A Morphometric Approachin Prioritization of Sub-Watersheds of the Kuttiadi River Basin, Kerala

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Abstract

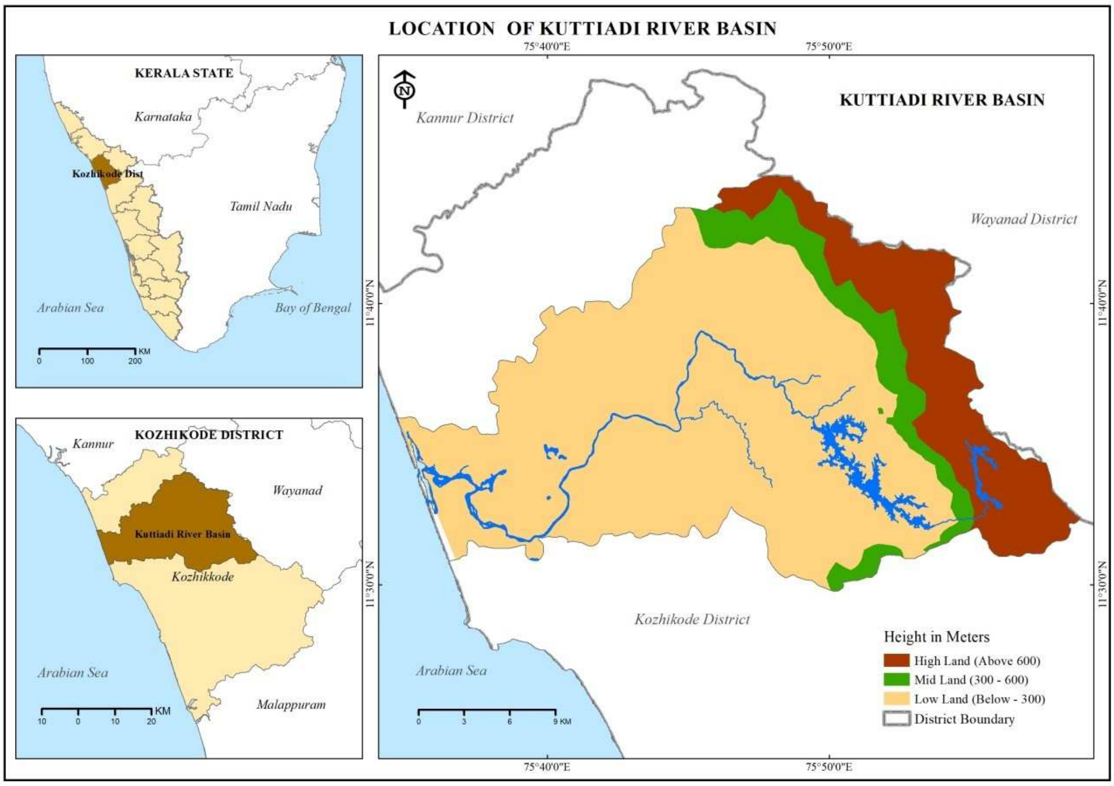
The Kuttiadi river basin is been divided into 47 sub-watersheds and morphometric features of all sub-watersheds are calculated usingGeographic Information System by ArcGIS-10 software. There are 36 morphometric parameters calculated sub-watershed wise.The sub-watersheds were ranked according the value of morphometric parameters. Highest rank 1 given to the high potential sub-watershed and lowest rank 47 was given to the least potential sub-watershed. Then the compound value of 26 morphometric parameters of 47 sub-watersheds has been calculated and sub-watersheds classified into three category of prioritization that is low, medium and high.

1. Introduction

Morphometric(from Greek*morphe*,"shape, form", and- *metria*, "measurement") or morphometry refers to the quantitative analysis of *form*, a concept at encompasses size and shape. Morphometry is the measurement and mathematical analysis of the configuration of the earth's surface,shape and dimension of its landforms. This analysis can be achieved through measurement of linear, aerial andrelief aspects of the basin drainage network.(Nag and Chakraborty, 2003).Morphometry is the measurement and mathematicalanalysis of the configuration of the earth's surface, shape and dimension of its landforms (Agarwal, 1998; ObiReddy et al., 2002).In Geography it is the measurement and mathematical analysis of the configuration of the earth's surface, shape and dimension of its landforms. Applying morphometric analysis in river basin studies provides important information of the geo-hydrological behaviour of drainage basin and it expresses the climate of river basin, geology, geomorphology, and structural background of the catchment, landuse and potentiality of river basin for various economical activities.River basin consists of distinct morphologic region and has special relevance to drainage pattern and geomorphology (Doornkamp and Cuchlaine, 1971). Morphometric analysis is important in any geo-hydrological researches to provide accurate information on ground water potential, ground water management and landuse change analysis.Primary controlling factors of river basin are Geology, Geomorphology, slope, relief, climate especially rainfall, if they are correlated with morphometric metric parameters can provide greater information of the function of a river basin. Geographical Information System (GIS) techniques are now-a-days in use for assessing various terrain and morphometric parameters of the drainage basins and watersheds, as it provide a flexible environment and an important tool for the manipulation and analysis of spatial information.The morphometric characteristics at the watershed scale may contain important information regarding its formation and development because all hydrologic and geomorphic processes occur within the watershed (Singh, 1992).

2. Study Area

The longitudinal extension of the watershed is 75^{O} 34′ 33″ to 75O 58′ 55″ East and the latitudinal extension is 11^{O} 21′ 45″ to 11^{o}44′ 33″. The Kuttiadiriverrising from the Narikota Ranges on the western slopes of the Western Ghats at an elevation of 1220 m above M.S.L flows through Vatakara and Quilandy Taluksof Kozhikode District.The total area drained by Kuttiadi river is 667 Square Kilometre and after flowing 74 kilometre it joins into the Arabian sea at Kottakkal 7 kilometre south of Vatakara town, there this river is known as Murat river.The physiography division of the watershed is classified into four according to the altitude. Coastal plains occupied 1.53% as a narrow stretch in the beach. The lowland with 10-300 meters consists 72.43% of the total area.The midland which is ranges from 300-600 meters and cover8.29% of the total area. Highland consists 17.75% of area above 600 metres which is located in the eastern side of the water shed.Maximum height of the watershed is 1750 mts.



3. Objectives

Prioritization of sub-watersheds of the Kuttiadi river basin based on the morphometric parameters.

4. Methodology

The sub-watershed map of Kuttiadi river basin is been digitized and coded according to the Watershed Atlas published by Ministry of Agriculture& Kerala State Land Use Board. The ArcGIS 10 GIS software is used for digitizing and Arc Tools has been effectively utilized at various stages in the analysis of morphometric parameters. Morphology Adopted for Kuttiadi river basin is the 36 Morphometric Parameters is calculated for each 47 sub-watersheds and the value of each morphometric analysis has been analysed, and ranked according to the standardised orderand interpreted. Then 26 selected morphometric parameters taken for ranking, and rank 1 is highest and 47 is the lowest and derived compound value of 26 parameters were used to classify to three classes of prioritization.

4. Analysis

The Table 1.1 shows the identified morphometric parameters of Kuttiadi river basin. The parameter has been classified in to four according to their Characteristics. Most of the parameters can be analysed with respect to two main sets of properties; the topographical aspects and stream networks interconnections of the system, whereas the geometrical aspects involve length, area, shape, relief and orientation parameters.

Table 1.1 - Morphometric Parameters for Drainage Analysis

I	**Drainage Net work**		
1	Stream Order	Hierarchical Rank	Strahler (1952)
2	Stream Length (Lu) in kms	Lu= L1+L2…… Ln	Strahler (1964)
3	Mean Stream Length Ratio	Lurm=Average of Mean Stream Length	Horton (1945)
4	Stream Length Ratio (Lur)	Lur= Lu / (Lu – 1)	Strahler (1964)
5	Weighted Mean Stream Length	Luwm=(Lur*Lur-r)/Lur-r	Horton (1945)
6	Stream Number	Nu= N1+N2+ …Nn	Horton(1945)
7	Bifurcation Ratio	Rb = Nu / (Nu + 1)	Strahler (1964)
8	Mean Bifurcation Ratio (Rbm)	Rbm=Average of bifurcation ratios of all	Strahler (1964)
9	Weighted Mean Bifurcation	Rbwm = (Rb*Nu-r)/Nu-r	Strahler (1964)
10	Length of Main Channel (Cl)	Software (ArcGIS 10)	
11	Rho Coefficient (Rho)	Rho = Lur / Rb	Horton (1945)
II	**Basin Geometry**		
12	Drainage Basin Area (A)	Software (ArcGIS 10)	Schumm(1956)
13	Drainage Basin Perimeter	Software (ArcGIS 10)	Schumm(1956)
14	Relative Perimeter (Pr)	Pr=A/P	Schumm(1956
15	Basin Length (Lb) Kms	Software (ArcGIS 10)	Schumm(1956)
16	Shape Factor (Bs)	Bs=Lb/Wb	Strahler (1957)
17	Length Area Relation (Lar)	$Lar=1.4*A^{0.6}$	Hack (1957)
18	Form Factor Ratio (Rf)	$Rf = A / Lb^2$	Horton (1932)
19	Lemniscate's (k)	$k = Lb^2/ A$	Chorley (1957)
20	Mean Basin Width (Wb)	Wb=A/Lb	Horton (1932)
21	Texture Ratio (Rt)	Rt = N1 / P	Schumm(1956)
22	Drainage Texture (Dt)	Dt = Nu / P	Horton (1945)
23	Circularity Ratio (Rc)	$Rc = 12.57 * (A / P^2)$	Miller (1968)
24	Compactness Coefficient (Cr)	$Cr = 0.2841 * P / A^{0.5}$	Gravelius(1914)
25	Elongation Ratio (Re)	$Re = 2 \sqrt{A} / \pi / Lb$	Schumm(1956)
III	**Drainage Texture Analysis**		
26	Drainage Intensity (Di)	Di = Fs / Dd	Faniran (1968)
27	Stream Frequency (Fs)	Fs = Nu / A	Horton (1932)
28	Drainage Density (Dd)	Dd = Lu /A	Horton (1932)
29	Constant of Channel	C = 1 / Dd	Schumm(1956)
30	Infiltration Ratio	If=Dd*Fs	Faniran (1968)
31	Length of Overland Flow (Lg)	Lg = A / 2 * Lu	Horton (1932)
IV	**Relief Aspect**		
32	Basin Relief (R) (in m)	R= Maximum Height-Minimum Height,	Strahler (1957)
33	Relief Ratio (Rh)	Rh = H / Lb	Schumm(1956)
34	Ruggedness Number (Rn)	Rn = Dd*(H/1000)	Strahler (1957)
35	Melton Ruggedness Number	$MRn = H/A^{0.5}$	Patton & Baker
36	Gradient Ratio	Gr=(H-h/Lb)	Sreedevi (2004)

Compiled by Author

Stream ordering is the initial process of quantifying the characteristics of watershed. The stream ordering systems has first advocated by Horton (1945). Then the Strahler (1952) has proposed this ordering system with some modifications. Strahler's method of stream ordering is used in this study (Table 1.2).

In this river basin stream frequency is decreasing by increasing the order. Stream order of drainage basin is the successive assimilation of the streams within a drainage basin. According to Strahler (1964) the smallest fingertip tributaries are designated as order 1. Where two first order streams join, a channel segment of order 2 is formed; where two of orders 2 join, segments of order 3 is formed; and so forth. The trunk stream through which all discharge of water and sediment passes is therefore the stream segment of highest order. The Kuttiadi River basin is a six order drainage network system (Figure 1.2) and figure 1.3 shows the sub-watersheds of Kuttiadi river basin.

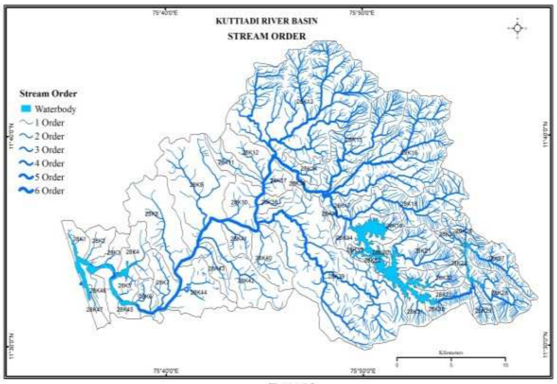


Figure : 1.2

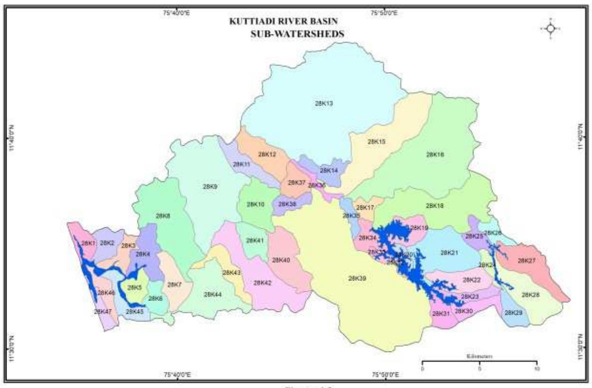


Figure : 1.3

Table 1.2 -Stream Ordering of Kuttiadi River Basin

Stream Order	Number of Streams	Length of Streams	Mean Stream Length (Lū)	Length Ratio (Lur)	Rb	Nu-r	Rb* Nu-r	Rbwm
I	1545	890.88	0.57	1.42	---	---		
II	339	275.76	0.81	1.94	4.56	1884	8591.04	
III	85	133.93	1.57	3.53	3.99	424	1691.76	
IV	17	94.17	5.54	1.65	5.00	102	510	
V	6	54.81	9.13	4.71	2.83	23	65.09	
VI	1	42.99	42.99	---	6	7	42	
Total	**1993**	**1492.54**		**13.25**	**22.38**	**2440**	**10899.89**	**4.467**
Rho = 0.59 (13.25/22.38)				Rbm=4.476				

Compiled by AuthorNu-r=Number of streams used in the ratio, Rbwm = Weighted Mean Bifurcation Ratio

The selected morphometric parameters to calculate the morphometric compound value is listed in table 1.3. The value of each parameter for 47 sub-watersheds has been identified and the sub-watersheds is been ranked 1 to 47 according to their suitability.

Table 1.3-Morphometric parameters used for Compound Value

Sl. No	Morphometric Parameter	Symbol	Lowest Value	Highest Value	Ranking Highest 1	Lowest 47
1	Mean bifurcation Ratio	Rbm	0	15 km	1	47
2	Shape factor	Bs	1.28	11.67	1	47
3	Mean Basin Width	Wb	0.29	8.39	47	1
4	Relative Perimeter	Pr	0.06	2.07	1	47
5	Basin Length	Lb	1.16	15.05	1	47
6	Length Area Relation	Lar	1.10	21.80	1	47
7	Form Factor	Rf	0.08	0.77	47	1
8	Lemniscate's	k	1.29	11.68	1	47
9	Texture Ratio	Rt	0.073	6.48	1	47
10	Stream frequency	Fs	0.22km^2	10.40 km^2	1	47
11	Drainage density	Dd	0.42 km/ km^2	3.8 km/ km^2	1	47
12	Drainage texture	Dt	0.07	8.65	1	47
13	Circulatory ratio	Rc	0.08	0.71	47	1
14	Compactness ratio	Cr	1.8	3.47	1	47
15	Elongation ratio	Re	0.33	0.99	47	1
16	Basin Relief	R	10	1660	1	47
17	Relief Ratio	Rh	0.002	0.201	1	47
18	Ruggedness Number	Rn	0.004	5.287	1	47
19	Melton Ruggedness	MRn	3.12	634.75	1	47
20	Drainage Intensity	Di	0.38	8.01	1	47
21	Stream Frequency	Fs	0.22	10.40	1	47
22	Drainage Density	Dd	0.36	3.80	1	47
23	Constant of Channel	C	0.26	2.74	47	1
24	Infiltration Ratio	If	0.13	27.49	1	47
25	Length of Overland Flow	Lg	0.13	1.26	47	1
26	Gradient ratio	Gr	2.20	189.12	1	47

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The table 1.4 shows the details of sub-watersheds of Kuttiadi river basin according to morphometric prioritization. Low prioritization sub-watersheds are concentrated in the low lands of Kuttiadi river basin. Medium prioritized sub-watersheds are concentrated in mid and high land region and high prioritized sub-watersheds are concentrated in high land region of this river basin. There are 17 watersheds comes under low prioritization category. It occupies 132.14 km^{2}areas of river basin and cover 19.81% of the total area of the river basin.

The Medium prioritization has 20 sub-watersheds,which occupied an area of 335.42 km^2 and cover 50.28% of the total area.Majority of these medium category sub-watersheds are occupied in low land and fewsub-watershedsare found eastern side of the basin,which are located in the high land region of the river basin. They are 28K24, 28K25, and 28K26 which is located in the northern side of the Kakkyam reservoir.

In high prioritization category, there are 10 sub-watersheds which occupy an area of 199.44 km^{2}and it covers 29.90% of the total area of the river basin. High prioritized sub-watersheds are located in the high lands of Kuttiadi river basin. It consist high density of streams, highly undulating relief which result severe erosion. The more priority should give to these areas for conserving natural resources. Having high land topography more measures to be adopted in this region to improve underground water potentiality, so that it may also improvethe underground water potentiality of mid land and low land of the river basin. More progressive activities related to water conservation, afforestation etc. should be concentrated in high prioritized sub-watersheds. The figure 1.4 shows sub-watershed wise prioritization of Kuttiadi river basin.

Table 1.4- Prioritization of Sub-Watersheds Based on Morphometry

Priority	Range of MCv	Number of Watersheds	Area in km^2 (In %)	Watershed Code
Low	Below 20	17	132.14 km^2 (19.81%)	28K1, 28K2, 28K3,28K4, 28K5, 28K6, 28K8, 28K10, 28K34, 28K36, 28K37, 28K38, 28K41, 28K44, 28K45, 28K46,28K47
Medium	20 to 30	20	335.42 km^2 (50.29%)	28K7, 28K9, 28K11, 28K12, 28K13, 28K14, 28K17, 28K19, 28K20, 28K31, 28K24, 28K25, 28K26, 28K32, 28K33, 28K35, 28K39, 28K42, 28K43, 28K40,
High	Above 30	10	199.44 km^2 (29.90%)	28K15, 28K16, 28K18, 28K21, 28K22, 28K23, 28K27, 28K28, 28K29, 28K30,
		47	**667 km^2**	

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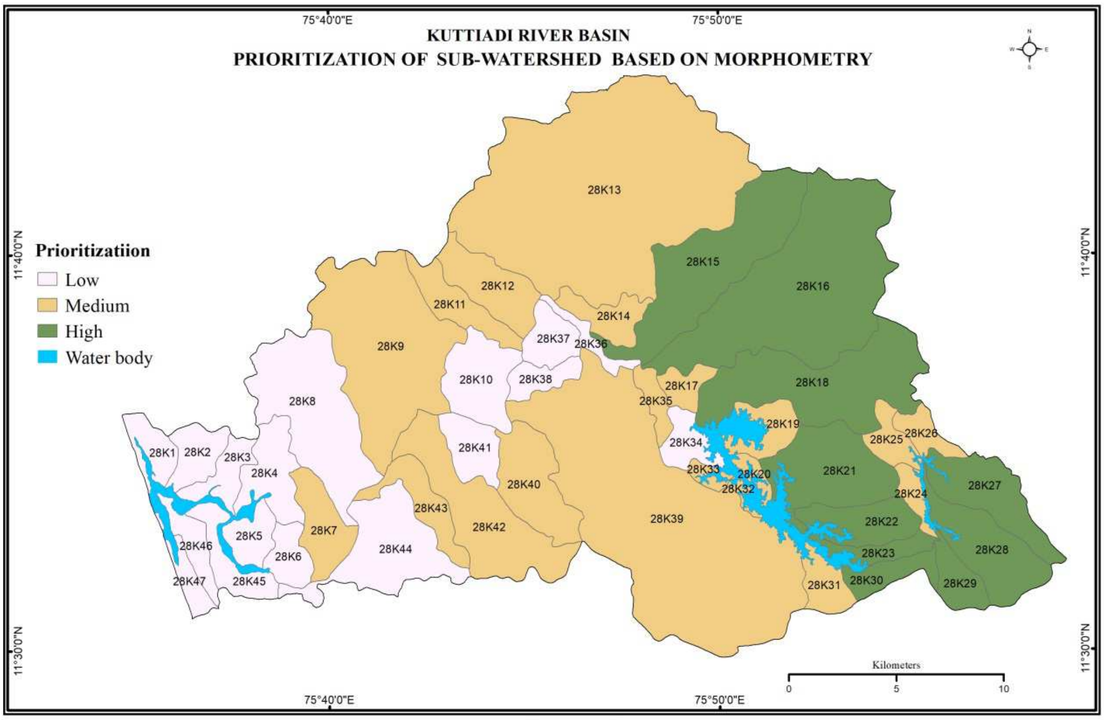

Figure : 1.4

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