as moderate level, and SW1 and SW3 as higher priority. LULC changes were assessed for Upper Godavari river basin sub-watersheds in 2004 and 2019. The result revealed that watershed management will be required for increased agriculture and watershed management.

Keywords: *Remote Sensing, Geographical Information System (GIS), Morphometric, Prioritization, Land use/ land cover.*

1. Introduction

Morphometric analysis is generally used to study the quantitative description of the drainage network [30] and prioritization of the watershed [19]. Analysis of the drainage network helps to study the hydrologic processes and environmental assessment by providing information about slope, topography, drainage characteristics and surface runoff generation [11]. Because of these benefits, morphometric analysis is also utilized in basin level planning, flood management planning [28], and planning for erosion control methods that are used for planning of watershed management strategies ([16]; [14]).

Horton first suggested morphometric studies of river basins, while Coates (1958) and Strahler (1964) expanded the concept. The simplest and most sensible method for determining the various watershed attributes is watershed analysis. Hydrological research benefit from its quantitative explanation of drainage patterns [25].

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Prioritizations are greatly influenced by morphometric features like shape and linear characteristics, where the priorities are directly related to the linear aspects and inversely related to the shape aspects. Increased soil loss intensifies the need for watershed development, whereas reduced soil loss lessens this requirement, emphasizing the role of morphological features and LULC in watershed prioritization [2].

Numerous studies have shown the usefulness of morphometric analysis integrated with geospatial techniques to develop sustainable resource management strategies and identify priority areas ([1]; [12]; [19]; [20]; [24]). Considering the importance of morphometric analysis and taking the advantages of this geospatial technology the present study was undertaken for sub-watershed prioritization of the Upper Godavari river basin.

1.1 Scope of study

- **Integration with Digital Technologies:** More use of remote sensing, GIS, LiDAR, drones, and big data for high-resolution, process-driven landscape mapping.
- **Automation and Machine Learning:** Semi-automated procedures and AI will allow rapid analysis and predictive modeling of landscape changes.

- **Anthropogenic Impact Research:** Studying human-induced landscape alterations and their implications for sustainability.
- **Planetary Geomorphology:** Comparative studies of landforms on Earth and other planets such as Mars.
- **Climate Change Adaptation:** Geomorphological insight will be vital for forecasting hazards and supporting environmental planning.

2. Materials and Methods

2.1 Study Area

In the present study, the Upper Godavari river basin was used as a study area, which is situated in Maharashtra, India. Its geographic size is approximately 8,927.22 km^2, and its latitudes range from 19°40' N to 20°30' N and its longitudes from 73°30' E to 74°50' E. The watershed's perimeter is 613.24 km. The study area's location map is displayed in Fig.1. The research area's highest temperature each year ranged from 31°C to 33.5°C. Less than 600 mm of rain fell annually in the Upper Godavari river basin [31].

2.2 Morphometric characteristics of the watershed for prioritization

The Upper Godavari river basin delineation was conducted using the ALOS PALSAR DEM (12.5 m resolution imagery downloaded from "https://search.asf.alaska.edu") in ArcGIS 10.3 software. The methodology adopted for extracting morphological characteristics of the Upper Godavari river basin is as given in Fig. 2.

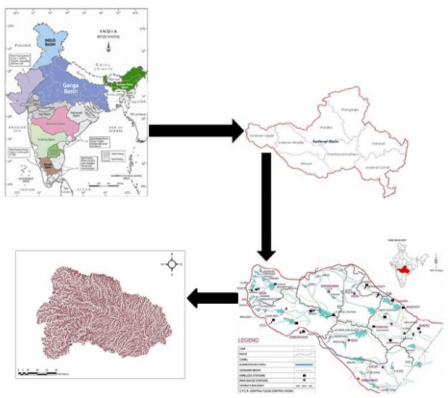

Figure 1: Upper Godavari river basin

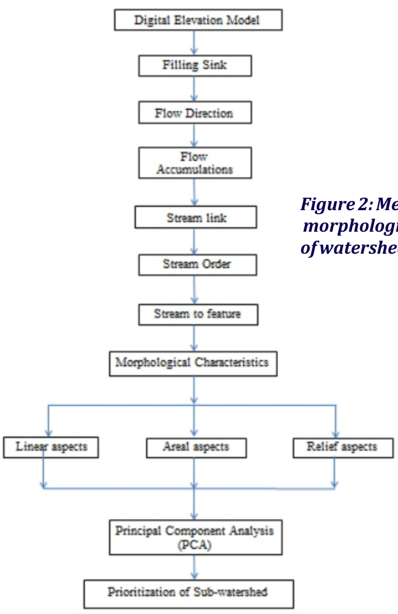

Figure 2: Methodology for morphological analysis of watershed

The following is a detailed description of the morphological analysis employed in this study.
According to Suresh (2023), the linear aspect is also known as the linear aspect of the channel system. This includes the analyses of the overland flow's length, drainage density, stream order, stream frequency, stream length, bifurcation ratio and drainage texture.

Stream order (U) and Stream number (Nu)

Streams having the smallest tributaries are considered first-order streams in Strahler's (1964) dendritic stream ordering system. Significantly, stream density is inversely correlated with landscape maturity; landscapes that are actively deteriorating tend to have higher densities [18].

Stream length (l_u)

All successive stream lengths inside the watershed are added together to determine the total stream length (Lu) [22]. Slope steepness and finer texture are indicated by shorter stream segments, while a watershed with a low gradient is indicated by longer segments [25]. It is a measure of the drainage extent and the hydrological properties of the bedrock [13].

Bifurcation ratio (R_b)

The number of streams in a given order divided by the number of streams in the next higher order is known as the bifurcation ratio (Rb) [25]. The stream orders distribution in a drainage area is measured by this dimensionless metric [3].
For a well-developed drainage network, the bifurcation ratio (Rb) ranged between 2 to 5 ([9]; [26]). A drainage basin that has a (Rb) value less than or equal to 2.0 is a flat or rolling drainage basin, whereas one that has a value of 3–4 is a very stable drainage basin and one that has a value of 4-5 is homogeneous bedrock [9].

The formula for bifurcation ratio [9] is

$$R_b = \frac{N_u}{N_{u+1}} \text{ ---- (1)}$$

Where,

R_b = Bifurcation ratio;
N_u =Total number of stream segments of order u;
N_u = Total number of stream segments of the next higher order

Drainage density (D_d)

The sum of all streams lengths in a unit area represents the drainage density (D_d), which is an important metric in drainage basin analysis ([8]; [9]; [25]).
The formula for drainage density is

$$D_d = \frac{\sum L_u}{A} \text{ ---- (2)}$$

Where,

D_d = Drainage density;
L_u = Total length of stream segments of order u;
A = Area of the basin

Stream frequency (F_s)

The total number of streams of all orders divided by basin area represents stream frequency [9].
The formula for stream frequency is

$$F_s = \frac{\sum N_u}{A} \text{ ---- (3)}$$

Where,

F_s = Stream frequency;
N_u =Total number of stream segments of order u;
A = Area of the basin

Drainage texture (R_t)

The total number of streams of all order divided by basin's perimeter represents drainage texture ([9]; [21]).

The formula for the drainage texture is

$$R_t = \frac{N}{P} \text{ ---- } (4)$$

Where,

R_t = Drainage texture;

N = Total number of stream segments of all orders;

P = Perimeter of the basin

Length of overland flow (L_g)

It is the reciprocal to drainage density, which is expressed by the distance that water travels across land before condensing into stream channels [9].

$$L_g = \frac{1}{2D_d} \text{ ---- } (5)$$

Where

L_g = Length of overland flow ;

D_d = Drainage density

2.2b Areal Aspects

It includes an explanation of the arrangement of the areal element's [27]. It comprises the compactness coefficient, basin shape, form factor, elongation ratio and circularity ratio.

Form factor (F_f)

It is represented by the ratio of the basin's size to the square of its length. Runoff patterns are greatly influenced by the form factor ([8]; [9]). While more compact basins have high form factors, which tend to have higher peak flows for shorter duration, elongated basins have low form factors, which tend to have lower peak flows for longer duration [29].

The formula for the form factor is

$$F_f = \frac{A}{{L_b}^2} \text{ ---- } (6)$$

Where,

F_f = Form factor;

A =Area of the basin;

L_b = Basin length

Basin Shape (B_s)

It represented by the ratio of the square of length of the basin to the basin area ([8]; [9]).

$$B_s = \frac{L_b^2}{A} \text{ ---- } (7)$$

Where,

B_s = Basin Shape;

A = Area of the basin;

L_b = basin length

Circularity ratio (R_c)

Geological formations that are very elongated, permeable, and homogeneous are indicated by (R_c) values that fall between 0.40 and 0.50 ([15]; [23]).

The formula for the circularity ratio is

$$R_c = \frac{4\pi A}{P^2} \text{ ---- } (8)$$

Where,

R_c = Circularity ratio;

A =Area of the basin;

P = Perimeter of the basin

Elongation ratio (R_e)

Strahler (1964) defined the elongation ratio (R_e) as follows: oval (between 0.8 to 0.9), circular (greater than 0.9), less elongated (between 0.7 to 0.8), and elongated (less than 0.7).

The formula for the elongation ratio is

$$(R_e) = (\frac{2}{L_b}) \text{ x } (\frac{A}{\pi})^{0.5} \text{ ---- } (9)$$

Where,

R_e = Elongation ratio;

A = Area of the basin

Compactness coefficient (C_c)

According to Gravelius (1914) and Horton (1945), the compactness coefficient is the ratio of the basin's actual perimeter to the perimeter of a circle having an area equal to the basin. Higher capacity for runoff and greater vulnerability to erosion are indicated by a lower compactness coefficient (Cc).

The formula for the compactness coefficient is

$$C_C = 0.2841 \text{ x } (\frac{P}{A})^{0.5} \text{ ---- } (10)$$

Where,

P = Perimeter of the basin;

A = Area of the basin

2.2c Relief Aspects

It includes the relief ratio and relative relief.

Relief ratio (R_f)

This ratio shows the steepness of the watershed and the susceptibility of the watershed to erosion.

The formula for the relief ratio is

$$R_f = \frac{H}{L_b} \text{ ---- } (11)$$

Where,

R_f = Relief ratio;

H =Total relief of the basin;

L_b = Basin length

Relative Relief (Rr)

This parameter relates basin steepness to erosion potential, essentially representing the average watershed slope. Studies have shown a strong correlation between (R_r) and sediment yield [21].

The formula for the relative relief is

$$R_r = \frac{H}{L_p} \text{ x } 100 \text{ ---- } (12)$$

Where,

R_r = Relative relief

H =Total relief of the basin

L_b = Length of perimeter

2.2d Sub-watershed prioritization for morphometric analysis

The first priority was assigned sub-watersheds that had the highest linear parameters, which were directly related to erosion properties. The ranks that followed were given in decreasing order. Shape parameters showed an inverse association with erosion properties; sub-watersheds with the lower values were given the higher ranking of priority, and ranks were then given in ascending order [2]. Sub-watershed prioritization for morphometric analysis was determined using the compound value (CP) of all ranks given to all parameters of morphometric analysis.

2.3 Land use and land cover (LULC) analysis for prioritization

The general purpose of mapping LULC is to find out changes in development and in land use. To comprehend how quickly LULC is changing over time and place, this change detection is crucial. Such land-use change monitoring aids in regulatory actions, policy decisions, and follow-up land-use activities [17].

In the present study, Saga GIS software was used to perform supervised classification utilizing Landsat 7 images for LULC analysis for the years 2004 and 2019. The various LULC types, including agricultural land (AL), forest land (FL), waste land (WL), waterbodies (WB) and Built-up (BU). The description of Landsat 7 imagery used for LULC (Table 1).

Table 1 Information about Landsat 7 imagery

Sr. No.	Satellite	Date	Path/Row	Source
1	Landsat 7	25 December 2014	147/46	https://earthexplorer.usgs.in
2	Landsat 7	7 December 2019	147/46	https://earthexplorer.usgs.in

2.3a Sub-watershed prioritization for LULC analysis

In the present study, the difference in per cent of area of each class with the total was used for sub-watersheds prioritization using LULC analysis. As per these values of this difference, the higher the percentage change the greater the requirement of the development of the watershed. Hence there is a first priority to such a watershed and vice versa [6]. Sub-watershed prioritization for LULC analysis was determined using the compound value (CP) of all ranks given to per cent change in area of LULC with total.

2.4 Final Sub-watershed prioritization by integrating morphometric analysis and LULC analysis

The ultimate sub-watershed prioritization of Upper Godavari river basin was determined in this study using the compound value (CP) of both morphometric and LULC analyses.

3. Results and discussions

3.1 Morphometric analysis

Fig. 3 represents a stream order map of the Upper Godavari river basin. The morphometric characteristics (shown in Fig. 4) of each sub-watershed of the Upper Godavari river basin were examined; the results are presented numerically in Tables 2 and 3.

3.1a Linear Aspects

Stream order (U) and Stream number (Nu)

The highest stream order in a drainage network carries massive runoff. First-order stream and second-order streams were most widely distributed in the sub-watersheds SW4 and SW5. This suggests that erosion predominates in these watersheds.

Stream length (L_u)

The stream lengths in SW4 and SW5, which were SW3, SW1, and SW2, respectively, were comparatively longer. This suggests that the greatest density of smaller streams in these places is causing the stream length to expand.

Bifurcation ratio (R_r)

The Upper Godavari river basin sub-watersheds had a bifurcation ratio between 3.45 and 4.66. SW1 had the greatest Rb (4.66), while SW5 had the lowest Rb (3.45).

Drainage density (D_d)

The sub-watersheds of the Upper Godavari river basin had drainage densities (Dd) ranging from 1.83 to 2.06. SW4 had the greatest Dd (2.06), while SW1 had the lowest Dd (1.83).

Stream frequency (F_s)

The sub-watersheds SW3 (2.07) and SW5 (2.05) had comparatively higher stream frequencies (Fs), which leads to the greatest runoff and increased susceptibility to soil erosion.

Drainage texture (R_t)

The drainage texture are classified as follows: very coarse (Rt < 2), coarse (2 ≤ Rt ≤ 4), moderate (4 ≤ Rt ≤ 6), fine (6 ≤ Rt ≤ 8), and very fine (Rt > 8) [10]. Based on classification, every sub-watershed had a drainage texture rating greater than eight, meaning that every sub-watershed in the Upper Godavari river basin had an exceptionally fine drainage texture.

Length of overland flow (L_g)

Length of overland flow (Lg) have higher value indicated a watershed with stronger percolation and less surface runoff [5]. The low overland flow length in all sub-watersheds of the Upper Godavari river basin indicated significant surface runoff and little percolation.

3.1b Areal Aspects

Form Factor (F_f)

Upper Godavari river basin sub-watersheds had a form factor values ranging from 0.46 (SW3) to 0.79 (SW5). With larger peak flows of shorter duration, all of the sub-watersheds had a fairly circular form, according to the higher value of form factor.

Basin Shape (B_s)

Table 5 shows that SW5 in the Upper Godavari river basin sub-watersheds had the lowest value of (B_s), indicating a high likelihood of flooding.

Circularity ratio (R_c)

Highly elongated, permeable, and uniform geological formations are indicated by the value of (R_c) for SW1, which ranged from 0.40 to 0.50 [15].

Elongation ratio (R_e)

For sub-watershed SW3, the elongation ratio (Re) was 0.76, indicating a less elongated sub-watershed structure. Other sub-watersheds of the Upper Godavari river basin watershed, such as SW5 (0.89), SW4 (0.87), SW2 (0.85), and SW1 (0.83), had oval to circular shapes, as indicated by their respective elongation ratios (Re), which were shown in brackets.

Compactness coefficient (C_c)

All of the sub-watersheds of the Upper Godavari river basin had compactness coefficients between 0.097 and 0.1299. Higher runoff potential and greater erosion susceptibility were indicated by the lower value of the compactness coefficient of sub-watersheds of the Upper Godavari river basin [7].

3.1c Relief Aspects

Relief ratio (R_f)

All sub-watersheds of the Upper Godavari river basin had relief ratios between 0.0089 and 0.0203.

Relative Relief (R_r)

All sub-watersheds of the Upper Godavari river basin had relief ratios between 0.111 and 0.5135.

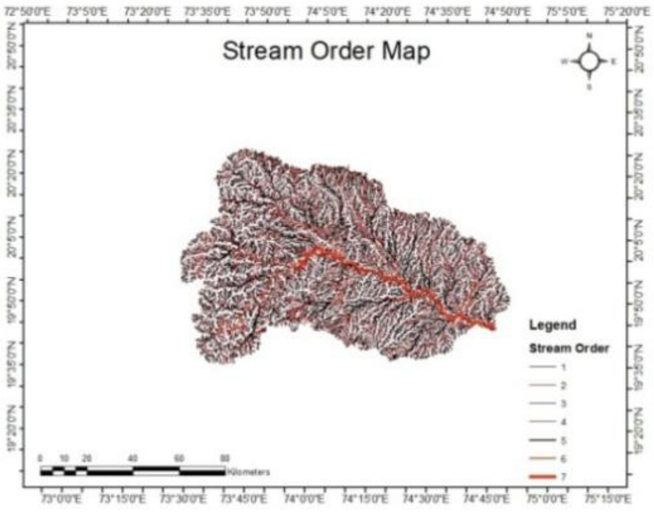

Figure 3: Upper Godavari river basin Stream order map

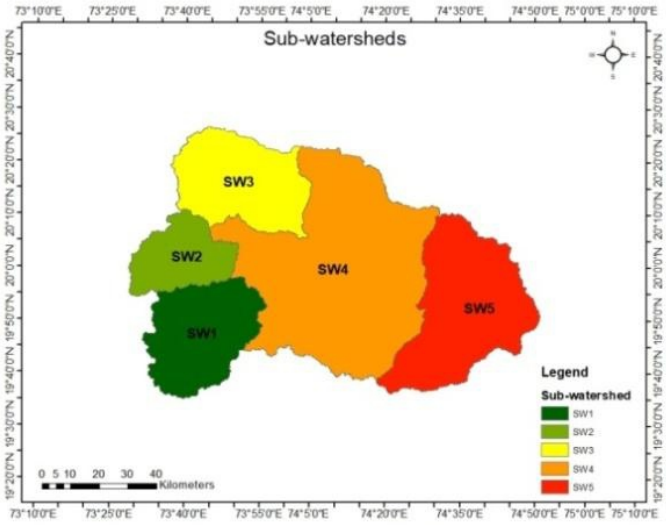

Figure 4: Sub-watershed of the Upper Godavari river basin

Table 2: Morphometric basic parameters for Sub-watersheds of the Upper Godavari river basin

Sub-wateSub-rshed	Number of stream order							Total length of stream (km)	Area of basin (km^2)	Basin perimeter (km)
	1^{st}	2^{nd}	3^{rd}	4^{th}	5^{th}	6^{th}	7^{th}			
SW1	1862	454	107	24	5	1	-	2268.1779	1238.424	190.646
SW2	1129	265	63	13	3	1	-	1397.5632	737.642	154.2529
SW3	2111	472	101	23	4	1	-	2570.3038	1311.331	210.532
SW4	5631	1290	279	65	14	6	1	7715.2433	3730.14	437.479
SW5	3025	702	145	36	9	2	1	3807.956	1909.689	291.241

Table 3: Morphometric analysis of Sub-watersheds of the Upper Godavari river basin

Sub-Watersheds	Morphometric Aspects											
	Linear aspects					Shape aspects					Relief aspects	
	R_b	D_d	F_s	R_t	L_g	F_f	B_s	R_c	R_e	C_c	R_f	R_r
SW1	4.66	1.83	1.98	12.87	0.27	0.53	1.86	0.43	0.83	0.1115	0.0203	0.5135
SW2	3.9	1.89	1.99	9.56	0.2639	0.57	1.74	0.38	0.85	0.1299	0.02	0.4655
SW3	4.62	1.96	2.07	12.88	0.2551	0.46	2.19	0.37	0.76	0.1138	0.01453	0.37
SW4	4.18	2.06	1.95	16.65	0.2428	0.59	1.7	0.24	0.87	0.097	0.0111	0.2016
SW5	3.45	1.99	2.05	13.46	0.2501	0.79	0.69	0.28	0.89	0.1109	0.0089	0.1112

3.2 Inter-correlation among the geomorphic parameters

Ten morphometric characteristics that were taken from five sub-watersheds of the Upper Godavari river basin were statistically correlated (Table 4). Rb and Bs, Dd and Rt, and Rt and Cc all show good positive correlations (> 0.75 > value > 0.9). Additionally, there was a substantial negative association between Rb and Ff, Rb and Re, Rt and Lg, and Bs and Re. While there was a strong negative connection between Dd and Lg; Dd and Rc; Lg and Cc; Ff and Bs; and Rc and Cc, there was a positive high correlation (> 0.9) between Dd and Cc and Lg and Rc. Fs showed no association.

Table 4: Matrix of inter-correlation for morphometric characteristics of sub-watersheds of the Upper Godavari river basin

	Rb	Dd	Fs	Rt	Lg	Ff	Bs	Rc	Re	Cc
Rb	1.000									
Dd	-.364	1.000								
Fs	-.115	.020	1.000							
Rt	.102	**.716**	-.266	1.000						
Lg	.385	**-.998**	-.033	**-.734**	1.000					
Ff	**-.833**	.301	.365	.105	-.349	1.000				
Bs	**.885**	-.291	-.153	-.116	.337	**-.974**	1.000			
Rc	.563	**-.949**	.122	-.696	**.958**	-.482	.521	1.000		
Re	**-.780**	.286	-.448	.216	-.314	.654	**-.808**	-.572	1.000	
Cc	-.486	**.934**	-.207	**.776**	**-.945**	.437	-.487	**-.991**	.579	1.000

(Note: Bold values represent good correlation)

3.3 Sub-watershed prioritization with morphometric analysis

The result of morphometric analysis revealed that sub-watersheds SW1 and SW2 were categorized as low priority, SW4 and SW5 as moderate priority, and SW3 as higher priority (Table 5).

3.4 Sub-watershed prioritization with LULC analysis

Land use and land Cover change of Sub-watersheds of the Upper Godavari river basin was carried out for the years 2004 and 2019 (Fig. 5 and Fig. 6). Sub-watersheds were divided into different LULC categories viz. Agriculture Land, Waste Land, Built-up, Waterbody and forest.

The built-up area increased from 2004 to 2019 for all sub-watersheds and agriculture and waste land reduced from 2004 to 2019 except SW3 and SW4 (Table 6). While, waterbody reduced from 2004 to 2019 in all sub-watersheds (Table 6). The result revealed that watershed management will be required for increased agriculture and sustainable management of water in the watershed. Sub-watersheds SW2 and SW5 were categorized as low priority, SW3 and SW4 as moderate priority, and SW1 as higher priority using LULC analysis (Table 7).

Table 5: Priority/ranking of Sub-watersheds of the Upper Godavari river basin using morphometric analysis

Sub-Watersheds	Morphometric Parameters											
	Linear Parameters					Shape Parameters					Compoud value	Final priority
	R_b	D_d	F_s	R_t	L_g	F_f	B_s	R_c	R_e	C_c		
SW1	4.66 (1)	1.83 (5)	1.98 (4)	12.87 (4)	0.27 (1)	0.53 (2)	1.86 (4)	0.43 (5)	0.83 (2)	0.1115 (3)	3.1	**Low**
SW2	3.9 (4)	1.89 (4)	1.99 (3)	9.56 (5)	0.2639 (2)	0.57 (3)	1.74 (3)	0.38 (4)	0.85 (3)	0.1299 (5)	3.6	**Low**
SW3	4.62 (2)	1.96 (3)	2.07 (1)	12.88 (3)	0.2551 (3)	0.46 (1)	2.19 (5)	0.37 (3)	0.76 (1)	0.1138 (4)	2.6	**High**
SW4	4.18 (3)	2.06 (1)	1.95 (5)	16.65 (1)	0.2428 (5)	0.59 (4)	1.7 (2)	0.24 (1)	0.87 (4)	0.097 (1)	2.7	**Medium**
SW5	3.45 (5)	1.99 (2)	2.05 (2)	13.46 (2)	0.2501 (4)	0.79 (5)	0.69 (1)	0.28 (2)	0.89 (5)	0.1109 (2)	3.0	**Medium**

(Note:- Bracket values represent the priority/rank)

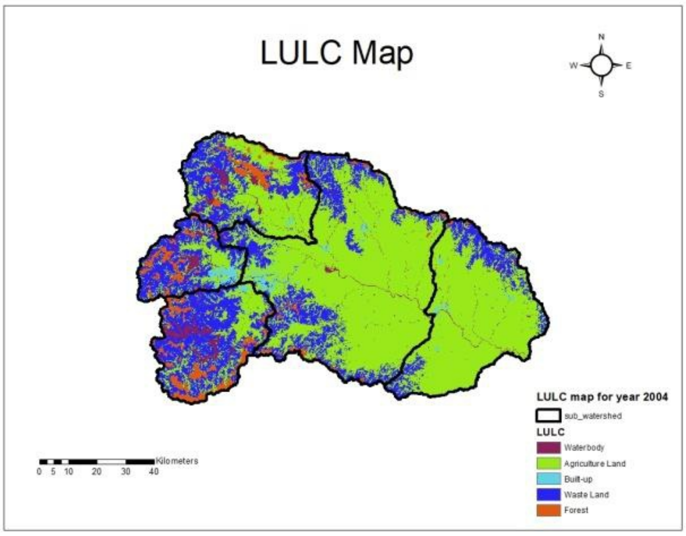

Figure 5: LULC map of the Upper Godavari river basin with sub-watershed for year 2004

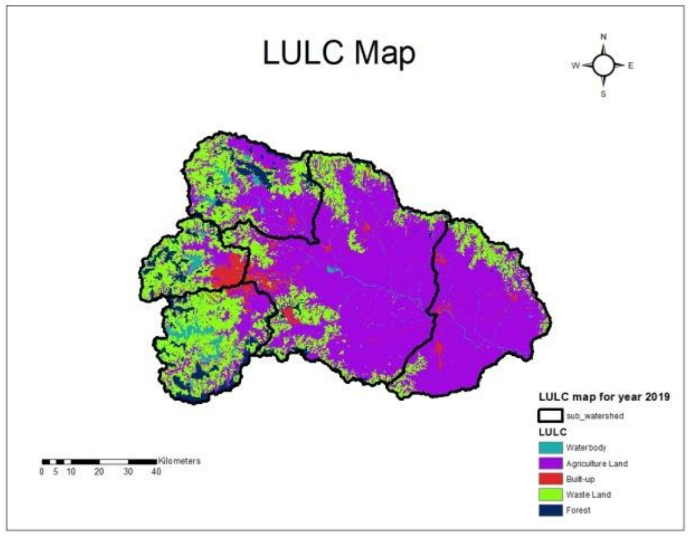

Figure 6: LULC map of the Upper Godavari river basin with sub-watershed for year 2019

Table 7: Priority/ranking of Sub-watersheds of the Upper Godavari river basin using LULC analysis

Sub-Watersheds	LULC categories and change in area (per cent)					
	AL (%)	WL (%)	BU (%)	WB (%)	Compound value (Cp)	Final Priority
SW1	**0.95** (4)	**1.22** (2)	2.07 (2)	0.11 (1)	2.25	**High**
SW2	**3.52** (5)	**3.36** (5)	6.87 (1)	0.01 (5)	4	**Low**
SW3	**0.86** (3)	0.11 (1)	0.66 (5)	0.09 (2)	2.75	**Medium**
SW4	0.66 (1)	**2.1** (4)	1.4 (3)	0.04 (3)	2.75	**Medium**
SW5	**0.02** (2)	**1.26** (3)	1.25 (4)	0.03 (4)	3.25	**Low**

(Note:- Bold values indicate positive change and bracket values represent the priority/rank)

3.5 Final prioritization of sub-watershed using the compound value of both morphometric analysis and LULC analysis

Final prioritization of sub-watershed using compound value of both morphometric analysis and LULC analysis was decided by mean of compound value (C_p) of both morphometric analysis and LULC analysis (Table 8). Result showed that sub-watersheds SW2 was categorized as low priority, SW4 and SW5 as moderate priority, and SW1 and SW3 as higher priority (Table 8).

Table 8: Sub-watersheds of the Upper Godavari river basin final priority based on morphometric and LULC analyses

Sub-Watersheds	(C_P) (Morphmetric analysis)	(C_P) (LULC analysis)	Mean (C_P)	Final Priority
SW1	3.1	2.25	2.675	**High**
SW2	3.6	4	3.8	**Low**
SW3	2.6	2.75	2.675	**High**
SW4	2.7	2.75	2.725	**Medium**
SW5	3.0	3.25	3.125	**Medium**

Table 6: Changes in LULC in the Upper Godavari river basin sub-watersheds between 2004 and 2019

LULC type	LULC for year 2004		LULC for year 2019		Land use change analysis between 2004 and 2019	
SW1	Area in (km^2)	Area in (%)	Area in (km^2)	Area in (%)	Difference in (km^2)	Difference in (%)
Agriculture Land (AL)	308.68	24.91	296.94	23.96	11.74	0.95
Waste Land (WL)	633.03	51.09	617.89	49.87	15.14	1.22
Built-up (BU)	15.83	1.28	41.45	3.35	-25.62	-2.07
Waterbody (WB)	89.25	7.2	90.57	7.31	-1.32	-0.11
Forest Land(FL)	192.27	15.52	192.21	15.51	0.06	0.01
	1239.06	100	1239.06	100		
SW2						
Agriculture Land (AL)	183.33	24.83	157.33	21.31	26	3.52
Waste Land (WL)	377.36	51.1	352.51	47.74	25.85	3.36
Built-up (BU)	43.62	5.91	94.36	12.78	-50.74	-6.87
Waterbody (WB)	31.68	4.29	31.79	4.3	-0.11	-0.01
Forest Land(FL)	102.44	13.87	102.44	13.87	No change	No change
	738.43	100	738.43	100		
SW3						
Agriculture Land (AL)	650.08	49.57	638.79	48.71	11.29	0.86
Waste Land (WL)	474.09	36.15	475.55	36.26	-1.46	-0.11
Built-up (BU)	6.85	0.52	15.44	1.18	-8.59	-0.66
Waterbody (WB)	52.7	4.02	53.94	4.11	-1.24	-0.09
Forest Land(FL)	127.8	9.74	127.8	9.74	No change	No change
	1311.52	100	1311.52	100		
SW4						
Agriculture Land (AL)	2810.11	75.33	2834.44	75.99	-24.33	-0.66
Waste Land (WL)	732.45	19.64	654.33	17.54	78.12	2.1
Built-up (BU)	65.64	1.76	117.78	3.16	-52.14	-1.4
Waterbody (WB)	47.12	1.26	48.78	1.3	-1.66	-0.04
Forest Land(FL)	74.93	2.01	74.92	2.01	0.01	No change
	3730.25	100	3730.25	100		
SW5						
Agriculture Land (AL)	1581.98	82.91	1581.47	82.89	0.51	0.02
Waste Land (WL)	275.48	14.44	251.44	13.18	24.04	1.26
Built-up (BU)	18.54	0.97	42.46	2.22	-23.92	-1.25
Waterbody (WB)	24.72	1.3	25.35	1.33	-0.63	-0.03
Forest Land(FL)	7.24	0.38	7.24	0.38	No change	No change
	1907.96	100	1907.96	100		

4. Conclusions

This study demonstrated the value of morphometric analysis in examining a basin's hydrological characteristics, particularly in ungagged basins. The seventh-order river basin was the Upper Godavari river basin sub-watersheds. All sub-watersheds in the Upper Godavari river basin had an elongated to circular shape, according to all morphometric criteria, including the circularity ratio (0.24–0.43), elongation ratio (0.76-0.89) and form factor (0.46-0.79). Sub-watersheds SW1 and SW2 were classified as low priority, SW4 and SW5 as moderate priority, and SW3 as higher priority based on morphological studies. Sub-watersheds SW2 and SW5 were classified as low priority, SW3 and SW4 as moderate priority, and SW1 as higher priority based on the LULC study. According to the sub-watershed's final prioritization, SW2 was categorized as low priority, SW4 and SW5 as moderate level, and SW1 and SW3 as higher priority. LULC changes were assessed for the Upper Godavari river basin sub-watersheds in 2004 and 2019. The result revealed that watershed management will be required for increased agriculture and watershed management.

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