IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG)
e-ISSN: 2321–0990, p-ISSN: 2321–0982.Volume 8, Issue 2 Ser. I (Mar – Apr 2020), PP 45-53
www.iosrjournals.org

Watersheds Morphometric Analysis of Kasari River Basin in Kolhapur District, Maharashtra, India

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Abstract: *Morphometric analysis of Kasari river and its 20 watersheds is carried out using Geographical Information System (GIS) techniques to study the behavior of the drainage and it topographical relation. The GIS techniques were used to study the linear, areal and relief aspects of the basin and its watersheds. Geologically, entire study area is covered by Deccan Volcanic Basaltic Province (DVBP) of late Cretaceous to early Eocene age. Laterite rocks are also occurs on the top of the hills. It belongs to Pleistocene period. Average Dd, and Fs values of the watersheds are high indicating high relief and low permeable sub-surface material. The average Rb values of most of the watersheds is less than 5 is point towards area is mountainous or highly dissected drainage basins. The average Rt values of the watersheds are increases with the basin area and stream ordering is increases. The Re, Rf and Rc values shows most of the watersheds are elongated in shape. Relief values show that area is steep sloping.*

Key Words: *Watershed, GIS, morphometry, Kasari.*

Date of Submission: 10-03-2020 Date of Acceptance: 24-03-2020

I. Introduction

Watersheds are the basic hydrologic units that have been used for morphometry and geomorphic characterization since the earlier published record[33]. It depends upon not only the climate and sub-surface geology of the area but also on the tectonic setting, shape and size of the watershed or sub-basin or basin[13]. For present study, morphometric analysis of Kasari river and its 20 watersheds are carried using Geographical Information System (GIS) techniques for study the behavior of the drainage and it topographical relationship. Morphometry is the measurement and mathematical analysis of the configuration of earth surface, shape and dimensions of its land forms[3,7,25]. Remote sensing and GIS techniques recently used to study the morphometry of the basins by [6,8,15,22,23,26-29]. It also proved efficient tools in the delineation of the watershed analysis, updating and augmenting the hydrogeomorphological analysis of drainage basin[10,14,17,18] and for study the geomorphology by[11]. The landslide zonation mapping using remote sensing and GIS is carried out in this area by [16] based on creep (mass wasting) movements observed during the rainy season, in hill and highly dissected part of the area.

II. Study Area

The Kasari river basin falls within the latitude 16°39'51"N to 16°55'13" N and longitude 73°42'51" E to 74°42'51" E in Survey of India (SOI) toposheet numbers 47L/1, 47L/2, 47H/9, 47H/13, and 47H/14 on the scale 1:50000. The basin is trending west to east and covers an area of about 631.7 sq km in Kolhapur district of Maharashtra (Fig. 01). It is major tributary of river Panchaganga. The climate of the area is sub-tropical characterised by high rainfall, cold and dry. Average rainfall in the basin is 1800 mm/year. The highest temperature is 40°c during May and lowest is 12°c during January.

III. Geology Of The Area

Geologically, Kasari river study area is covered by Deccan Volcanic Basaltic (DVB) lava flows of late Cretaceous to early Eocene age (Fig. 02). At some places these flows are separated by red bole beds (Tachylitic bands) as observed in the hills, valley exposures and in to the well sections. In the Joytiba and Panhala hill (watershed divider of Kasari river and Kadvi river) geological mapping is already done by Geological Survey of India (GSI) by[1] There are two types of basaltic rocks occurs in the basin namely, compact basalt (simple 'aa') and vesicular-amygdaloidal (compound pahoehoe). The large part of the area is covered by black cotton soil, which is important for agriculture purpose. The hill top is covered by laterites of Pleistocene age. Based on lithostratigraphy, present study area comes under Mahabaleshwar formation of Upper Deccan Traps in India[9]. In DVB terrain availability of groundwater is of limited extent. It occurs in fractures/joints of the basaltic rocks

[2,4,12]. In present study area, watersheds shows well developed dendritic to sub-dendritic drainage pattern. It is the indications of regional slope, homogeneous lithology and relief [3].

IV. Methodology

In the present study, laboratory analysis method has applied for study the morphometric analysis of the Kasari river and its 20 watersheds. For this, important morphometric parameters such as linear, areal and relief parameters are analyzed. The watersheds are selected based on its individual stream order. The stream order more than 4th order is selected for this study. Based on these, 20 watersheds are demarcated (10 on southern flank of the basin and 10 on northern flank of the Kasari river. To carry out laboratory study, Survey of Indian Toposheets on 1:50000 scales were used for preparation of base map i. e. location map (Fig. 01) and Drainage map (Fig. 04), watershed map (Fig. 05). Streams of 01st to 07th order were marked on map following the method of Strahler (1957). The following methodology is applied for present study it is represented based on the flow chart (Fig. 03). Finally all the watershed data is represented in the Table 01, 02 and 03.

V. Result And Discussion

Linear morphometric parameters

The linear morphometric parameters determined include stream order (u), stream number (Nu), Stream length (Lu) and bifurcation ratio (Rb) is analyzed for Kasari as well as its watersheds.

Stream order (u)

Stream order of drainage basin is the successive assimilation of the stream within a drainage basin. The ordering of the basin has been carried out by the method suggested by[31]. The Kasari river basin is 7th order (Fig. 04). More than forth order watersheds no. are 01, 03, 04, 05, 08, 09, 10, 11, 12, 13, 15, 16, 18, 19 and 20. 5th order watersheds no. are 02, 06, 07 and 17 and 6th order watersheds no. is 14 (Table 03).

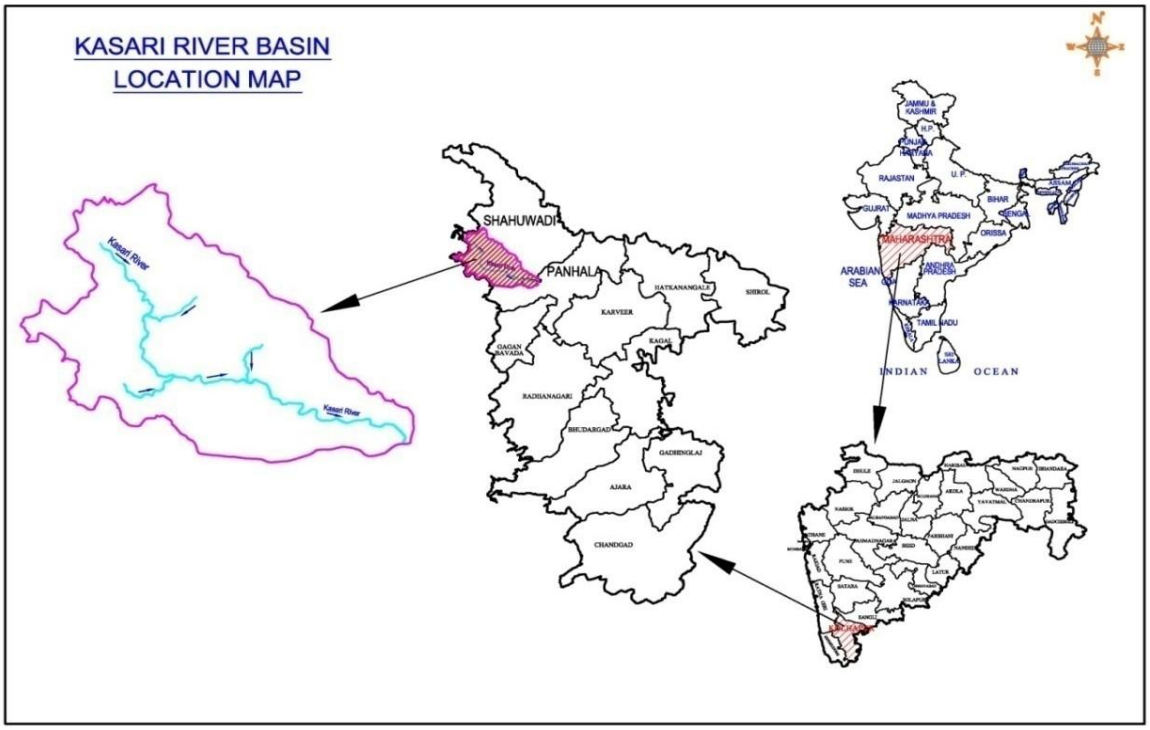

Fig. 01 Location map of Kasari river basin.

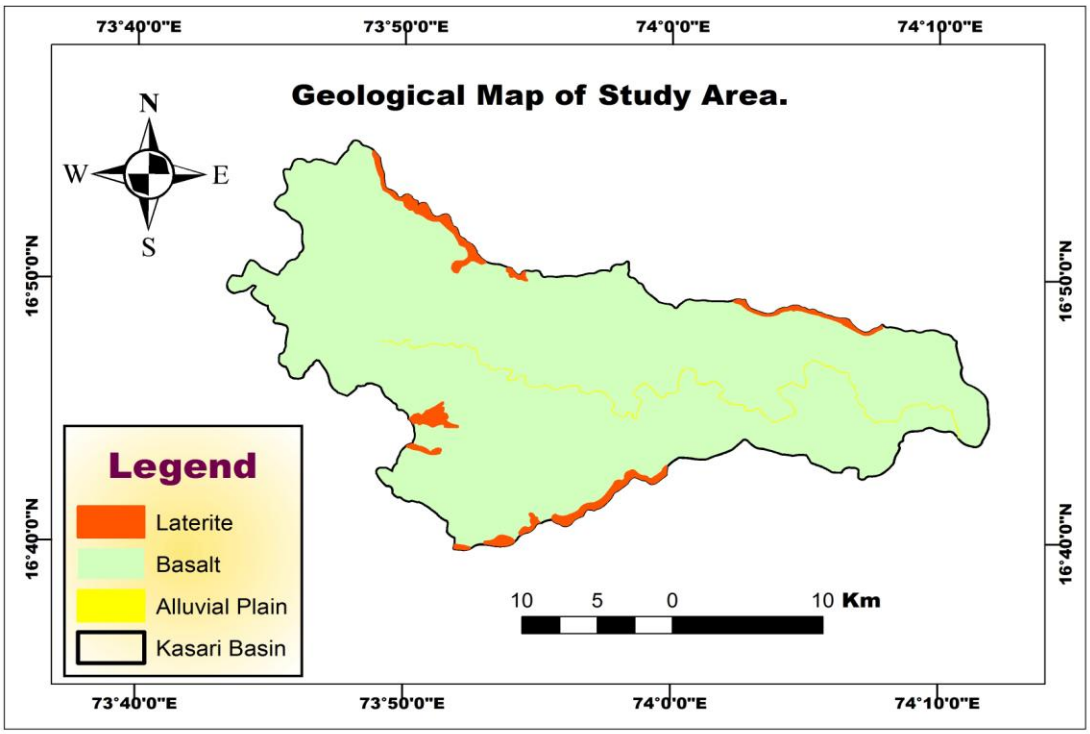

Fig. 02 Geological map of Kasari river basin.

Stream Number (Nu)

After assigning stream order, the segments of each order are counted to get the number of segments of the given order (u). Individual counting of the stream in the river basin reveals the total number of the stream. In the 4th order watersheds average stream are 64, in the 5th order watersheds average stream is 243, and 6th order watersheds average stream is 656. Whole Kasari river basin contains 3427 streams (Table 01).

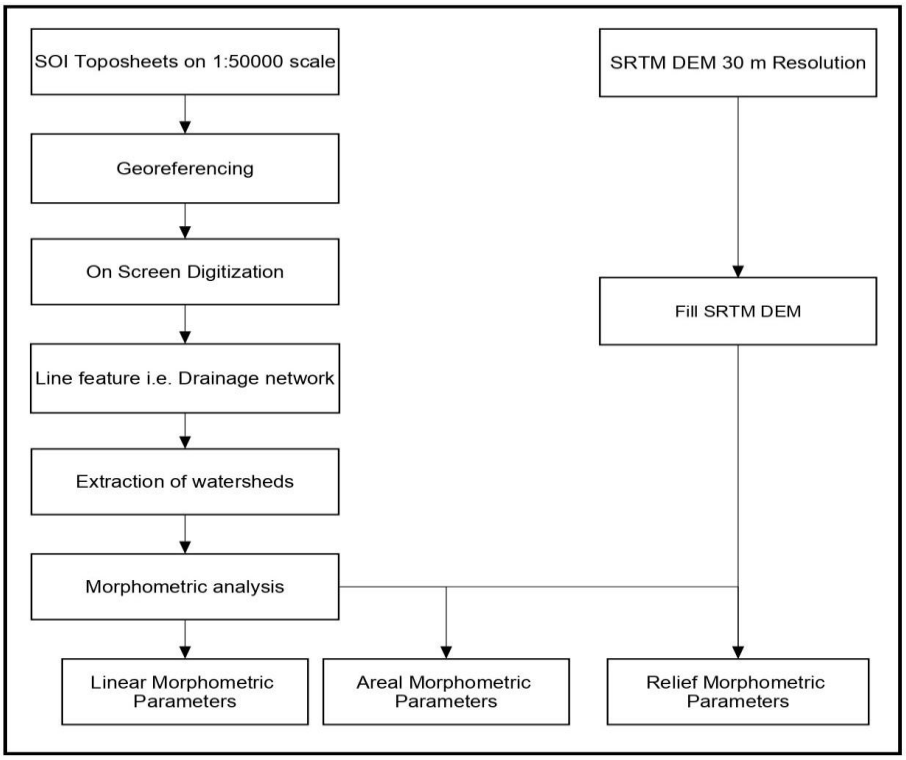

Fig. 03 Flow chart of methodology of the present researchwork.

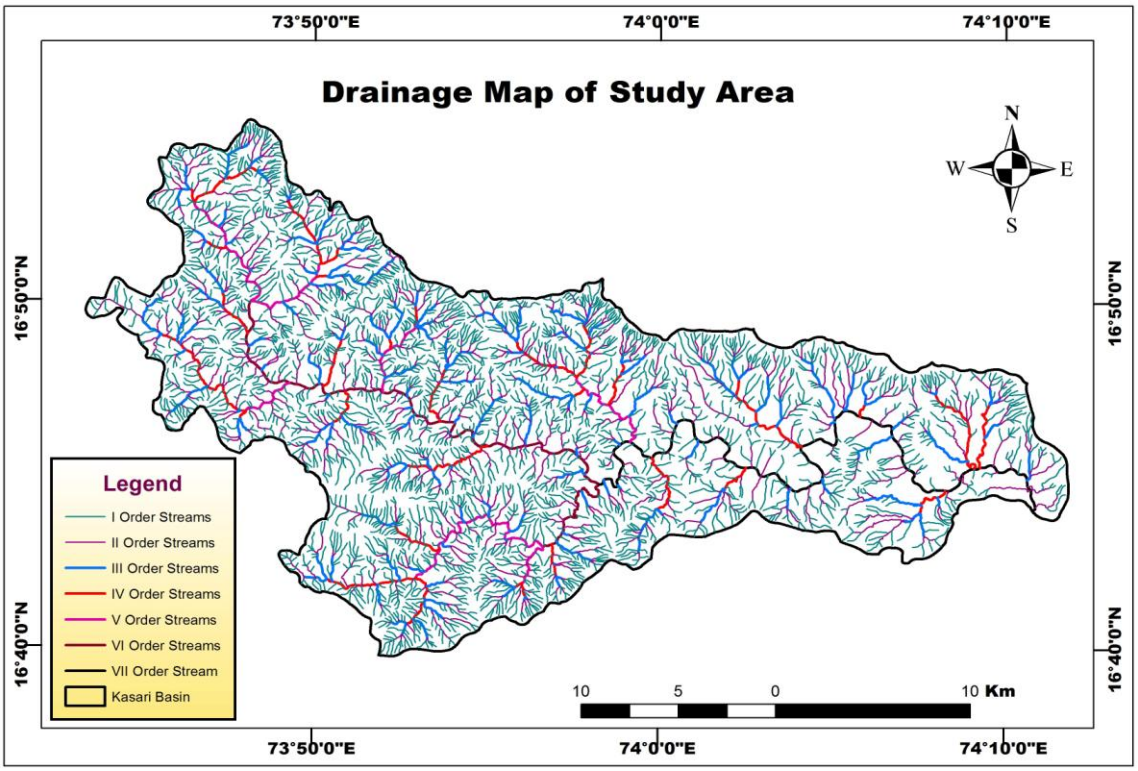

Fig. 04 Drainage map of Kasari river basin.

Bifurcation Ratio (Rb)

It is the ratio of number of streams of any given order to the number of streams in the next lower order[21]. It is calculated by using the formula, Rb=Nu/Nu+1, where, Nu is the total number of streams of all orders[21,34]. According to Strahler (1957) bifurcation ratio greater than 5 indicates structurally controlled development of the drainage network. In bifurcation ratio ranges from about 2 for flat or rolling drainage basins up to 3 or 4 for mountainous or highly dissected drainage basins[21]. Rb value of Kasari river basin ranges from 4.69 to 2.00 (Table 01). In the 4th order watersheds average Rb value is 3.48, in the 5th order watersheds average Rb value is 4.21, and 6th order watershed Rb average value is 5.44. The average bifurcation ratio of Kasari river basin is 3.85 (Table 01).

Table 01 Morphometric parameters of Kasari river basin.

Linear morphometric parameters of Kasari river						**Areal and Relief parameters of Kasari river**		
						parameters	**Symbol/ Formula**	**value**
u	**Nu**	**Rb**	**Lu**	**MSl**	**Rl**	Area (A) in sq km	GIS analysis	631.7 sq km
01	2599		1410	0.54		Perimeter (P) (km)	GIS analysis	159.2 km
		4.09				Drainage density (Dd)	Dd=Lu/A	3.54 km/km^2
02	636		447.3	0.70	1.30	Stream frequency (Fs)	Fs=Nu/A	5.43 stre. / km^2.
		4.24				Texture ratio (Rt)	Rt=N1/P	21.53 km^{-1}
03	150		179.5	1.20	1.70	Basin Elongation ratio (Re)	Re = (2√A:√π)/LB	0.56
		4.69				Basin Length (LB) (km)	GIS analysis	50.6
04	32		86.1	2.69	2.25	Circulatory Ratio (Rc)	Rc=4πA/P^2	0.31
		4.57				Form Factor Ratio (Rf)	Rf=A/Lb^2	0.25
05	07		40.0	5.71	2.12	Max. elevation in the Area (m)	Height of source	1023 m
		3.50				Min. elevation in the Area (m)	Height of mouth	474 m
06	02		34.0	17.00	2.98	Basin relief (H) (m)	H=Max. Ele-Min. Ele.	549 m
		2.00				Ruggedness number (Rn)	Rn=H*Dd	1.944
07	01		40.7	40.7	2.39			
Total	**3427**		**2238**	**68.56**	**12.74**			
Mean		**3.85**						

Where, u (Stream order), Nu (No. of Streams), Rb (Bifurcation Ratio), Lu (Length of streams), MSL (Mean stream length), RL (Length ratio).

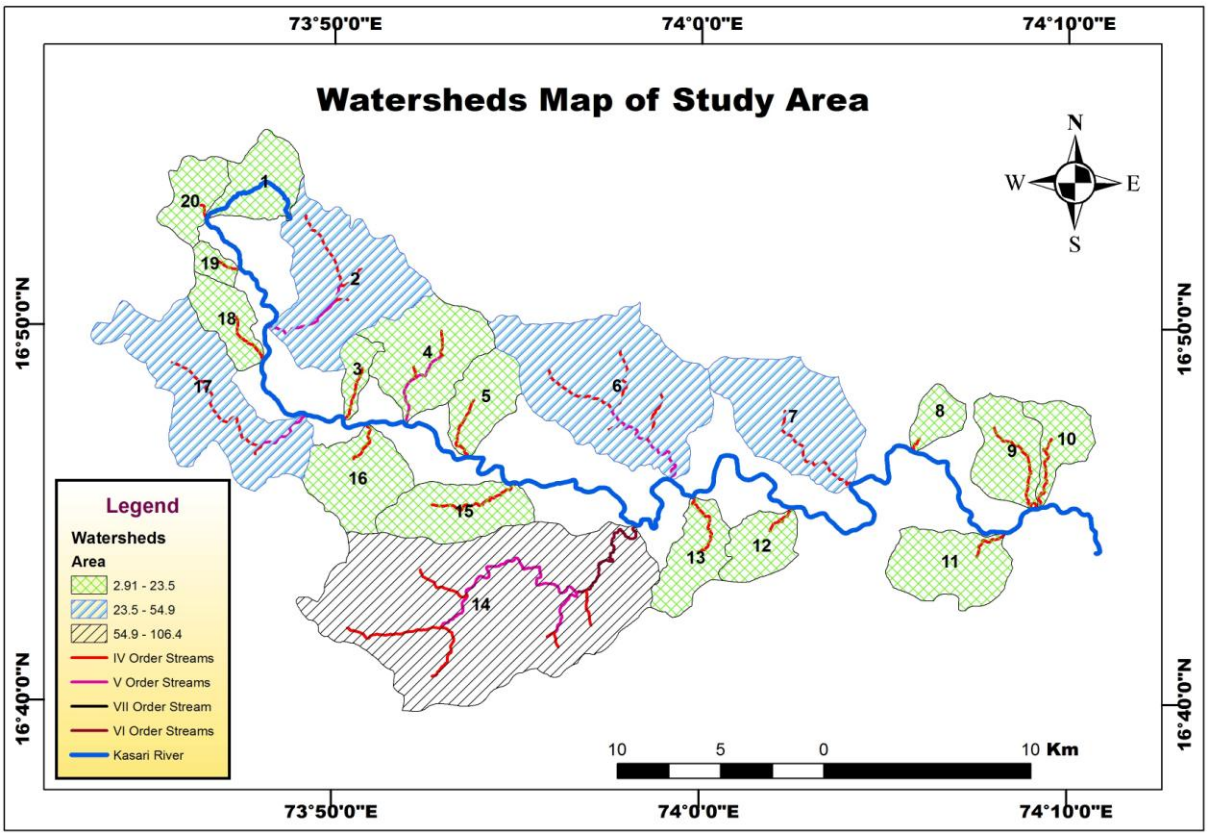

Fig. 05 Watershed map of Kasari river basin.

Stream Length (Lu)

Stream length of the basin is is inversely proportional to the stream order. Stream of relatively smaller length are characteristics of area with greater slope. In the 4th order watersheds average stream length is 43.6 km, in the 5th order watersheds average streams length is 149.4 km, and 6th order watersheds average streams length is 419.2 km. Whole Kasari river basin contains 2237.9 km streams.

Areal morphometric parameters

The areal morphometric parameters determined include Basin Area (A), Drainage Density (Dd), Stream Frequency (Fs), Texture Ratio (Rt), Form Factor Ratio (Rf), Basin Elongation Ratio (Re) and Circulatory Ratio (Rc) is analyzed for Kasari as well as its watersheds.

Basin Area (A)

Basin area is the direct outcome of the drainage development in a particular basin. In the 4th order watersheds area is 12.5 sq km, in the 5th order watersheds average area is 39.0 sq km and 6th order watersheds average area is 106.4 sq km. The area of Kasari river basin is about 631.7 sq km (Table 01).

Table 02 Stream order and the streams data in the watersheds of Kasari river basin.

W	No. of streams in each order						Length of the streams in each order						Bifurcation ratio				
	I	II	III	IV	V	VI	I	II	III	IV	V	VI	I/II	II/III	III/IV	IV/V	V/VI
01	72	14	04	01	-	-	37.7	10.2	4.62	4.13	-	-	5.14	3.50	4.00	-	-
02	179	47	11	03	01	-	92.7	25.6	15.5	6.10	5.04	-	3.81	4.27	3.67	3.00	-
03	25	07	02	01	-	-	11.8	2.23	1.16	2.80	-	-	3.57	3.50	2.00	-	-
04	136	31	09	03	01	-	67.7	17.2	12.1	1.91	4.52	-	4.39	3.44	3.00	3.00	-
05	75	17	03	01	-	-	35.2	8.09	5.31	3.40	-	-	4.41	5.67	3.00	-	-
06	246	61	16	04	01	-	132.1	38.8	22.2	10.8	6.17	-	4.03	3.81	4.00	4.00	-
07	97	20	06	01	-	-	64.6	21.4	9.23	6.05	-	-	4.85	3.33	6.00	-	-
08	18	05	02	01	-	-	9.20	3.91	2.42	0.75	-	-	3.60	2.50	2.00	-	-
09	39	10	03	01	-	-	22.7	8.25	3.57	5.74	-	-	3.90	3.33	3.00	-	-
10	27	07	03	01	-	-	16.7	5.41	2.69	4.13	-	-	3.86	2.33	3.00	-	-
11	37	10	04	01	-	-	26.8	12.3	6.44	2.27	-	-	3.70	2.50	4.00	-	-
12	26	07	02	01	-	-	18.5	6.14	2.60	1.88	-	-	3.71	3.50	2.00	-	-
13	53	11	02	01	-	-	31.1	7.28	3.16	3.76	-	-	4.82	5.50	2.00	-	-
14	502	116	29	06	02	01	281.0	77.4	27.9	12.4	13.8	6.68	4.33	4.00	4.83	3.00	2.00
15	82	22	05	01	-	-	45.5	13.4	3.93	5.20	-	-	3.73	4.40	5.00	-	-
16	67	17	03	01	-	-	42.7	13.3	5.12	2.27	-	-	3.94	5.67	3.00	-	-
17	170	40	09	02	01	-	85.1	31.7	11.6	7.65	3.10	-	4.25	4.44	4.50	2.00	-
18	48	13	03	01	-	-	24.7	6.67	3.42	2.85	-	-	3.69	4.33	3.00	-	-
19	19	07	02	01	-	-	7.81	1.80	1.27	1.15	-	-	2.71	3.50	2.00	-	-
20	41	10	02	01	-	-	20.5	9.90	2.75	4.13	-	-	4.10	5.00	2.00	-	-

Drainage Density (Dd)

Drainage density is defined as a 'ratio of total length of all streams to the total area of the basin'[20]. Drainage density of Kasari river are calculated with the help of following formula, Dd=Lu/A where, Lu is length of the streams and A is the area of the basin or watershed. The overall drainage density (Dd) of the Kasari river basin is 3.54 km/km^2 (Table 01). According to Strahler (1957), value of drainage density increases as the size of individual drainage basin proportional decreases. In the 4th order watersheds average Dd value is 3.58 km/km^2, in the 5th order watersheds average Dd value is 3.89 km/km^2 and 6th order watersheds Dd value is 3.94 km/km^2.

Stream Frequency (Fs)

The stream Frequency of the basin is the ratio of total number of stream segments of all orders to the basin area[21]. Fs values of Kasari river are calculated with the help of following formula, Fs=Nu/A where, Nu is Number of the streams and A is the area of the basin or watershed. In the 4th order watersheds average Fs value is 5.67 streams/km^2, in the 5th order watersheds average Fs value is 6.40 streams/km^2 and 6th order watersheds Fs value is 6.17 streams/km^2. The overall drainage density (Dd) of the Kasari river basin is 5.43 streams/km^2 (Table 01).

Texture Ratio (Rt)

It is the ratio of total stream numbers to the total perimeter of the basin[21]. Rt values of Kasari river are calculated with the help of following formula, Rt =Nu/P where, Nu is the total no of streams present in the basin and P is the perimeter of the basin. In the present study texture ratio of the Kasari river is 21.53 km^{-1} (Table 02). Smith (1950) has classified drainage density into five different textures i.e. very course (<2), course (2-4), moderate (4-6), fine (6-8), and very fine (>8). Based on this observed that watersheds of 4th order average Rt value is 4.13 km^{-1}, in the 5th order watersheds average Rt value is 7.72 km^{-1} and 6th order watershed Rt value is 13.72 km^{-1}.

Form Factor Ratio (Rf)

Form factor ratio is the dimensionless ratio of the basin area to the square of basin length[20]. Form factor values of Kasari river are calculated with the help of following formula, Rf = A/Lb2 where, A is the area of the basin and Lb is length of the basin. In the 4th order watersheds average Rf value is 0.43, in the 5th order watersheds average Rf value is 0.44 and 6th order watersheds Rf value is 0.45. The overall Form Factor Ratio (Rf) of the Kasari river basin is 0.25 streams/km^2 (Table 01).

Circulatory Ratio (Rc)

Circulatory ratio is the ratio of basin area to the area of circle having the same perimeter as the basin[24]. It is calculated with the help of formula, Rc =4πA/P2 where, A is the area of the basin P is the perimeter of the basin and π is 3.14. In the 4th order watersheds average Rc value is 0.47, in the 5th order watersheds average Rc

value is 0.48 and 6th order watersheds Rc value is 0.51. The overall Form Factor Ratio (Rf) of the Kasari river basin is 0.25 streams/km^2 (Table 01).

Basin Elongation Ratio (Re)

Basin elongation ratio is defined as the ratio of diameter of a circle of the same area as the basin to the maximum basin length[31]. The basin elongation ratio is calculated with the help of following equation, Re = (2√A:√π)/LB Where, Re is the basin elongation ratio factor, A is the diameter of a circle of drainage basin and L is the maximum length of the basin[5]. Value close to 1.0 are typical of regions of very low relief whereas that of 0.6-0.8 are associated with high relief and steep ground sloped into three categories, namely circular (>0.9), oval (0.9-0.8), and elongated(<0.7) (Bull and McFadden, 1977). The watersheds of 4th, 5th and 6th order Re values are 0.43, 0.44 and 0.45 respectively. The basin elongation ratio of the Kasari river basin is 0.56 (Table 01), which indicates basin and watersheds in the basin are elongated in shape.

Table 03 Areal morphometric parameter results of Kasari river watersheds.

W	u	A	P	LB	Nu	Lu	Rb	Dd	Fs	Rt	Re	Rf	Rc	MinE	MaxE	H	Rn
01	04	12.8	16.2	5.47	91	56.7	3.79	4.43	7.11	5.62	0.43	0.43	0.61	1023	618	405	1.79
02	05	37.3	31.6	7.49	241	144.9	4.72	3.89	6.46	7.63	0.52	0.66	0.47	999	575	424	1.65
03	04	4.59	11	4.22	35	18.0	2.92	3.92	7.63	3.18	0.32	0.26	0.48	844	561	283	1.11
04	05	23.5	22.5	6.60	180	103.4	4.69	4.40	7.66	8.00	0.47	0.54	0.58	1004	558	446	1.96
05	04	12.1	14.4	5.50	96	52.0	4.08	4.30	7.93	6.67	0.40	0.40	0.73	983	552	431	1.85
06	05	54.9	34.2	11.2	328	210.1	4.38	3.83	5.97	9.59	0.42	0.44	0.59	1004	546	458	1.75
07	04	31.9	23.6	8.86	124	101.3	3.01	3.17	3.89	5.25	0.41	0.41	0.72	976	542	434	1.38
08	04	5.53	9.5	3.52	26	16.3	2.78	2.94	4.70	2.74	0.43	0.45	0.77	956	542	414	1.22
09	04	14.7	16.9	6.05	53	40.3	2.50	2.74	3.61	3.14	0.32	0.40	0.65	948	540	408	1.12
10	04	9.05	15.6	5.38	38	28.9	2.28	3.20	4.20	2.44	0.51	0.31	0.47	949	538	411	1.31
11	04	18.2	18.2	5.84	52	47.8	2.68	2.63	2.86	2.86	0.47	0.53	0.69	800	541	259	0.68
12	04	9.88	13.3	4.55	36	29.1	2.65	2.95	3.64	2.71	0.44	0.48	0.70	881	548	333	0.98
13	04	12.5	17.1	5.86	67	45.3	2.92	3.62	5.36	3.92	0.38	0.36	0.54	926	550	376	1.36
14	06	106.4	47.8	14.5	656	419.2	5.44	3.94	6.17	13.7	0.45	0.51	0.58	986	552	434	1.71
15	04	17.3	18.6	6.68	110	68.0	3.58	3.93	6.36	5.91	0.40	0.39	0.63	987	553	434	1.71
16	04	17.9	17.7	5.45	88	63.4	3.71	3.54	4.92	4.97	0.49	0.60	0.72	995	561	434	1.54
17	05	40.2	39.2	12.1	222	139.2	3.05	3.46	5.52	5.66	0.33	0.28	0.33	820	565	255	0.88
18	04	9.38	14.1	4.91	65	37.6	3.44	4.01	6.93	4.61	0.40	0.39	0.59	830	569	261	1.05
19	04	2.91	7.27	2.26	29	12.0	4.43	4.13	9.97	3.99	0.48	0.57	0.69	817	616	201	0.83
20	04	9.01	13.7	2.94	54	37.3	4.94	4.14	5.99	3.94	0.65	1.04	0.60	810	614	196	0.81
Average							**3.60**	**3.66**	**5.84**	**5.33**	**0.44**	**0.47**	**0.61**	**927**	**562**	**365**	**1.33**

Where, Watersheds (W), Stream order (u), Area (A), Perimeter (P), Length of the basin (LB), Number of streams (Nu), length of the streams (Lu), Bifurcation ratio (Rb), Drainage density (Dd) km/km^2, Stream frequency (Fs) Streams/km^2, Textural ratio (Rt) km^{-1}, Basin Elongation Ratio (Re),Circulatory Ratio (Rc), Form Factor Ratio (Rf), Relief (H), Minimum Elevation (Min. E), Maximum Elevation (Max. E) and Ruggedness no. (Rn).

Relief morphometric parameters

The relief morphometric parameters determined include Basin Relief (H) Relief Ratio (Rh) and Ruggedness Number (Rn) is analysed for Kasari as well as its watersheds.

Basin Relief (H)

The vertical distance difference between point of maximum elevation and minimum elevation is the relief of basin. Basin relief (H) determines the stream gradient and influences flood pattern and volume of sediment that can be transported [19]. For study relief of the basin SRTM DEM map are prepared through ArcGIS10.1. It is very useful for studying the maximum and minimum elevation of the basin. In the study area the H values of watersheds 4th, 5th and 6th orders are 369, 396 and 434 respectively. The maximum elevation is 1023 metre and minimum elevation is 474 metre. Therefore, the basin relief of Kasari river is 549 meters (Table 01).

Ruggedness Number (Rn)

Ruggedness number is the product relief of basin (H) and drainage density (Dd). The ruggedness number of Kasari river basin 1.94 (Table 01). The relief ratio of Kasari river basin is 0.010 (Table 02). It is calculated with the help of formula, Rn=H*Dd/1000 where, where, H is the relief of the area and Dd is the drainage density of the basin. In the study area the H values of watersheds 4th, 5th and 6th orders are 1.29, 1.56 and 1.71 respectively.

VI. Discussion

In the present study, based on linear, areal and relief morphometric parameter analysis of Kasari river and its 20 watersheds observed that, area is homogeneous terrain and steep sloping. It is observed based on the average values of Rb (3.60), Dd (3.66 km/km^2), Fs (5.84 Streams/km^2) and H (365m) (Table 03) values of the watersheds. Same morphometric parameters of Kasari river Rb value is 3.85, Dd is 3.54 km/km^2, Fs is 5.43 streams / km^2 and H is 474 m. High drainage density and high stream frequency point towards impermeable and steep sloping surface[17]. According to Strahler (1957), value of drainage density increases as the size of individual drainage basin proportional decreases. Very small amount of change taken place in between average values Rb, Dd, Fs, Rt, and H of watersheds with whole Kasari river basin is due to different erosional condition of the lithology within the basin. Small watersheds are less affected by erosion as compared to the large watershed[12]. Similarly, average values of shape parameters like Re, Rf and Rc values of watersheds are 0.44, 0.47 and 0.61 respectively (Table 03). Whole Kasari river such parameters shows that Re value is 0.56, Rf is 0.25 is and Rc is 0.31 (Table 01).

VII. Conclusion

In present study, morphometric analysis of 20 watersheds and Kasari river is carried and observed that the average values of Dd, and Fs is high indicating high relief and low permeable sub-surface material. The average Rb values of most of the watersheds is less than 5 except watershed no 14 (5.44), is point towards area is mountainous or highly dissected drainage basins. It is also reveals that there appears to be no strong geological control in the development of the drainage, homogeneous nature of lithology and drainage network in study area is well developed stage. The average Rt values of the watersheds are increases with the basin area and stream ordering increases. The Re, Rf and Rc values shows that most of the watersheds are elongated in shape. Relief value shows that area is steep sloping.

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