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RESEARCH ARTICLE

Morphometric analysis and prioritization of Palathodi watershed in Parambikulam-Aliyar basin, Tamil Nadu using RS and GIS

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ABSTRACT : The geomorphological characteristics of a watershed are more commonly used for developing the regional hydrological models for solving the various hydrological problems of the ungauged watersheds or inadequate data situations. Therefore, in this study morphometric analysis and prioritization of twenty one sub watersheds of palathodi watershed, which is tributary of Parambikulam-Aliyar river basin considered for this study. The morphometric parameters considered for analysis are stream order, stream length, stream frequency, drainage density, drainage texture, form factor, circulatory ratio, elongation ratio, constant channel maintenance, length of over land flow and compactness constant. After analysis of morphometric parameters compound parameter values are calculated and prioritization rating of twenty one sub watersheds is carried out. The sub watershed (Malumichampatti village) 4 has lowest compound parameter value 6.1 is likely to be subjected to a maximum soil erosion; hence, it requires immediate attention for provisions of soil conservation measures.

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Key Words :
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Availability of natural resources *i.e.*, land and water is decreasing day by day, due to growing population pressure. So, planning and management of these natural resources is the need of time. Proper scientific planning and management requires immense data. Therefore, geomorphological characteristics of a watershed are commonly used for developing the regional hydrological models for solving the various hydrological problems of the ungauged sub watersheds or inadequate data situations. Applications of Geographic Information System (GIS) techniques are much easier, time saving and suitable for spatial planning. GIS can handle complex issues and large databases for manipulation and retrieval. The use of computer has made GIS automated and today the technique is not only capable of handling large datasets but can also solve many complex issues besides facilitating retrieval and querying of data.

Population pressure is increasing over the years which resulted in the scarcity of availability of land and water resources. Industrial expansion is also a need of the time, which requires infrastructural facilities; which intern forms a feedback resulting in further pressure on finite land and water resources. About 53 per cent of the total area of India which is 172 m ha suffers from serious soil erosion and other forms of degradation. A country like India that supports 16 per cent of world population on 2 per cent of the global land area, the problem is serious enough (Sebestain *et al.*, 1995). So, planning and management of land and water resources on a sustainable basis without deterioration and with constant increasing productivity is the main stay in the mankind. The watersheds or hydrological units are considered more efficient and appropriate for necessary survey and investigation for the assessment of these resources and subsequent planning and implementation of various development programmes like soil and water conservation, command area development, erosion control in catchment river, dry land/rainfed farming, reclamation of ravine lands etc. the hydrologic units are equally important for the development of water resources through major, medium, and minor storage projects as well as farm level water harvesting structures. So, the watershed approach is more rational because land and water resources have optimum interaction and synergetic effect when developed on the watershed basis.

An accurate understanding of the hydrological behaviour of watershed is important for the effective management. Intensive study of individual watershed is therefore, necessary for developing management plan, which requires immense data. In India most of the watersheds are ungauged one. The morphometric analysis of watershed can play an important role in inadequate data situation. The morphometric analysis of watershed represents its attributes and can be helpful in synthesizing its hydrological behaviour (Pandey *et al.*, 2004). It is very difficult to develop the large area in one stretch due to some geo-environmetal or economic conditions. There is a need to prioritize the area while applying the developmental programme. Studies conducted by Sanware *et al.* (1988); Prasad *et al.* (1992); and Sharda *et al.* (1993), reveled the remote sensing and gis techniques are of great use in characterization and prioritization of watershed area. Goel (2003) in his study, soan river catchment pointed out that a little correlation of drainage density with lemniscates ratio. Chaudhary and Sharma (1998) carried out their study in giri river catchment of north Himalayas for erosion hazard assessment and treatment prioritization. Using morphometric parameters and F factor approach critical sub watersheds of Dikrong river basin of eastern Himalayas were identified which are suffering from maximum soil erosion (Dabral and Pandey, 2007). Morphometric parameters were used to prioritize the five sub watersheds of sarpha river drainage basin of sahadol district of Madhya Pradesh, India using GIS technique by Sharma *et al.* (2008).

This study is aimed at studying the geomorphological characteristics of study sub-basin and including indentification and evaluation of watershed which contributes to excessive erosion losses using faster and indirect methods and established relationships. This will prove to be helpful in the cases which are, as the present case is, remotely placed and for those no other direct observational set up is available. In the present study morphometric analysis and prioritization of sub watersheds are carried out of twenty one sub watersheds of palathodi watershed, which is tributary of Parambikulam-Aliyar river basin, Tamil Nadu by using RS and GIS technique for further development planning.

Study area :

The Palathodi watershed is one of the sub-basins of Parambikulam-Aliyar river basin in Tamil Nadu (Fig. A). Parambikulam - Aliyar sub basin has an undulating topography with maximum contour elevation in the Hill is 2504 m and the minimum spot height in the plain is 256 m above MSL. The temperature slowly rises to its maximum in summer upto May and afterwards shows a gradual decline. The maximum temperature ranges from 36° C to 41°C and the minimum temperature varies from 14° C to 31° C. The mean daily temperature during summer (March - May) varies from 33° C to 40° C and the mean daily temperature during winter varies from 15° C to 36° C. The major crops grown in this sub basin area are coconut, sugarcane, banana, sapota, mango, fodder, besides annual crops such as paddy, groundnut, cotton, vegetables, pulses, fodder, tomato, gourds, maize as I crop, and Paddy and Groundnut as II crop.

Parambikulam and Aliyar river basin comprises mainly of crystalline rocks of Archaean age. Charnokites form the major rock type of the basin followed by the granites, granitic gneisses, dunites, limestones, quartzite basic and ultra basic intrusives of pegmaties and quaternery veins. Charnockites and associated migmatites occupy a major part of the area. The geological setup is quite terse in terms of structural as well as geomorphic lineation of prominent and hidden nature. Owing to this geological setup, basins are likely to be prone to erosional processes. The appreciation of the situation as such.

Experimental Methodology

The palathodi watershed boundary of the study area was delineated using SOI toposheet (58B13) on 1:50000 scale. The delineated watershed boundary was further subdivided into sub watersheds (Fig. A). The figure also shows digitized stream network. Morphometric analysis was carried out for their twenty one sub watersheds. The parameters computed in the present study using GIS technique including stream order, stream length, stream frequency, drainage density, drainage texture, form factor, circulatory ratio, elongation ratio, Constant channel maintenance, length of over land flow, and Compactness constant. The input parameters for the present study such as area, perimeter, elevation, stream length etc. were obtained from digitized coverage of drainage network map in GIS environment.

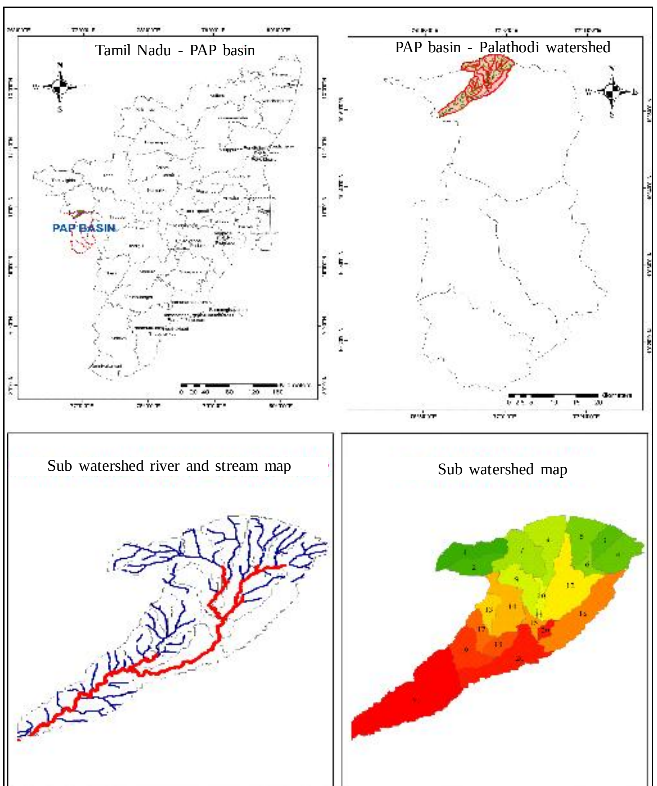

Fig. A : Location map and stream network of PAP Basin - Palathodi watershed

Morphometric analysis :

Quantitative analysis is very advantageous as the basins variables derived are in the form of ratios or dimensionless numbers thus, providing an effective comparison regardless of scale.

Stream order :

The first step in morphometric analysis of a drainage basin is the designation of stream order, stream ordering as suggested by Strahler (1964) was used for this study. Streams that orginate at a source are defined as first order stream. When two streams of first order join, an order two stream is created. When two stream of different orders join, the channel segment immediately downstream has the higher of the order of the two joining stream. The order of a basin is the order of the highest stream.

Stream number (N_u) :

It is the number of stream segment of various order and is inversely proportional to the stream order.

Total stream length (L_a) :

It is the length of all the streams having order u. it indicates the contributing area of the basin of that order.

Main stream length :

It is the length of the main stream having maximum length.

Watershed perimeter (P_r) :

It is the length of the watershed boundary.

Maximum length of watershed (L_b) :

It is the distance between watershed outlet and the farthest point in the watershed.

Form factor (R_f) :

It is the ratio of basin area A, to the square of maximum length of the basin :

$$R_f = \frac{A}{L_b^2}$$

Elongation ratio (R_e) :

It is defined as the ratio between the diameter of a circle with the same area that of the basin to the maximum length of the basin, and is computed as :

$$R_f = \frac{2}{L_b}\sqrt{\frac{A}{\pi}}$$

The elongation ratio ranges from 0.6 to 1.0 over a wide variety of climatic and geological environments.

Values nearing 1.0 are typical of regions of low relief, whereas values in the range of 0.6 to 0.8 are generally associated with strong relief and steep ground slopes. Elongated basins with high bifurcations yield a low but extended peak flow.

Circulatory ratio (R_c):

It is the ratio of the watershed area to the area of circle of having equal perimeter as the perimeter watershed (Pr). Circular basins with low bifurcations ratio produce a sharp peak. It is computed as :

$$R_c = \frac{12.57\,A}{P_r^2}$$

Drainage density (D_d):

Drainage density is one of the important indicator of the linear scale of land form in stream eroded topography, and is defined as the ratio of total length of the streams of all orders of basin to the area of basin. The drainage density, expressed in km/km^2, indicates closeness of spacing of channels, thus, providing a quantitative measure of the average length of stream channel for the whole basin. Further it also gives an idea of the physical properties of the underlying rocks. Low drainage density occurs in regions of highly resistant and permeable sub soil materials with dense vegetation and low relief, whereas high drainage density is prevalent in regions of weak, impermeable sub surface materials which are sparsely vegetated and have high relief (Strahler, 1964).

Drainage frequency (D_f) :

Drainage frequency is the total number of streams per unit area of the basin. It mainly depends upon the lithology of the basin and reflects the texture of the drainage network.

Drainage texture (D_t) :

Drainage texture is defined as the total number of stream segments of all orders per perimeter of that area (Horton, 1945).

Constant of channel maintenance (*Cm*) :

It is defined as the ratio of the area of drainage basin and total length of all the streams of all the orders. Hence, it is the reciprocal of the drainage density :

$$C_m = \frac{1}{D_d}$$

Compactness co-efficient (*Cc*):

It is the ratio of the catchment perimeter to that of equivalent circle having area that of the basin.

Maximum basin relief (*H*) :

It is the difference between lowest and highest points of a watershed.

Relief ratio (R_h) :

The maximum relief to horizontal distance along the longest dimension of the basin parallel to the principal drainage line is termed as relief ratio (Schumn, 1956).

Relative relief (R_f) :

It is defined as the ratio of the maximum watershed relief to the perimeter of the watershed.

For morphometric analysis, area, perimeter, maximum length of watershed, drainage network, stream length of each order, number of streams of each order and watershed relief values is required. These inputs were derived using RS and GIS software. The necessary parameters for morphomertic analysis were calculated by using the equation as discussed above.

Prioritization of sub watersheds :

The resources considerations for implementation of watershed management programme or various other reasons pertaining to administrative or even political consideration may limit the implementation to few sub watersheds. Even otherwise it is always better to start management measures from the highest priority sub watersheds, which makes it mandatory to prioritize the sub watersheds available. Watershed prioritization is thus, ranking of different sub watersheds according to the order in which they have to be taken for treatment and soil conservation measures. Hence it was necessary to evolve suitable mechanism for prioritizing the sub watersheds. Morphometric analysis is a significant tool for prioritization of micro-watersheds even without considering the soil map (Biswas *et al.*, 1999).

The parameter drainage density, stream frequency, texture ratio, form factor, circulatory ratio, elongation ratio, compactness ratio are also termed as erosion risk assessment parameters (Thakker and Dhiman, 2007) and these parameters have been used in during their study for prioritizing sub watersheds for conservation measures. For prioritization the highest value of drainage density, stream frequency and texture ratio, form factor, circulatory ratio, elongation ratio and compactness ratio, has given the least value was first rank and the highest value was given the last rank. The lowest compound parameter value is given the highest priority for final prioritization rating of sub watersheds.

Experimental Findings and Discussion

Morphometric parameters of sub watersheds were calculated in RS and GIS environment are presented in Table 1 and 2. Prioritization sub watersheds using morphological parameters a result has given in Table 3. After analysis of drainage map it was found that Palathodi watershed is of 5th order type and drainage pattern is dendritic.

In general shape of the basin affects the stream flow hydrographs and peak flows. The important parameter describe the shape of the basin Form factor, Circulatory ratio and Elongation ratio were computed for all twenty one sub watersheds (Table 2). The value of Form factor would always be less than 0.7854 (for perfectly circular basin). The smaller value of form factor more elongated will be the basin. The basin will high form factor has high peak flows of shorter duration. Whereas with low Form factor have lower peaks flows of longer duration. In the present case sub watersheds have lower R_f value (0.09 to 0.31) indicating them to be elongated in shape and suggesting flatter peak for longer duration. Flood flows of such elongated basins are easier to manage than those of circular basin. Circulatory ratio (R_c) is influenced by the length and frequency of streams, geological structures, land use/land cover, climate, relief and slope of the basin. In the present case Circulatory ratios for sub watersheds are 0.14 to 0.39 indicating that the area is characterized by high relief and drainage system is structurally controlled. The value of Elongation ratio (R_e) for sub watersheds varies between 0.33 to 0.66 indicates sub watersheds to be elongated with high relief and steep slopes.

Drainage density (D_d) and Drainage frequency (D_f) and computed for all the sub watersheds and are given on Table 2. Drainage frequency values of all the sub watersheds have close correlation with Drainage density indicating the increase in stream population with respect to increase in Drainage density. High value of D_f in the sub watershed 3 produces more runoff compared to others. In general it has been observed over wide range of geologic and climatic types that low D_d is more likely

Table 1: Sub watershed wise morphometric parameters

Sub watershed No.	Area (km^2)	Perimeter (km)	Max elevation (m)	Min elevation (m)	Total relief (m)	No. of stream	Max length of watershed (km)	Total stream length (km)
1.	4.25	14.4	734	389	345	8	5.37	8.51
2.	2.91	10.92	722	389	333	5	3.98	4.91
3.	2.19	9.96	423	367	56	5	3.75	5.43
4.	4.39	12.24	422	366	56	11	3.84	7.11
5.	4.31	13.98	419	355	64	7	4.49	7.12
6.	1.26	8.34	393	354	39	2	2.93	0.70
7.	5.68	17.34	597	348	249	7	5.50	6.63
8.	5.69	16.74	458	348	110	7	5.96	7.71
9.	3.96	13.38	597	328	269	1	5.27	1.19
10.	0.92	7.92	371	328	43	0	3.21	0
11.	0.14	2.52	337	324	13	0	0.80	0
12.	8.95	22.08	398	324	74	5	6.77	8.06
13.	1.99	9.06	457	289	168	3	3.38	2.74
14.	5.67	16.98	597	290	307	6	5.66	6.94
15.	1.16	8.52	346	311	35	0	2.76	0
16.	8.10	22.74	406	311	95	1	8.45	0.85
17.	2.14	10.38	343	272	71	7	3.51	4.10
18.	1.96	7.86	330	272	58	5	3.45	3.14
19.	4.22	12.30	320	250	70	6	3.68	3.58
20.	8.43	28.02	347	251	96	0	8.33	0
21.	17.05	27.96	292	181	111	21	10.58	22.29

Table 2 : Stream morphometric parameters

SW. No.	Drainage density	Drainage texture	Stream frequency	Circulatory ratio	Form factor	Elongation ratio	Constant channel maintenance	Compactness constant	Length of over land flow
1.	2.01	0.56	1.88	0.26	0.15	0.43	0.5	1.97	0.25
2.	1.69	0.46	1.72	0.31	0.18	0.48	0.01	1.81	0.30
3.	2.48	0.50	2.28	0.28	0.16	0.45	0.40	1.89	0.20
4.	1.62	0.89	2.51	0.37	0.29	0.62	0.62	1.65	0.31
5.	1.65	0.50	1.62	0.28	0.21	0.52	0.61	1.89	0.30
6.	0.56	0.24	1.59	0.23	0.15	0.43	1.79	2.09	0.9
7.	1.17	0.40	1.23	0.24	0.19	0.66	0.86	2.05	0.43
8.	1.36	0.42	1.23	0.26	0.16	0.45	0.74	1.98	0.37
9.	0.23	0.08	0.25	0.28	0.14	0.43	4.35	1.89	2.17
10.	0	0	0	0.18	0.09	0.33	0	2.33	0
11.	0	0	0	0.28	0.22	0.53	0	1.89	0
12.	0.90	0.23	0.56	0.23	0.19	0.49	1.11	2.08	0.56
13.	1.38	0.33	1.51	0.31	0.17	0.47	0.73	1.81	1.32
14.	1.22	0.35	1.06	0.25	0.18	0.47	0.82	2.01	0.41
15.	0	0	0	0.20	0.15	0.44	0	2.23	0
16.	0.11	0.11	0.12	0.19	0.11	0.38	9.52	2.27	4.76
17.	1.92	0.67	3.27	0.25	0.17	0.47	0.52	2.01	0.26
18.	1.60	0.64	2.55	0.39	0.17	0.46	0.63	1.58	0.31
19.	0.85	0.49	1.42	0.35	0.31	0.63	1.18	1.69	0.59
20.	0	0	0	0.14	0.12	0.39	0	2.72	0
21.	1.31	0.75	1.23	0.28	0.15	0.44	0.77	1.91	0.38

Table 3: Prioritization sub watersheds using morphological parameters

SW. No.	Drainage density	Drainage texture	Stream frequency	Circulatory ratio	Form factor	Elongation ratio	Constant channel maintenance	Compactness constant	Length of over land flow	Compound parameter	Final priority
1.	2	5	5	6	9	12	15	10	14	8.6	10
2.	4	8	6	4	6	7	17	13	12	8.5	9
3.	1	6	4	5	8	10	16	12	15	8.5	9
4.	6	1	3	2	2	3	12	15	11	6.1	1
5.	5	6	7	5	4	5	13	12	12	7.6	6
6.	13	13	8	9	9	12	3	5	4	8.4	8
7.	10	10	11	8	5	1	6	7	7	7.2	4
8.	9	9	12	6	8	10	9	9	10	9.1	11
9.	14	15	15	5	10	12	2	12	2	9.6	12
10.	16	16	17	5	13	15	18	2	16	13.1	15
11.	16	16	17	5	3	4	18	12	16	11.8	13
12.	11	14	14	9	5	6	5	6	6	8.4	8
13.	8	12	9	4	7	8	10	13	3	8.2	7
14.	10	11	13	7	6	8	7	8	8	8.6	10
15.	16	16	17	10	9	11	18	4	16	13	14
16.	15	14	16	11	12	14	1	3	1	9.6	12
17.	3	3	1	7	7	8	14	8	13	7.1	3
18.	7	4	2	1	7	9	11	16	10	7.4	5
19.	12	7	10	3	1	2	4	14	5	6.4	2
20.	16	16	17	12	11	13	18	1	16	13.3	16
21.	9	2	12	5	9	11	8	11	9	8.44	8

to occur in regions of highly permeable sub soil material under dense vegetation cover and where relief is low. In contrast high D_d is favored in regions of weak or impermeable subsurface material, sparse vegetation and mountainous relief (Nag and Chakraborty, 2013). In the present study low value of D_d for sub watershed 10,11,15 and 20 indicates that it has highly resistant, impermeable sub soil material with dense vegetation cover and low relief. It is obvious from the Table 1 that sub watershed 10,11,15 and 20 has 43,13,35 and 90 m relief. The sub watershed with high value of D_d indicates well developed network, which is conducive for quick disposal of runoff resulting in intense floods and also characterized by a region of weak sub surface materials, high relief and sparse vegetation.

Constant of channel maintenance (C_m) was also computed for all the sub watersheds (Table 2). This factor depends upon not only the rock type and permeability, climate, regime, vegetative cover and relief but also on the duration of erosion and climate history. In general, this constant will be extremely low in areas of close dissection. To facilitate the phase wise implementation, all the sub watersheds are prioritized on the basis of morphometric analysis. The compound parameter values of twenty one sub watersheds of Parambikulam Aliyar river basin are calculated and prioritization rating is shown in Table 3. The sub watershed 4 with a compound parameter value of 6.1 receives the highest priority (one) with the next in the priority is sub watershed 19 having compound parameter value of 6.4. Highest priority indicates the greater degree of erosion in the particular sub watershed and it becomes potential candidate for applying soil conservation measures. Thus, soil conservation measures can first be applied to sub watershed 4 and then to other depending on their priority.

Conclusion :

The quantitative morphometric analysis was carried out in twenty one sub watersheds of Parambikulam-Aliyar sub basin using RS and GIS technique for determining the linear aspects such as stream order, stream length, and aerial aspects such as drainage density and constant of channel maintenance. The conventional methods of morphomertic analysis are time consuming, tiresome and error prone, while use of GIS technique allows for more reliable and accurate estimation of similar parameter of watersheds. The morphometric analysis of different sub watersheds shows their relative characteristics with respect to hydrological response of the watershed. The results of morphometric analysis shows that sub watershed 4 and 19 are prone to relatively higher erosion and soil loss. Hence, suitable soil erosion control measures are required in these sub watersheds to preserve the land from further erosion.

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