Sub watershed Prioritization Based on Morphometric Techniques and Machine Learning Approaches in The Sobha River Basin Using Geospatial Techniques, India

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Abstract:

Morphometric analysis is important in any hydrological investigation and it is inevitable in the development and management of drainage basin. In the present paper, an attempt has been made to study the morphometric parameters of the Sobha micro-watershed in Purulia, West Bengal. To know the watershed dynamics and manage those in terms of drought and flash flood reduction of a plateau river (Sobha River) and to manage soil erodibility and groundwater potentiality; we have taken the aforesaid watershed for our case study. For this study, hydrology-based GIS functions have been used in the evaluation of linear, aerial, and relief morphometry of the Sobha watershed. Several 11 morphometric indices have been generated for all the sub-watersheds to understand the geomorphological behavior of the Sobha watershed. The total area of the basin is 137 Sq.km and lies between 22º42'19''N to 23º42'00''N latitude and 85º49'19''E to 86º54'25''E longitude. Poor soil cover, sparse vegetation, low amount of rainfall, and lack of soil moisture characterize the study area for most of the year. So the entire study area has been further divided into 37 sub-watersheds, named MWS 1, MWS 2…..MWS 37 ranges in several geographical areas. The drainage density values of sub-watersheds MWS 10, 14, 16, 23, and 24 indicate that it has highly resistant power with dense vegetative cover and high relief. The elongation ratio varies from 12.44 to 77.89 which indicates very rugged terrain and steep ground slope. The composite score values are calculated and the sub-watersheds 7, 15, 16, 21, 23, 27, 34 and 36 has a minimum composite score value of 1, 2, 5, 11, 12, 20, 27, 28, 30, and 31 is likely to be subjected to maximum soil erosion and susceptible to natural hazards. Hence this maximum vulnerable watershed should be provided with immediate soil conservation techniques.

Index Terms: Morphometric Analysis, Geospatial techniques, Machine learning, Sub-watersheds Prioritization

1. Introduction:

In fluvial landscape dynamisms are a common element and its determinants are geomorphology, geology, hydrology, soil, vegetation, climate, etc. of that region (Strahler 1964; Mesa 2006; Rekha et al. 2011; Romohoo et al. 2012; Puno and Puno 2019; Singh et al. 2021). Physical and hydrological characteristics like area, slope, size, shape, length, drainage density, etc. are correlated to understand the control of drainage basin morphometry upon the landscape of a basin (Clarke 1966; Rastogi and Sharma 1976; Rastogi et al. 1976; Pakhmode et al. 2003; Sreedevi et al. 2009; Das et al. 2013; Amulya et al. 2018). This analysis is very useful for any kind of basin-scale management activities such as soil erosion, flood modeling, sustainable resource management, basin evolution prediction, etc. So, this method is a useful alternative tool where field data are limited because of accessibility, remoteness or scarcity of field based technological advancement (Nookaratnam et al. 2005; Borga et al. 2008; Javed et al. 2009; Sharma et al. 2010; Romshoo et al. 2012; Altaf et al. 2013; Aher et al. 2014; Ajay et al. 2014; Bhatt and Ahmed 2014; Abuzied et al. 2016; Ayele et al. 2017; Balasubramanian et al. 2017; Gajbhiye and Sharma 2017; Taha et al. 2017; Ameri et al. 2018; Kannan et al. 2018; Shivhare et al. 2018; Andan et al. 2019; Asfaw and Workinch 2019; Charizopoulos et al. 2019; Gunjan et al. 2019; Hussein et al. 2019; Karabulut and Ozdemir 2019; Mahmood and Rahman 2019; Nitheshnirmal et al. 2019; Puno and Puno 2019; Abdeta et al. 2020; Alam et al. 2020; Arefin et al. 2020; Das 2020; Gabriel et al. 2020; Meshram et al. 2020; Ogarekpe et al. 2020; Pan et al. 2020; Rajsekhar et al. 2020; Sangma and Guru 2020; Obeidat et al. 2021; Singh et al. 2021, Tukura et al. 2021). This technique is also very helpful for developing and underdeveloped countries where food security strategy is of utmost important and thus water resource conservation is needed to protect the basin environment (Desa et al. 2005; Sharma et al. 2005; German et al.2007; Kerr 2007; Draghouth et al. 2008; Kumar and Palanisami 2009; Alemu and Kidane 2014; Iqbal and Sajjad 2014; Mekhonnen and Fekadu 2015; Worku and Tripathi 2015; Abdeta et al. 2020).

The morphometric analysis involves numerical measurement of size, shape, and other related dimensions of the basin surface (Clarke 1996; Agarwal 1998; Obi et al. 2002). It involves numerous quantitative parameters which are practices nowadays are congregated from different pioneer works like Horton, Smith, Strahler; Miller and Schumm (Horton 1932, 1945; Smith 1950; Strahler 1952, 1964; Miller 1953; Schumm 1956; Obi Reddy et al. 2002; Vaidya et al. 2013; Kaur et al. 2014). This approach measured various attributes in three broad categories such as linear, areal, and relief aspects to get insights about the basin characteristics (Melton 1957; Strahler 1964; Sreedevi et al. 2009; Arnous et al.2011; Charizopoulos et al.2019; Abedeta et al. 2020; Obeidat et al.2021; Singh et al. 2021). Morphometry-based prioritization of different sub-watersheds is made by comparing each of them (Sharma et al. 2010; Kumar et al. 2015; Kumar and Lal 2017; Thapliyal et al. 2017).

The Sobha River basin is characterized as semi-arid to sub-humid in different seasons throughout all the year. As most of the inhabitants of this plateau region depend on limited agriculture and livestock farming they depend on groundwater resources. Geologically the basin region is typically a rolling plain, barren land, and granite-gneissic-quartzite complex zone. Thus, scarcity of surface water is most common. On the other hand, dependency on groundwater resulted in the declination of groundwater levels for unrestricted and overutilization of this resource. So, reaching a scale watershed prioritization scheme is a requisite of the region. For this reason, we used SRTM DEM data to investigate different morphometric aspects (Moore et al. 1991; Nag 1998; Farr and Kobrick 2000; Smith and Sandwell 2003; Grohmann 2004; Chopra et al. 2005; Das and Mukherjee 2005; Korup et al. 2005; Ratnam et al. 2005; Grohmann et al. 2007; kale and Shejwalker 2007; Lindsay and Evans 2008; Rudraiah et al. 2008; Sreedevi et al. 2009; Patel and Sarkar 2010; Wang et al. 2010; Pareta and Pareta 2011; Altaf et al. 2013; Magesh et al. 2013; Jacques et al. 2014; Das et al. 2016; Senthamizhan et al. 2016). Remote sensing techniques have great potential because of wide synoptic view, multispectral and multi-temporal capabilities, repetitiveness, and compute-compatibility (Pareta and Pareta 2011, 2012; Das et al. 2018). Hence integrated management of river basins remote sensing and GIS-based geospatial techniques are reliably used in present-day studies (Fransisco and Rola 2004; Pandey et al. 2007; Chatterjee et al. 2013; Chandniha and Kansal 2014; Okumura and Araujo 2014; Syed et al. 2017; Rahmati et al. 2019; Abedeta et al. 2020; Borah and deka 2020; Obeidat et al. 2021). Remote sensing and GIS tools are utilized for the water resource management and development of water resources. Due to advancements in satellite and sensing technology, it is now possible to map finer details of the earth's surface and it provides scope for micro-level planning and management. The present study aims at the proper management of water resources and controlling surface soil loss. Water resource management by prioritization of micro-watershed-based analysis using remote sensing data and GIS overlying techniques. This research contributes to the framework for management practices of basin as micro-watersheds wise implemented by local administrative authorities as well as homogeneous basin management programs. This study is also helpful for increasing the agriculturally based livelihood, and irrigation facilities and to find the solution of uncontrolled soil loss. A watershed is an ideal unit for the management of water for land and water resources for mitigation of the impact of natural disasters for achieving sustainable development.

The significant factors for planning and development of a watershed are its physiography, drainage, geomorphology, soil, land use, land cover, and available water resources. Remote sensing and GIS are the most proven tools for watershed development as well as management and the studies on prioritization of micro-watershed development and management.

2. Study Area:

The study area is in Purulia, the westernmost district of the Indian state of West Bengal and a part of Jharkhand state in Chotanagpur Plateau is located between the graticule 22º42'19" N to 23º42'00"N latitude and 85º49'19"E to 86º54'25"E longitude covering an area of 166 sq km. The study area comprises with Sobha watershed of Purulia district of West Bengal, India. The Sobha River is a tributary of the Kistobazar River in the southern part of the Ajodhya hill which further moves toward south west and meets the Subarnarekha River.

It is traversed by the tropic of cancer. This is located in the foothill of Ajodhya in Baghmundi P.S. and the main areas are Ajodhya, Baghmundi and Mathaburu etc. The Bay of Bengal and the Hooghly estuary are within 200 km from the center of the district. It is surrounded by Paschim Medinipur, Bankura, and Burdwan districts of West Bengal and Dhanbad, Bokaro, Hazaribag, East and West Singhbhum of Jharkhand state. Its physiographic location is also distinguishable as a zone of transition between the young alluvial plains of West Bengal and the ancient plateau of Southeast Bihar.

Climatically, the area is sub-tropical and sub-humid, with hot wet summers and cool dry winters characterized by high evaporation and low precipitation with an annual mean temperature of 25.6ºC and mean summer and mean winter temperature of 29.0ºC and 21.3ºC, respectively. The monsoon is the main source of precipitation, which shapes a ‘funnel’ like meteorological functions. It funnels the tropical monsoon current from the Bay of Bengal to the sub-tropical parts of North West India. It starts in May and continues up to October. It has an annual average precipitation of 1393 mm. About 82% of the annual rainfall occurs during the monsoon which lasts roughly from June to September but uneven, scanty, and erratic rainfall results in agricultural drought in the kharif season.

Plate 1: Some glimpse of the study area and different field observations

The main rivers passing through the district are Kangsabati, Kumari, Darakeswar, Subarnarekha, and Damodar but the study area comprises Turga Nala, Kistobazar Nala, and Daurigarha Nala. Soil erosion is the most prominent phenomenon in this area resulting huge deposition of fertile soil in the valley region. As a result, the area is facing a crisis due to the depletion of top fertile soil and water loss. The study area is a ‘White Zone’ concerning groundwater status (i.e., 60% of available Ground annual recharge is in use). In general, during the rainy season, the water table in the wells rises from 1.00 to 3.50 m bgl till the end of October and gradually falls to a maximum of 6 to 14 m bgl during April-May.

Geologically the area is a part of the Chotanagpur Gneissic complex of the Eastern Indian peninsular shield, lying to the north of Singhbhum craton. China clay occurrences in this area are invariably associated with granitic rocks and meta-sediments of the Chotanagpur Gneissic complex of the Precambrian age. The topography is undulating with moderate to gentle slopes. It has a thick stratigraphic succession of mostly Archaean granitic gneiss and to a much lesser extent, Quaternary semi-consolidated sediments, promo-carboniferous sandstone, and shale. Precambrian massive granites and quartzite sand with recent alluvium sediments deposition. Mineralogically these rocks are composed mainly of quartz, feldspar, muscovite, biotite, illite, and kaolinite.

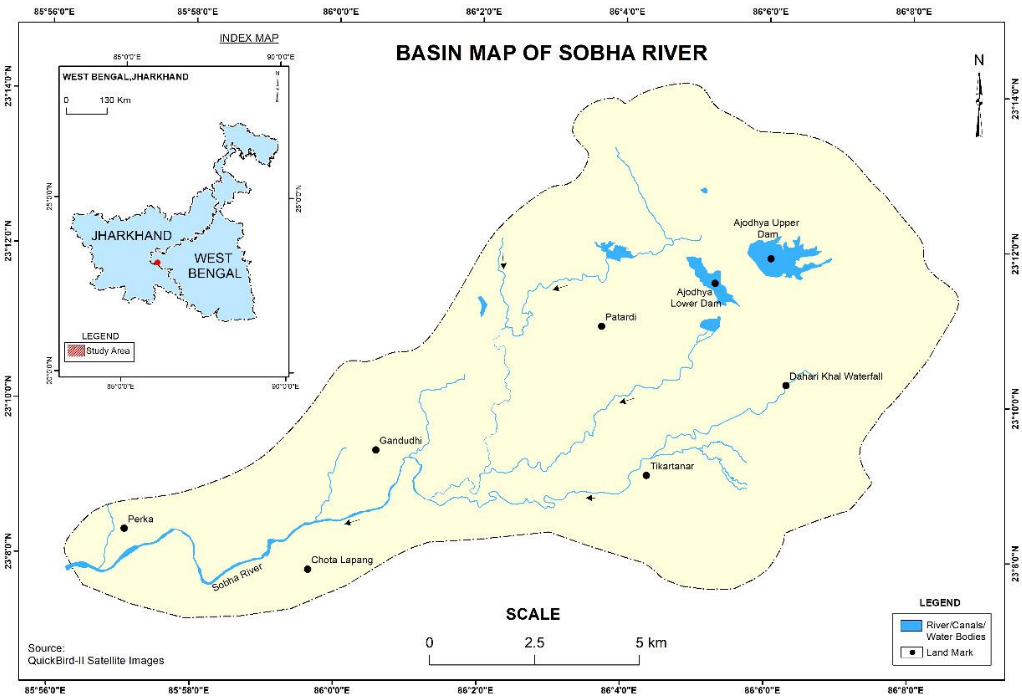


Figure 1: Location Map

3. Database and Methodology:

The present study is mainly concerned with evaluating morphometric characteristics of the river basin at the sub-watershed level to assess the prioritization of the Sobha micro-watershed with geospatial techniques. For this, both SOI (Survey of India) Toposheets (73I/4, 73E/16) and SRTM DEM data (30m. resolution) were used in the GIS environment. At the outset, SRTM data is used as input in Arc SWAT and delineates watersheds as well as 37 sub-watersheds. Georeferencing of toposheets was done in TNT Mips 2014 and ARC GIS 10.1 version software and mosaic the same to subset the study region.

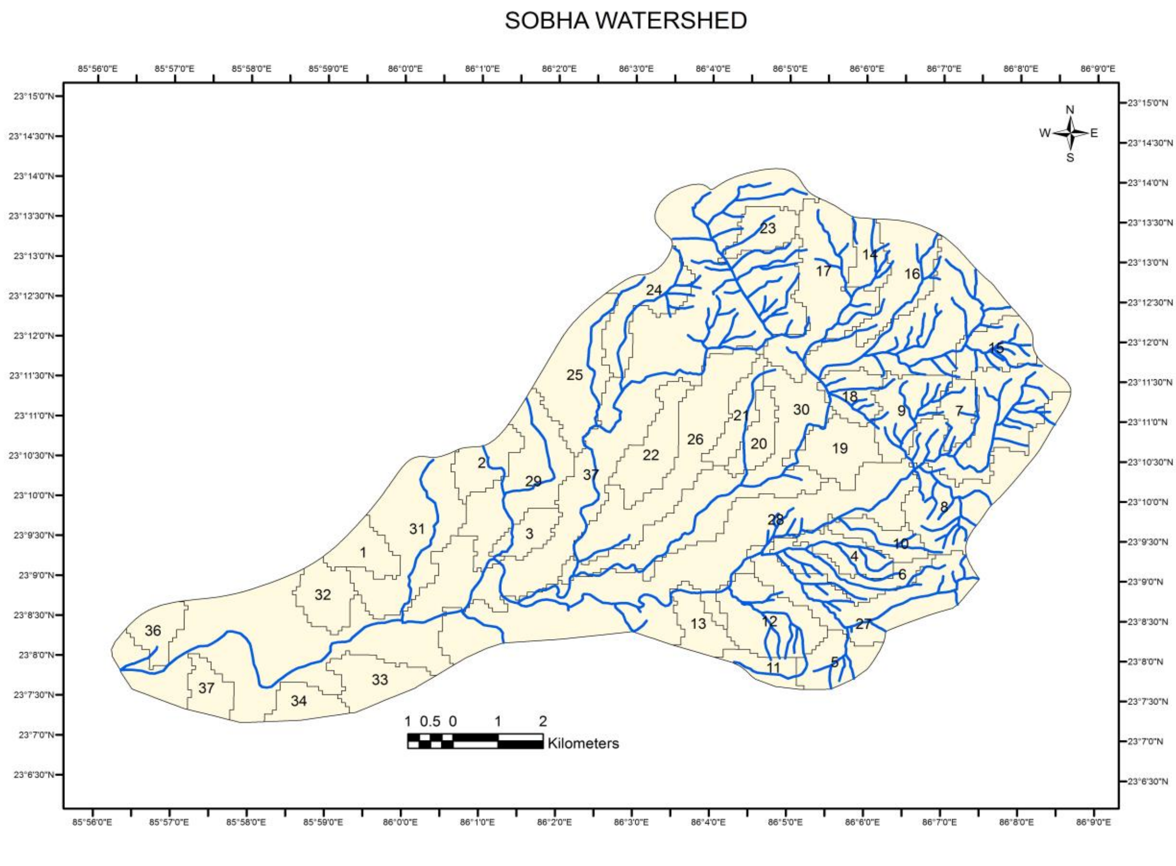


Figure 2: Sub-watersheds of the study area

The rectification method has been employed to obtain a geometrically corrected subset image. Standard methods of Strahler's, Horton's, Miller's, and Schumm's were applied to examine morphometric characteristics. Every single morphometric element is considered in the prioritization of watershed and weightage (composite score) has been assigned. For the linear aspect, high weightage was assigned for high values, and aerial aspect low weightage was assigned for high values (Panhalkar and pawar, 2011; Panhalkar et al., 2012) The compound values of all parameters at the sub-watershed level were calculated and highest priority has assigned to sub-watershed having lowest average compound weightage (composite score) and vice versa. Here priority implies the necessity of land resource conservation and the need to implement suitable remedial measures.

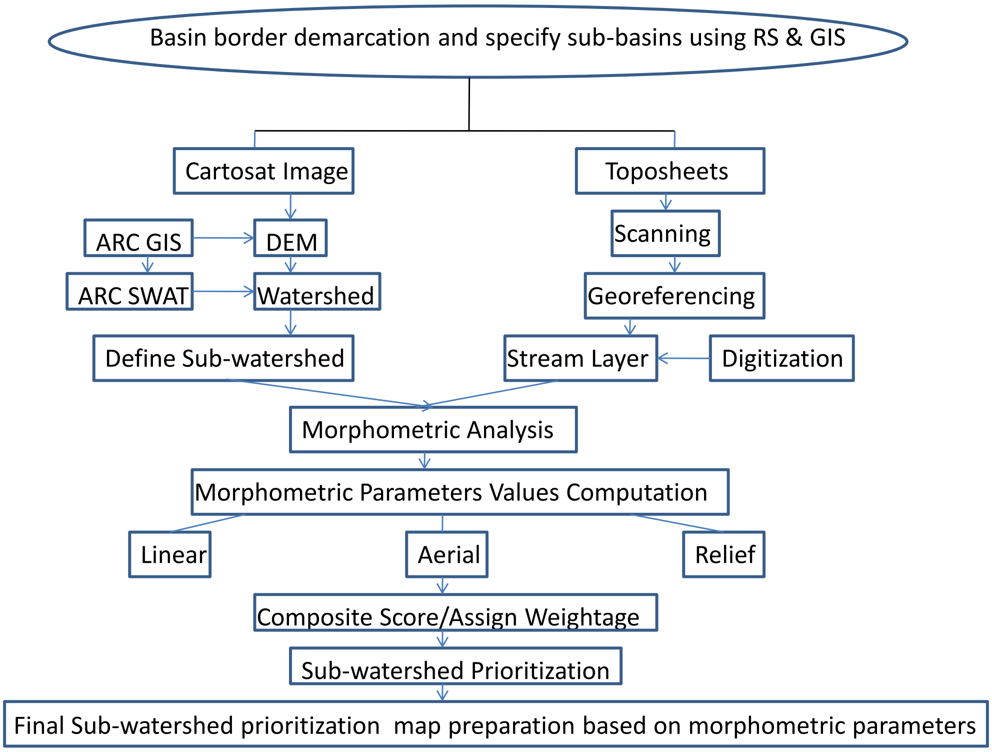


Figure 3: Methodology

4. Result and Discussion:

The prioritization of the Sobha watershed has been carried out based on morphometric characteristics. 37 sub-watersheds have been generated in ARC SWAT software. Details of morphometric analysis of the Sobha watershed are enumerated in Tables 1, 2, and 3.

Table 1: Descriptive Characteristics of morphometric parameters

Aspect	Parameters	Characteristics
A. Linear	• Average length of stream (L_{um})	It is the characteristic property related to the drainage network and its associated surfaces. Generally, the higher the order, the longer the length of the stream is noticed in nature.
	• Bifurcation Ratio (R_b)	Its ratio characteristically ranges between 3.0 and 5.0 for watersheds in which the geologic structures do not distort the drainage pattern but if it is <1 then it is vice versa.
	• Stream Length Ratio (L_{ur})	It is a successive stream order which varies due to differences in slope and topographic conditions and has an important relationship with the surface flow discharge and erosional stage of the basin.
	• Stream Frequency (F_s)	It is the total no. of stream segments of all orders per unit area. Generally, high stream frequency is related to impermeable sub-surface material, sparse vegetation, high relief conditions, and low infiltration capacity.
B. Aerial	• Length of Overland Flow (L_g)	It is defined as the length of the runoff of the rainwater on the ground surface before it is localized into definite channels.
	• Drainage Density (D_d)	It is a measure of the degree of fluvial dissection. It indicates the closeness of spacing of channels influenced by resistance to erosion, infiltration capacity, vegetation cover, surface roughness and runoff intensity, climatic condition, etc. (Reddy et al., 2004) Low Dd leads to coarse drainage texture while high Dd leads to fine drainage texture.
	• Constant of Channel maintenance (C)	The constant indicates the no. of km^2 of basin surface required to develop and sustain a channel 1 km long. The constant of channel maintenance indicates the relative size of landform units in a drainage basin and has a specific genetic connotation (Strahler, 1957).
	• Form Ratio (F_f)	It is defined as the ratio of basin area to the square of basin length. The value of Ff would always be less than 0.7854 (for a perfectly circular basin). The smaller the value of Ff, the more elongated will be the basin. The basins with high Ff have high peak flows of shorter duration, whereas, elongated form factors have lower peak flows of longer duration.
	• Elongation Ratio (R_e)	Elongation Ratio is defined as the ratio of the diameter of a circle of the same area as the basin to the maximum basin length. It helps to give an idea about the hydrological character of a drainage basin.
C. Relief	• Relief Ratio (R_h)	The elevation difference between the highest and lowest points on the valley floor of a sub-watershed.
	• Ruggedness Number (R_n)	It is the product of the basin relief and drainage density and usefully combines slope steepness with its length.

Table 2: Ranges of Morphometric Parameters

Aspects	Morphometric Parameters	Formula	Reference	Results (Ranges)
Linear	Stream length Ratio (L_{ur})	$L_{ur}=L_{u-1}$	Strahler (1964)	0.691 – 7.154
	Bifurcation ratio (R_b)	$R_b= N_u/ N_{u+1}$	Schumm (1956)	0.500 – 2.000
	Total stream length (L_u)km	$L_u=L_{1+} L_{2+....+} L_n$	Strahler (1964)	1235.100 – 42747.470
	Stream frequency (F_s)	$F_s=N_u/A$	Horton (1932)	0.00000007 – 0.00000186
Aerial	Drainage density (D_d) km/ km^2	$D_d= L_u/A$	Horton (1945)	0.000162 – 0.202171
	Form ratio (F_f)	$F_f=C_L/P$	Horton (1932)	121.4687 – 4765.1305
	Elongation ratio (R_e)	$R_e=2/L_b*(A/\pi)^{0.5}$	Schumm (1956)	12.440 – 77.890
	Length of overland flow (L_g) km	$L_g=A/2* L_u$	Horton (1945)	230.280 – 3089.000
	Constant of channel maintenance(C) km/ km^2	$C=1/D_d$	Schumm (1956)	460.560 – 6177.990
Relief	Relief ratio (R_h)	$R_h=H/L_b$	Schumm (1956)	0.190 – 17.990
	Ruggedness number (R_n)	$R_n=D_d*(H/1000)$	Strahler (1950)	0.024979 – 0.623150

Table 3: Descriptive Analysis of Components

Micro-watershed code no.	Average stream length	Bifurcation ratio	Stream length ratio	Drainage density	Constant of channel maintenance	Length of overland flow	stream frequency	Form ratio	Elongation Ratio	Relief ratio	Ruggedness no.	Composite Score
MWS 1	1607.78	1.000	1.000	0.001237	808.25	404.12	0.00000077	2884.5362	60.60	1.41	0.037117	**309.44899**
MWS 2	1404.88	1.000	1.000	0.001008	992.11	496.06	0.00000072	4765.1305	77.89	1.64	0.028223	**489.80438**
MWS 3	1683.74	1.000	1.000	0.001607	622.09	311.04	0.00000095	2811.8941	59.83	1.50	0.046617	**294.05665**
MWS 4	1823.67	1.000	1.000	0.000712	1403.52	701.76	0.00000039	197.9775	15.88	2.43	0.196648	**119.08568**
MWS 5	1268.46	1.000	1.000	0.000861	1161.24	580.62	0.00000068	4595.9086	76.50	17.99	0.277290	**510.29021**

MWS 19	**MWS 18**	**MWS 17**	**MWS 16**	**MWS 15**	**MWS 14**	**MWS 13**	**MWS 12**	**MWS 11**	**MWS 10**	**MWS 9**	**MWS 8**	**MWS 7**	**MWS 6**
3205.34	1235.10	4495.30	4854.31	1522.35	1867.82	1934.40	2658.57	2658.57	1823.67	2876.22	2416.51	1496.78	3933.11
2.000	1.000	1.000	2.000	1.000	1.000	1.000	1.000	1.000	1.000	2.000	1.000	1.000	1.000
5.317	1.000	0.691	1.700	1.000	1.000	1.000	1.000	1.000	1.000	1.106	1.000	1.000	5.635
0.001519	0.000928	0.000933	0.001824	0.000899	0.001636	0.001574	0.000353	0.000353	0.000712	0.001291	0.000869	0.001408	0.002171
658.38	1077.37	1071.77	548.14	1111.92	611.11	635.20	2835.19	2835.19	1403.52	774.74	1150.38	710.18	460.56
329.19	538.69	535.89	274.07	555.96	305.56	317.60	1417.60	1417.60	701.76	387.37	575.19	355.09	230.28
0.00000142	0.00000075	0.00000042	0.00000113	0.00000059	0.0000008 8	0.00000081	0.00000013	0.00000013	0.00000039	0.00000135	0.00000036	0.00000094	0.00000110
940.2269	391.0826	583.8144	297.9481	194.3765	141.0155	1550.4463	2028.1352	2028.1352	197.9775	525.9808	746.7860	223.5734	956.1592
34.60	22.31	27.26	19.48	15.73	13.40	44.43	50.82	50.82	15.88	25.88	30.84	16.87	34.89
4.96	4.23	3.32	1.11	0.73	0.77	2.77	5.95	5.95	2.43	3.69	3.54	2.44	6.59
0.356935	0.229261	0.281777	0.191558	0.061156	0.112908	0.122796	0.128034	0.128034	0.196648	0.309782	0.187763	0.236561	0.623150
145.36635	**114.89813**	**140.46412**	**72.36353**	**84.56149**	**56.52938**	**183.95666**	**357.14489**	**357.14489**	**119.08568**	**113.76556**	**148.68682**	**76.10549**	**142.33744**

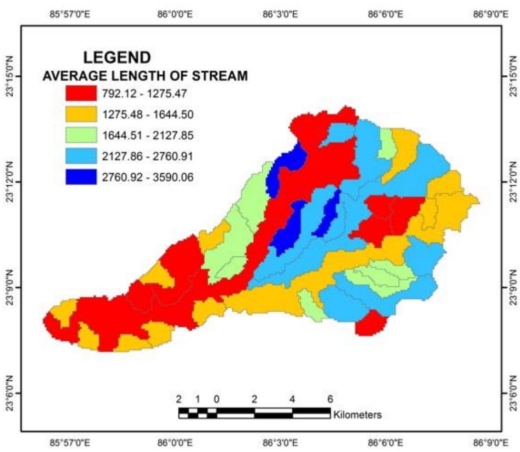
MWS 33	MWS 32	MWS 31	MWS 30	MWS 29	MWS 28	MWS 27	MWS 26	MWS 25	MWS 24	MWS 23	MWS 22	MWS 21	MWS 20
1548.07	2376.35	5973.56	1574.33	5275.33	21282.49	1326.64	6627.31	5698.55	3590.06	2163.39	3359.83	2799.37	2184.52
1.000	2.000	1.000	1.000	0.500	1.111	1.000	0.500	2.000	1.000	1.000	1.000	1.000	1.000
1.000	5.437	1.155	1.000	1.176	3.100	1.000	0.699	7.154	1.000	1.000	1.000	1.000	1.000
0.001098	0.001472	0.001200	0.001063	0.001218	0.001346	0.001238	0.001307	0.001672	0.001556	0.001696	0.001492	0.002142	0.000162
910.82	679.45	833.22	940.59	821.02	743.03	807.54	765.20	598.26	642.52	589.46	670.29	466.92	6177.99
455.41	339.73	416.61	470.29	410.51	371.51	403.77	382.60	299.13	321.26	294.73	335.15	233.46	3089.00
0.00000071	0.00000186	0.00000121	0.00000068	0.00000069	0.00000089	0.00000093	0.00000059	0.00000088	0.00000043	0.00000078	0.00000044	0.00000077	0.00000007
594.3165	563.6647	3011.9747	3455.7629	1521.5651	634.7094	146.9065	1907.5373	612.4560	370.1083	167.9584	1010.5787	529.0756	1543.7192
27.51	26.79	61.93	66.33	44.01	28.43	13.68	49.28	27.92	21.71	14.62	35.87	25.95	44.33
0.62	0.65	0.91	1.64	0.81	2.50	0.43	3.76	0.51	3.74	1.74	0.80	3.44	4.02
0.032937	0.051512	0.044406	0.036148	0.052374	0.531609	0.045818	0.253530	0.063517	0.459127	0.257865	0.056692	0.366230	0.060861
105.32678	**93.34960**	**324.66124**	**368.25172**	**188.63422**	**144.97638**	**62.65726**	**235.47223**	**96.53182**	**99.38378**	**65.49539**	**133.60606**	**92.27297**	**468.42115**

MWS 34	1529.55	1.000	1.000	0.001348	741.63	370.81	0.00000088	243.8166	17.62	0.43	0.039103	**66.53864**
MWS 35	1326.64	1.000	1.000	0.001238	807.54	403.77	0.00000093	146.9065	13.68	0.43	0.045818	**62.65726**
MWS 36	1584.93	1.000	1.000	0.001388	720.60	360.30	0.00000088	121.4687	12.44	0.19	0.024979	**55.58045**
MWS 37	42747.47	1.841	1.673	0.001421	703.52	351.76	0.00000130	646.7129	28.70	1.84	0.562887	**149.52040**

4.1. Linear Parameters:

4.1.1. **Average length of stream (L_{um}):** It exhibits that total stream length decreases with increasing order. The total average stream length of all order segments in the Sobha watershed is 151926.09m and the highest average length is MWS 28 i.e., 21282.49 m and the lowest in MWS 18 i.e., 1235.10m.

4.1.2. **Bifurcation ratio (R_b):** Bifurcation shows a small range of variation for different regions or for different environment except where the powerful geological control dominates (Strahler, 1952 & 1957). The Bifurcation ratio at sub-watershed level has been carried out in GIS environment. In Sobha watershed it ranges from 0.500 to 2.000 and the mean R_b in sub-watersheds is 1.053. The MWS 10, 15, 18, 24 and 30 are having highest R_b which exhibits low permeability and structural control over it.



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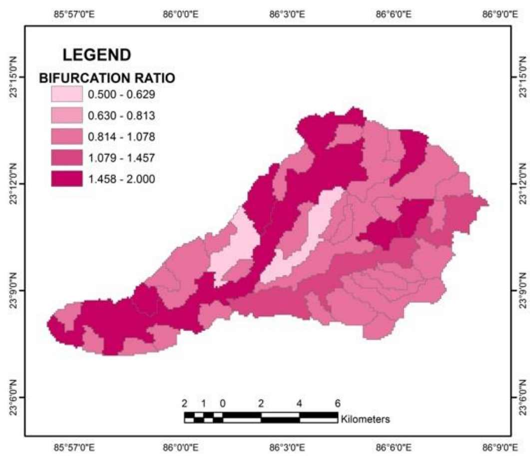

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Figure 4: Linear Parameters-1. Average Length of Stream 2. Bifurcation Ratio

4.1.3. **Stream length ratio (L_{ur}):** The stream length ratio of Sobha watershed ranges in 0.691 to 7.154 and changes of stream length ratio from one order to another indicating their late youth stage of geomorphic development. (Singh and Singh, 1997). The highest stream length ratio observed in MWS 24 and lowest in MWS 16 and 25.

4.1.4. **Stream frequency (F_s):** generally high stream frequency is related to impermeable sub-surface material, sparse vegetation, high relief, and low infiltration capacity of the region. The watershed has low stream frequency and it varies from sub-watershed to sub-watershed. The highest and lowest stream frequency occurred in MWS 30 and MWS 19 respectively.

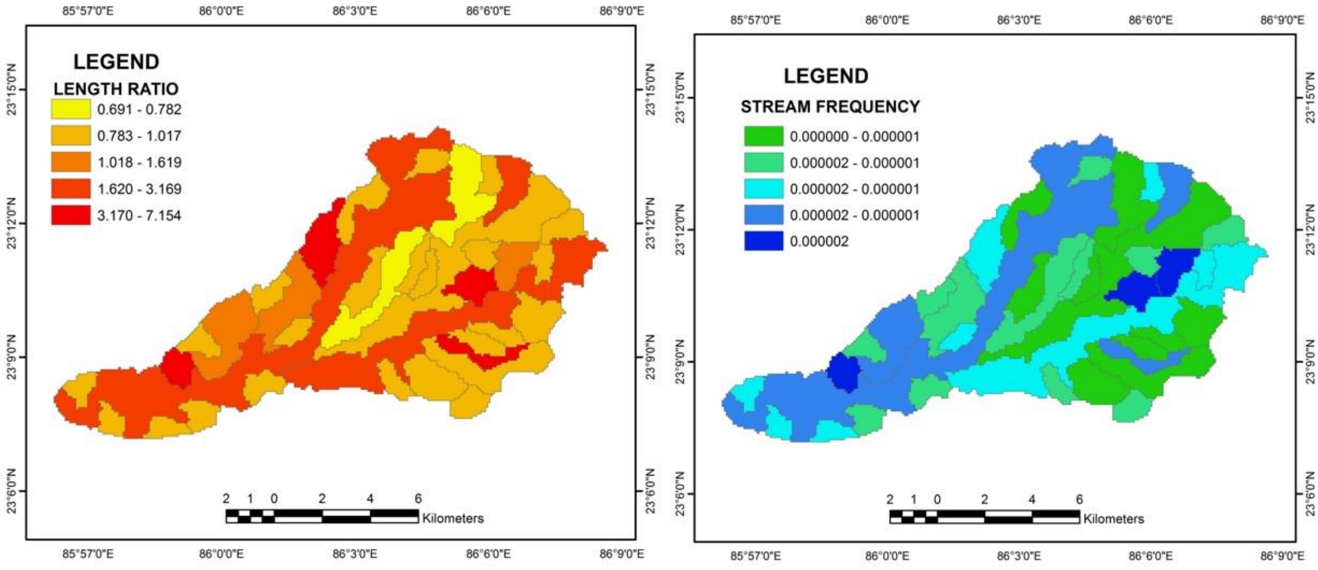

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Figure 5: Linear Parameters-3. Length Ratio 4. Stream Frequency

4.2. Aerial Parameters:

4.2.1. **Length of overland flow (L_g):** It means the length of the runoff of the rain water on the ground surface before it is localized into definite channels. It is highest in MWS 19 and lowest in MWS 7.

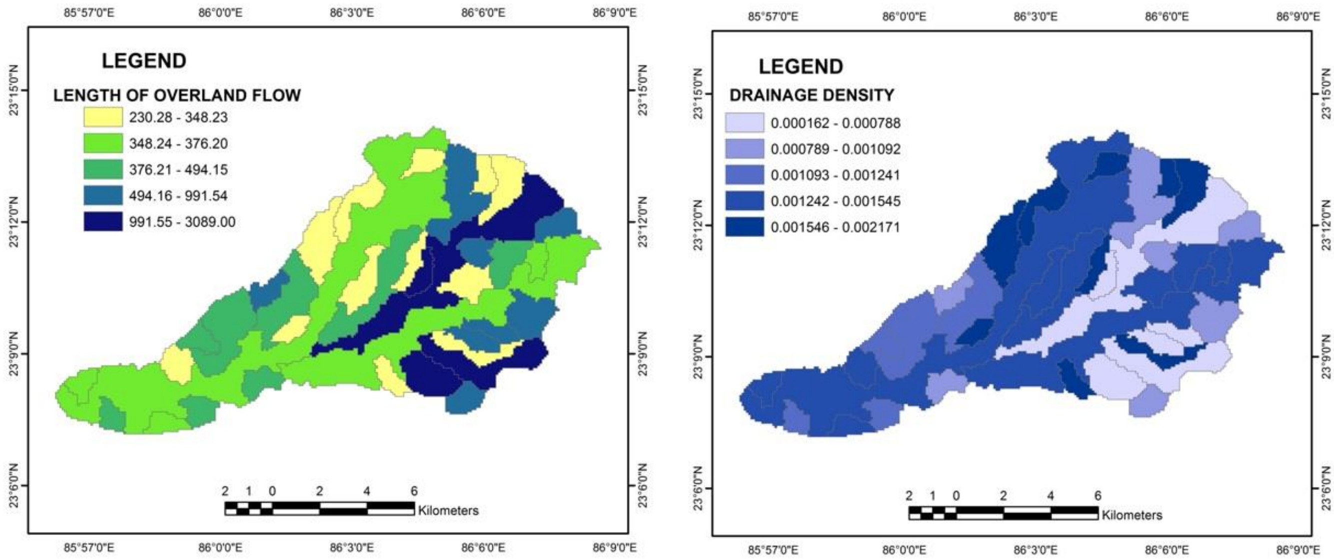

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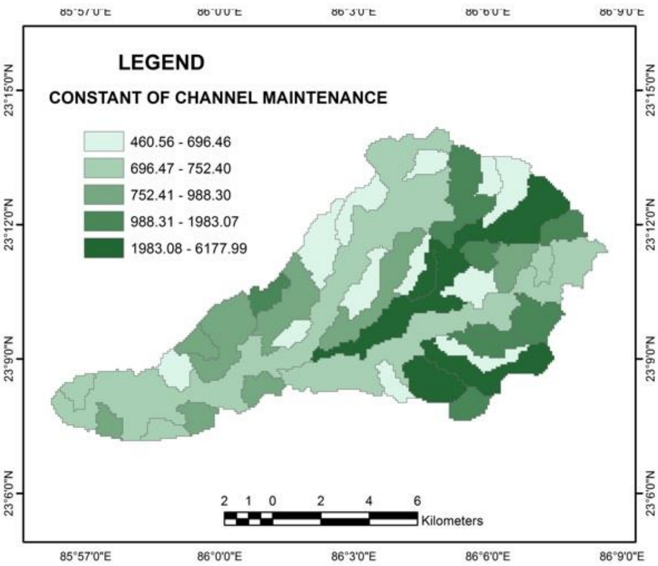
Figure 6: Aerial Parameters-5. Length of overland flow 6. Drainage Density

4.2.2. **Drainage density (D_d):** It is vital element of drainage morphometry to study the landscape dissection, runoff potential, infiltration capacity of the land, climatic condition, and vegetation cover of the watershed. The drainage density of whole Sobha watershed indicates very low density which is only 0.04 m/m^2. Sub-watershed 7, 20, 15 are having high drainage density resultant of weak or impermeable subsurface material, sparse vegetation, and rugged relief. Despite of this low drainage density in MWS 19, 11, 5 leads to coarse drainage texture and high permeable sub-soil material.

4.2.3. **Constant of channel maintenance (C):** It indicates the relative size of landform units in a drainage basin and has a specific genetic condition (Strahler, 1957). The total value of whole watershed is 34444.21 where MWS 7 has lowest value and MWS 19 has shown highest value.

4.2.4. **Form ratio (F_f):** This is an important dimensionless property which enumerates the shape of the basin. Form factor of Sobha watershed is 40917.32 and it ranges from 121.469 to 4765.13 in sub-watersheds. MWS 3 with highest form ratio showing high peak flow of shorter duration. Lowest form ratio observed in MWS 34. In short, the shape of the watershed is quite elongated.



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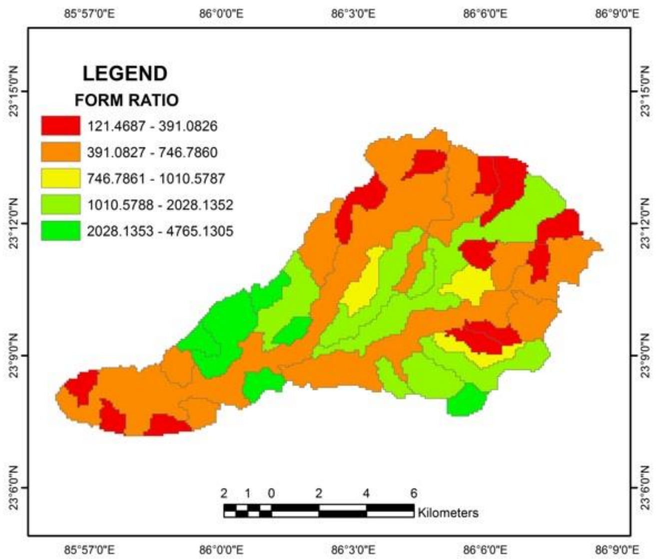

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Figure 7: Aerial Parameters-7. Constant of channel maintenance 8. Form Ratio

4.2.5. **Elongation ratio (R_e):** The elongation ratio runs between 12.44 and 77.89 for all sub-watersheds. The lowest and highest elongation ratio reveals in MWS 36 and MWS 2 respectively. Sobha watershed is having high relief and steep valley side with almost circular in nature.

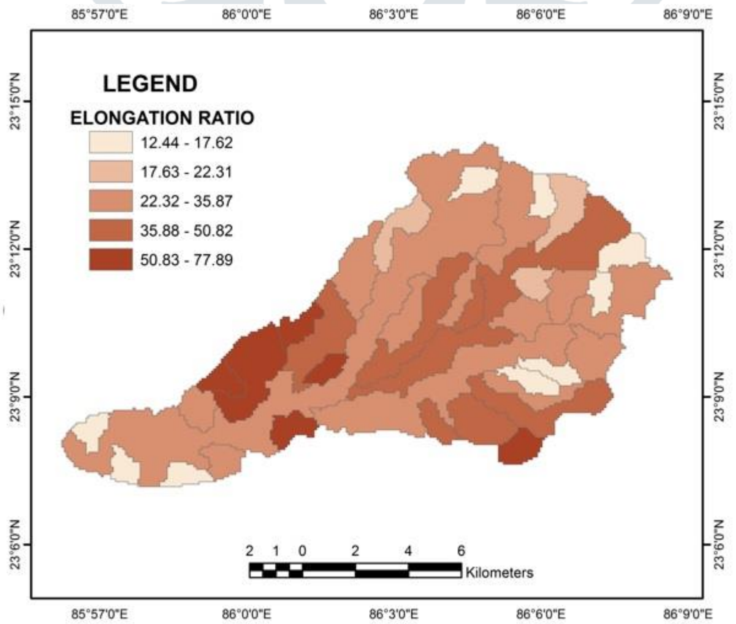

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Figure 8: Aerial Parameters-9. Elongation Ratio

4.3. Relief Parameters:

4.3.1. **Relief ratio (R_h):** The elevation differences between the highest and lowest points on the valley floor of a sub-watershed. The relief ratio normally increases with decreasing drainage area and size of sub-watersheds of a given drainage basin. It is highest in MWS 5 and lowest in MWS 36.

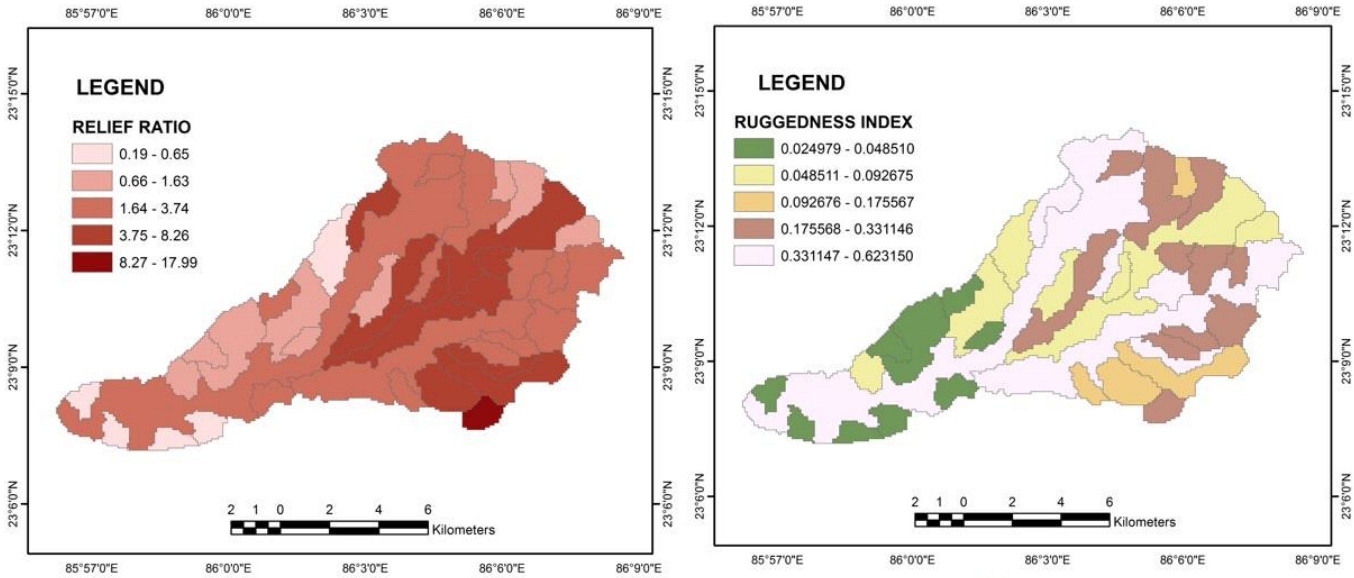

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Figure 9: Relief Parameters-10. Relief Ratio 11. Ruggedness Index

4.3.2. **Ruggedness number (R_n):** It is the product of the basin relief and the drainage density and usefully combines slope steepness with its length. The MWS 6, 3 7, 28 have highest value implies more prone soil erosion whereas MWS 36, 5, 33 have shown lowest value and indicates lower volume of soil erosion.

Table 4: Prioritization Classes based on Composite Score

Priority classes	Prioritized Zones (Composite score value)	MWS code numbers
Critical	55.58045 – 80.51194	7, 14, 16, 23, 34, 35, 36
Very high	80.51195 – 129.45791	4, 9, 10, 15, 18, 21, 24, 25, 32, 33
High	129.45792 – 225.54957	6, 8, 13, 17, 19, 22, 28, 29, 37
Moderate	225.54958 – 414.19855	1, 3, 11, 12, 26, 30, 31
Low	414.19856 – 570.29021	2, 5, 20

5. Prioritization of Sub-Watersheds:

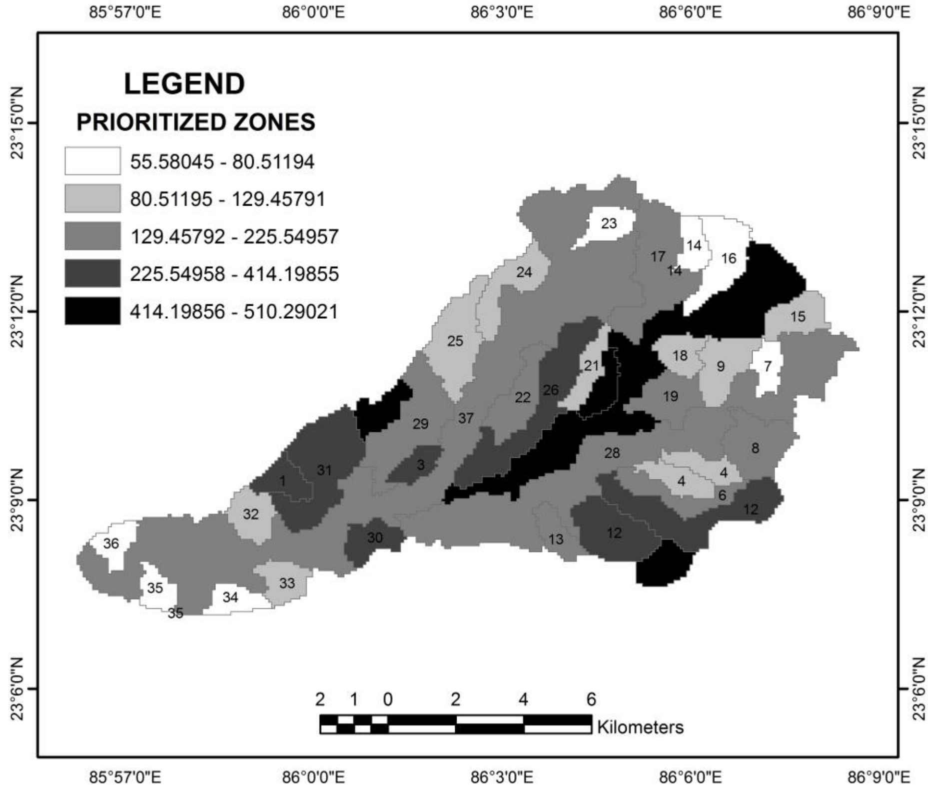

Figure 10: Prioritized zones of sub-watersheds

The composite parameter value of all 37 micro-watersheds of Sobha watershed is calculated and prioritization rating is shown in table- 4. The sub-watersheds have been classified into five priority zones according to their composite values.

Sub-watersheds falling under high to critical class are under very severe erosion susceptibility zone. Thus, need immediate attention to take up mechanical soil conservation measures gully control structures like check dams and grass waterways to protect the top soil loss. While sub-watersheds falling under moderate to low priority have very slight erosion susceptibility zone and may need agronomical measures to check the sheet and rill erosion.

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