International Journal of Innovation and Scientific Research
ISSN 2351-8014 Vol. 16 No. 1 Jun. 2015, pp. 86-94

http://www.ijisr.issr-journals.org/

Micro-watershed Prioritization of Kokkayar Sub-watershed, Manimala River Basin, Kerala, India

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ABSTRACT: Morphometric analysis is important in any hydrological investigation and it is inevitable in development and management of drainage basin. The present study is an attempt to evaluate and compare various morphometric parameters and prioritization of micro-watersheds based on water holding capacity of Kokkayar sub-watershed, a typical highland sub-watershed of Manimala river basin. Morphometric analysis and prioritization of micro-watersheds have been achieved through measurement of linear, aerial and relief aspects of basins by using remote sensing and GIS techniques, and it necessitates preparation of a detailed drainage map. For prioritization, 9 micro-watersheds are delineated and morphometric parameters such as Rb, Dd, Fs,T, Lof and C are calculated separately and prioritization has been done by using the Raster calculator option of Spatial analyst. The analysis reveals that the stream order varies from 1 to 4 and the total number of stream segments of all orders counted as 200. Lsm varies from 0.50 to 7.55. Higher value of mean Rb (4.17) (linear parameters), higher values of Bh (0.08), Rh (0.07) and Rn (3.02) (relief parameters), high values of Dd (3.2), Fs (6.3), T (5.63) and low values of Lof (0.16) and C (0.31) (aerial parameters) all together reveal that the sub-watershed has a complex structure, mountainous relief, high runoff and low infiltration. The maximum area is covered by high prioritized zones (12.72 km^2) followed by very high (10.63km^2) while very low zone is only 9.37 km^2.

KEYWORDS: Linear parameters, Relief parameters, Aerial parameters Kokkayar sub-watershed, Manimala river basin.

1 INTRODUCTION

Prioritization of micro-watersheds has gained immense significance in natural resource management, especially in of watershed management. Morphometric analysis has been commonly applied for the prioritization. It is the measurement and mathematical analysis of the configuration of the earth's surface, shape and the dimensions of its landforms [1];[2]. This can be achieved through measurement of linear, aerial and relief aspects of the basins and slope contributions [3];[4]. Morphometric parameters can be used in various studies of geomorphology, surface water hydrology and evolution of base morphology [5];[6];[7];[8];[9]. A better knowledge about these are vital for an overall understanding of basin development and its management. Thus the application of various morphometric techniques is a major advance in the quantitative and qualitative description of the geometry and network of the drainage basins. Further using these techniques comparison of different drainage networks, influence of various variables such as lithology, Geology, rock, structure, rainfall etc can also be carried out.

Morphometric analysis using remote sensing techniques has been attempted by [10];[11];[12] and have concluded that remote sensing has emerged as a powerful tool in morphometric analysis. Geographical Information System (GIS) techniques have already been used for assessing various terrain and morphometric parameters of the drainage basins and watersheds as they provide a flexible environment and a powerful tool for the manipulation and analysis of the spatial information particularly for better understanding of the future scenario [13].

2 METHODOLOGY

Assessment of various morphometric parameters is essential for the exploration of water potential zones with in a watershed. Present study is an attempt to calculate various morphometric parameters of the entire Kokkayar sub-watershed and its micro-watersheds for prioritization of micro-watershed based on water holding capacity. Kokkayar sub-watershed (Fig.1) is a typical highland sub-watershed of Manimala river basin and it lies between 9°30'00" to 9°45'00" N latitude and 76°45'00" to 77°00'00" E longitude. It covers an area of 39.22 km^2. Geologically the area is Precambian in origin, characterised by rocks of charnockite, gabbro, and quartzite.

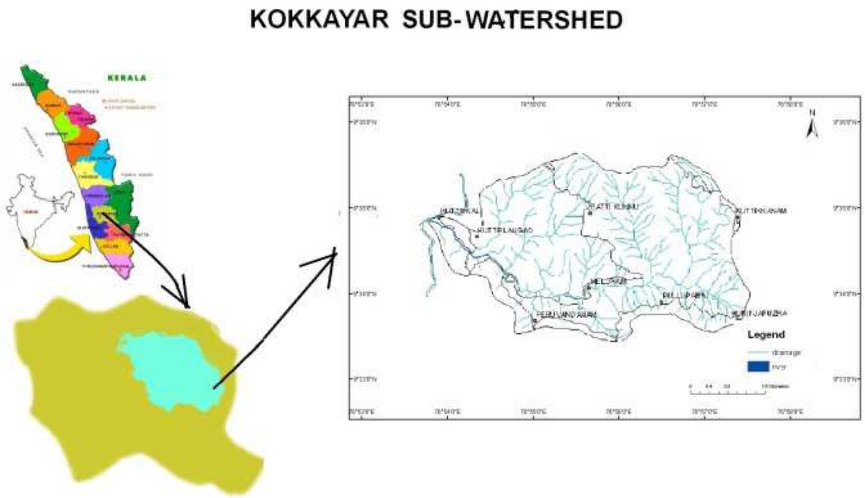

Fig. 1. Study area-Location map

The Kokkayar sub-watershed and associated drainage networks were delineated from Survey of India topographical map (No.58 C/14, of 1:50000 scale) and morphometric analysis was carried out using Arc GIS 9.2 (Fig. 2). The methodology adopted for the calculation of morphometric parameters are given in (Table. 1). Various parameters such as stream length (Lu), mean stream length (Lsm), bifurcation ratio (Rb), (linear parameters), basin relief (Bh), ruggedness number (Rn) (relief parameters), drainage density (Dd) texture ratio (T), stream frequency (Fs), circulatory ratio (Rc), constant channel maintenance (C) and length of overland flow (Lof) (aerial parameters) has been carried out for the entire basin of Kokkayar. Morphometric analysis is also a significant tool for prioritization of micro-watersheds even without considering the soil map. In the present study, seven micro-watersheds were delineated (Fig.3). morphometric parameters such as drainage density (Dd), bifurcation ratio (Rb), texture ratio (T), stream frequency (Fs), length of overland flow (Lof) and constant channel maintenance (C) of the delineated micro-watersheds were carried out separately.

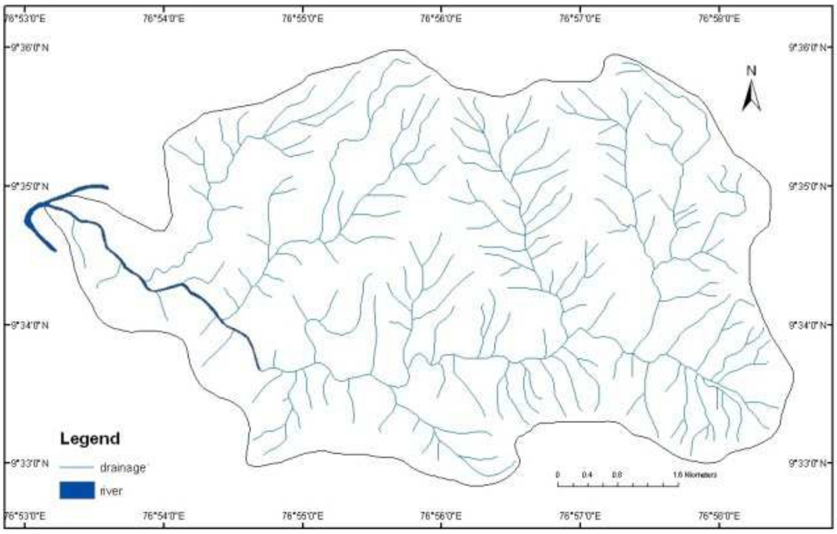

Fig. 2. Drainage of Kokkayar sub-watershed

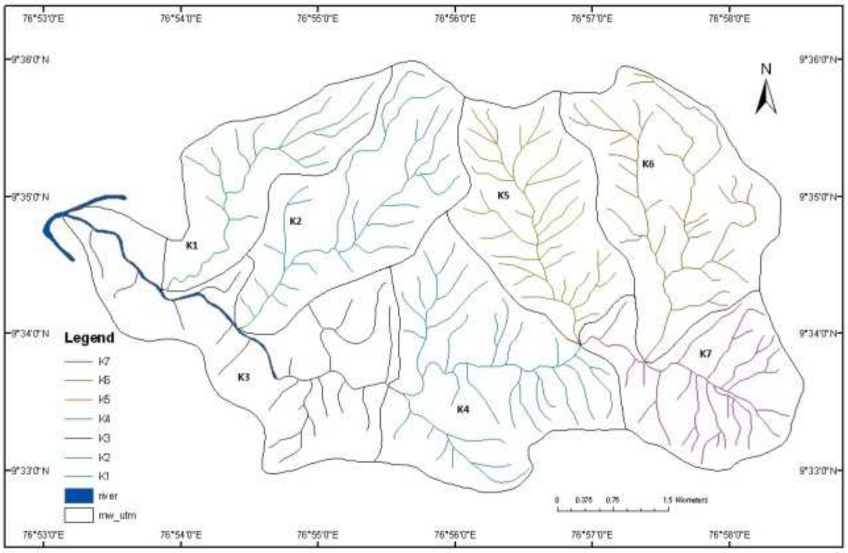

Fig. 3. Micro-watershed of of Kokkayar sub-watershed

Table 1. Methods of calculation of morphometric parameters

MP	Methods
Linear parameters	
U	Hierarchical order
Lu	Length of stream
Lsm	Lsm=Lu/Nu; Where, Lu=Stream length of order 'U'; Nu=Total number of stream segments of order 'U'.
Rb	Rb = Nu/ Nu+1; Nu=Total number of stream segment of order'u'; Nu+1=Segment of next higher order.
Relief parameters	
Bh	Bh=Vertical distance between lowest and highest point of watershed.
Rn	Rn=Bh X Dd; Where, Bh=Basin relief; Dd=Drainage density.
Arial parameters	
Dd	Dd = L/A where, L=Total length of streams; A=Area of watershed.
Fs	Fs = N/A where, N=Total number of streams; A=Area of watershed.
T	T = N1/P where, N1=Total number of first order streams; P=Perimeter of watershed.
C	C=1/Dd, Where, Dd=Drainage density.
Lof	Lof=1/2Dd, Where, Dd=Drainage density.
MP= Morphometric Parameters.	

3 RESULT AND DISCUSSION

The results of the morphometric analysis are represented in (Table. 2 and table. 3). The linear parameters analyzed include, stream order, stream length (Lu), mean stream length (Lsm) and bifurcation ratio (Rb). The designation of the stream order is the first step in drainage basin analysis and is based on the hierarchic ranking of the stream [10]. The number of streams in various orders was counted and total length of each order streams (Lu) was calculated at sub-watershed level using Arc GIS 9.2. The total length of stream segments is maximum in first order streams and decreases as the stream order increases. The mean stream length (Lsm) is the characteristic property related to the drainage network and its associated surfaces. In Kokkayar, stream order varies from 1 to 4 and the total number of stream segments of all orders together is 200. Lsm is varies from 0.50 to 7.55. Bifurcation ratio (Rb), which is the ratio of the number of stream segments of given order to the number of segments of the next higher order [12]. It usually shows only a small range of variation for different regions or for different environment except in areas where powerful geological control dominates. These irregularities are depend up on the geological and lithological development of the drainage basin [2], [14]. The Rb is not one same from order to its next order. Lower values of Rb are characteristics of sub-watersheds, that suffered less structural disturbances which also indicates that, the drainage pattern has not been distorted [15]. The high Rb value of Kokkayar sub-watershed reveals that, this sub-watershed is geologically more complex.

Table 2. Mean stream length of Kokkayar sub-watershed

Name	Stream order	Lu	Nu	Lsm
Kokkayar sub-watershed	1	81.42	162	0.50
	2	22.40	30	0.75
	3	14.00	7	2.00
	4	7.55	1	7.55
Lu=Stream length of order 'U' (km); Nu=Total number of stream segments; Lsm=Mean stream length.				

Table 3. Results of morphometric parameters of Kokkayar sub-watershed

Morphometric parameters	Result
Area (km^2)	39.22
Perimeter (km)	28.77
Basin order	4
Basin relief (Bh)	80
Ruggedness number (Rn)	0.26
Bifurcation ratio (Rb)	4.17
Drainage density (Dd) (km^2)	3.20
Stream frequency (Fs) (km^2)	6.30
Texture ratio (T) (km)	5.63
Length of overland flow (lof) (km)	0.16
Constant channel maintenance (C) (km)	0.31

Relief aspect of the watershed plays an important role in drainage development surface and subsurface water flow, permeability, landform development and associated features of the terrain. The relief parameters analyzed in the present study includes basin relief (Bh) and ruggedness number (Rn). Basin relief is the vertical distance between lowest and highest point of the sub-watershed area [11]. There is also a correlation between hydrological characteristics and relief ratio of drainage basin. The high Bh value of 0.08 shows that low infiltration and high runoff Kokkayar sub-watershed. It has steep slope, high relief and structural complexity of the terrain and also it implies that, the sub-watershed area is also susceptible to soil erosion due to high ruggedness number.

The aerial parameters analyzed are drainage density (Dd), stream frequency (Fs), Texture ratio (T), Form factor (Rf), Circulatory ratio (Rc) and constant channel maintenance (C). Drainage density (Dd) provides a numerical measurement of landscape dissection and runoff potential. The high drainage density of 3.2 km/km^2 from the present study area can be attributed to the presence of weak or impermeable subsurface material, sparse vegetation and mountainous relief. Stream frequency (Fs) ie, the total number of stream segments of all orders per unit area is related to permeability, infiltration capacity and relief of the sub-watersheds. The High stream frequency, 6.3 of Kokkayar can be attributed to high relief and low infiltration capacity, resulting in an increase in stream population. Texture ratio (T) is an important factor in drainage morphometric analysis. The ratio of total number of first order streams to the perimeter of watershed gives the texture ratio [2]. It depends on underlying lithology, infiltration capacity and relief aspect of the terrain. Here the texture ratio 5.63 of kokkayar sub-watershed can be attributed to presence of high reliefs.

Constant channel maintenance (C) is the inverse of drainage density and it depends on rock type, permeability, climatic regime, vegetation cover as well as duration of erosion. The low value of the constant channel maintenance of Kokkayar ie, 0.31 and length of overland flow ie, 0.16 indicates high run off, low permeability and complex structure of the terrain. After the calculation of various morphometric parameters, the results (Table. 4) were represented as attribute data.

Table 4. Results of morphometric parameters of micro-watersheds of Kokkayar sub-watershed

N	Rb	Dd	Fs	T	Lof	C
K1	2.16	2.90	4.04	1.09	0.17	0.34
K2	2.72	3.16	4.45	1.81	0.16	0.32
K3	2.77	2.06	3.91	1.18	0.24	0.49
K4	1.25	3.38	5.21	2.52	0.15	0.29
K5	2.83	3.99	7.40	2.93	0.13	0.25
K6	2.81	3.29	6.13	2.70	0.15	0.30
K7	2.94	3.98	7.59	2.32	0.13	0.25
N=Name of micro-watersheds						

Among the delineated micro-watersheds, bifurcation ratio is maximum for K7 and minimum for K4. The low Rb value indicates that, K4 have suffered less structural disturbances and the drainage pattern has not been distorted and K7 also is geologically more complex and structurally more controlled than K4. Drainage density is one of the important indicators of the fluvial control. Its measurement provides a numerical measurement of landscape dissection and runoff potential. The high drainage density observed in K5 can be attributed to the weak or impermeable subsurface material and the consequent high resistance to infiltration. Higher value of stream frequency of 7.59 of K7 and texture ratio of K5 can be attributed to high relief and low infiltration capacity. From the analysis of constant channel maintenance and length overland flow it has been concluded that K5 and K7 have less infiltration capacity and high runoff and so water holding capacity is less. After that all the themes (Fig. 4 to Fig. 9) were converted into raster format and reclassified by using spatial analyst extension of Arc GIS software. For the prioritization of micro-watershed, a specific weightage and rank was given to each theme and individual features, based on the influence of parameters in water holding capacity (Table. 5). After assigning the weightage and rank, the themes were normalized by dividing the theme weightage by 100. The raster calculator option of spatial analyst was used to prepare the integrated final prioritized map (Fig.10) of Kokkayar sub-watershed. The map algebra used in raster calculator is,

Prioritized map = Drainage density x 0.3 + Bifurcation ratio x 0.25 + Stream frequency x 0.2 + Texture ratio x 0.15 + Length of overland flow x 0.1 + Constant channel maintenance x 0.05

4 CONCLUSION

From the prioritized map it has been concluded that the micro-watershed K5 and K7 comes under low zone (9.37 km^2) due to the high Dd, Rb, Fs, T and low Lof and C and it indicates run off nature and low infiltration capacity of the micro-watershed. K6 comes under the medium zone because the parametric values are less than that of K5 and K4. It covers an area of 6.52 km^2 . In the high prioritized zones, the micro-watersheds K2 and K4 have comparatively more infiltration due to the low relief and less complex nature of the terrain and here the Dd ,Rb, Fs, T are low and Lof and C are high (12.72 km^2). In very high prioritized zone, all the parameters except C and Lof shows very low value. Hence K1 and K3 have high water holding capacity mainly due to low relief and good potential for water (Table. 6).

Table 5. Weightage and rank assigned for theme and layer class

Theme	Weightage	Layer class and its rank
Drainage density (Dd)	30	2-2.5=1; 2.5-3=3; 3-3.5=6; 3.5-4=9; 4-4.5=10
Bifurcation ratio (Rb)	25	1.25-1.65=1; 1.65-2.05=5; 2.05-2.45=7; 2.45-2.85=8; 2.85-3.25=10
Stream frequency (Fs)	20	3.5-4.5=10; 4.5-5.5=8; 5.5-6.5=6; 6.5-7.5=3; 7.5-8.5=1
Textureratio (T)	15	1.1-1.6=10; 1.6-2.1=8; 2.1-2.6=4; 2.6-3.1=1
Length of overland flow (Lof)	10	0.12-0.15=10; 0.15-0.18=8; 0.18-0.21=6; 0.21-0.24=3; 0.24-0.27=1
Constant channel maintenance (c)	5	0.24-0.3=10; 0.30-0.36=9; 0.36-0.42=7; 0.42-0.48=3; 0.48-0.54=1

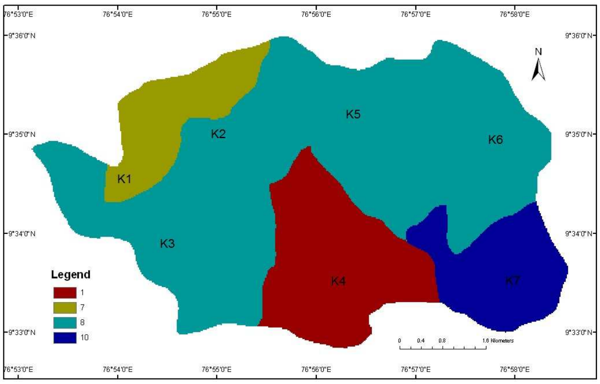

Fig. 4. Bifurcation ratio (Rb)of micro-watersheds of Kokkayar sub-watershed

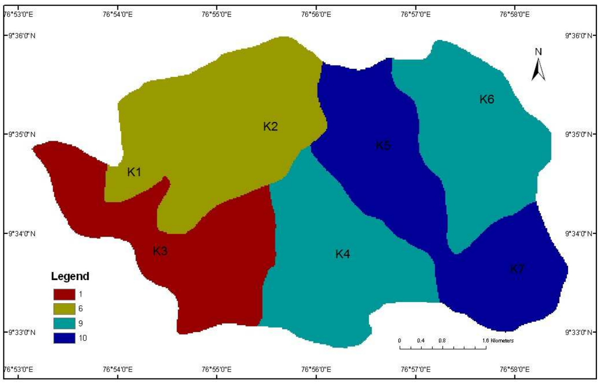

Fig. 5. Drainage density (Dd) of micro-watersheds of Kokkayar sub-watershed

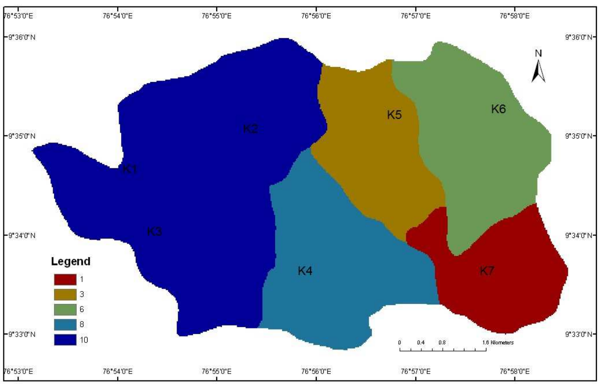

Fig. 6. Stream frequency (Fs) of micro-watersheds of Kokkayar sub-watershed

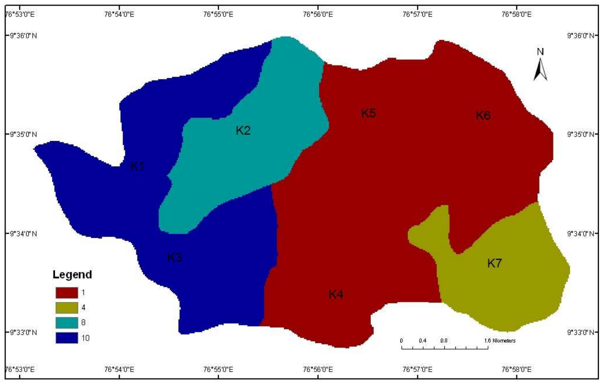

Fig. 7. Texture ratio (T) of micro-watersheds of Kokkayar sub-watershed

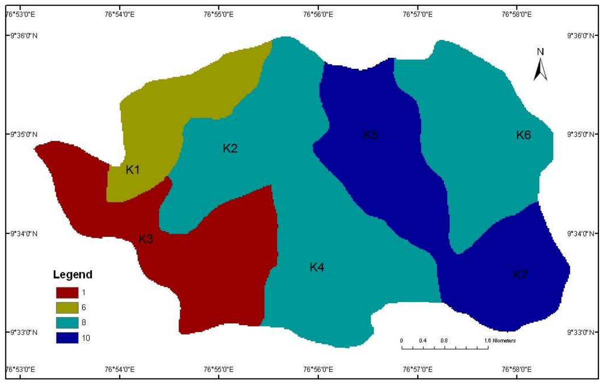

Fig. 8. Length of overland flow (Lof) micro-watersheds of Kokkayar sub-watershed

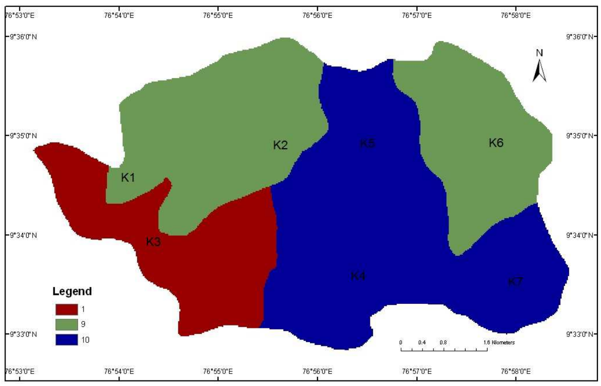

Fig. 9. Constant channel maintenance(C) micro-watersheds of Kokkayar sub-watershed

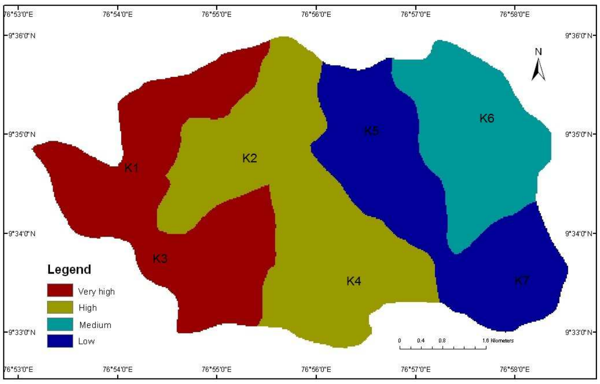

Fig. 10. Prioritized zones of Kokkayar sub-watersheds

Table 6. Prioritized zones of Kokkayar sub-watershed with area

Prioritized zones	Area in km2	Area in %
Very high	10.63	27.10
High	12.72	32.43
Medium	6.52	16.22
Low	9.37	23.89

ACKNOWLEDGMENT

The authors gratefully acknowledge Head, Department of Environmental Science, Central University of Kerala, Kasaragode, for the support and facilities provided.

REFERENCES

[1] J.I. Clarke, “Morphometry from Maps. Essays in geomorphology. Elsevier Publications,’’ New York. pp. 235 – 274, 1996.

[2] R. E. Horton, “Erosional development of streams and their drainage basins: Hydrophysical approach to quantitative morphology,’’ *Geological Society of America Bulletin*, vol. 56, pp.275-370, 1945.

[3] S.K. Nag, and Chakraborty .S, “Influence of rock types and structures in the development of drainage network in hard rock area,” *Journal of Indian Society of Remote Sensing*, vol.31(1), pp. 25-35, 2003.

[4] J.P. Jolly, “A proposed method of accurately calculating sediment yields from reservoir deposition volumes, recent developments in the explanation and prediction of erosion and sediment yield,’’ *Proceedings of Exeter Symposium, IAHS Publication*. pp. 153-161, 1982.

[5] S. K. Jenson, “Application of hydrologic information automatically extracted from Digital Elevation Models. *Hydrological processes*,” vol.5, pp. 31-41, 1991.

[6] R. Brelinger, H. Duster, and Weingartner, R. “Methods of catchment characteristic of erosion and sediment yield. Proceedings of Exeter Symposium, *International Association of Hydrological Science*,’’ vol.137, pp. 153-161, 1993.

[7] H. Vijith, and Satheesh, R. “GIS based morphometric analysis of two major upland sub-watersheds of Meenachil river in Kerala,” *Journal of Indian society of remote sensing*, vol.34, pp. 181-185, 2006.

[8] V.K. Srivastava, and Mitra, D., “Study of Drainage pattern of Raniganj coalfield (Burdwan District) as observed on Landsat-TM/IRS LISS II Imagery,” *Journal of Indian Society of Remote Sensing*, vol.23 (4), pp. 225-235, 1995.

[9] V.K. Srivastava, “Study of d pattern of Jharia coalfield (Bihar), India, through remote sensing technology,” *Journal of Indian Society of Remote Sensing*, vol. 25(1), pp.41-46, 1997.

[10] S. K. Nag, “Morphometric analysis using remote sensing techniques in the Chaka sub-basin,” Purulia District, West Bengal.” *Journal of Indian Society of Remote Sensing*, vol.26 (1& 2), pp 69 – 76, 1998.

[11] A.N. Strahler, “Quantitative geomorphology of drainage basins and channel networks,” In: V.T.Chow (ed), *Handbook of Applied Hydrology*, McGraw Hill Book Company, New York.Section 4-II. pp. 439-476, 1964.

[12] S.A. Schumm, "Evolution of drainage systems and slopes in badlands at Perth Amboy,'' New Jersey," *Geology*, vol. 67, pp. 597- 646, 1956.

[13] V. B. Rekha, A. V. George and M. Rita, "Morphometric Analysis and Micro-watershed Prioritization of Peruvanthanam Sub-watershed, the Manimala River Basin, Kerala, South India," *Environmental Research, Engineering and Management*, vol. 3, no. 57, pp. 6 – 14, 2011.

[14] V.B. Rekha, A.V. George, K.R. Vineeth and U. Johnson, "Morphometric Analysis and Prioritization of Micro-watersheds in Valiyathodu sub-Watershed of Manimala River, Kerala, India," *Proceedings of Applied Geoinformatics for Society and Environment organised by Stuttgart University of Applied Sciences, Universidad Catolica de Santa Maria, Arequipa, Peru*, vol 109, pp. 77-81, 2010.

[15] V. B. Rekha, A. V. George and M. Suma, "A Comparative Study of GIS Based Morphometric Analysis of Midland and Upland Sub-watersheds of Manimala River in Kerala." *Proceedings of The Green Path to Sustainability: Prospects and Challenges", at Assumption College, Changanassery, Kerala, India*, pp. 245-251, 2010.