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Original Research Paper

Morphometric Characteristics of Nandiyar River Basin, Tamil Nadu, India

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ABSTRACT

Nandiyar river basin, located in the central Tamil Nadu plains, was subjected to dimensional analysis. Initially, through correlation matrix, the interrelationship between the various morphometric variables of the basin was found out. Using factor analysis, the individual morphometric parameters were grouped into a small number of factors and through the analysis of the factor scores, the sub basins of the Nandiyar river were studied to find out the existing relation between the factors and the sub basins. In addition, remedial measures have been suggested for the various environmental problems of the Nandiyar basin.

INTRODUCTION

Morphometric analysis is an important aspect of quantitative geomorphology and is used primarily to study the geometrical aspects of the landforms. Traditionally, it has been used to study the terrain features in general and watersheds in particular. Among the various aspects of morphometric analysis, basin morphometry dealing exclusively with watersheds has received much attention from the hydrologists and geomorphologists since watersheds/drainage basins can be effectively utilised to solve wide variety of environmental problems like soil erosion, surface runoff, slope instability to name a few.

At the same time, basin morphometric studies usually involve large set of morphometric parameters. Often, the availability of such large data hinders the identification of those morphometric parameters that really play a dominant role within a drainage basin. Hence, in basin morphometric studies, statistical methods like factor analysis which help in data reduction and detect the underlying structure in relationship between various morphometric parameters have proved to be highly useful (Klovan 1975). In the present study, morphometric parameters of the Nandiyar basin have been subjected to statistical analysis as to identify the interrelationship among the large set of morphometric variables. Later, factor analysis was carried out to identify the small number of factors that explain most of the variance observed within the much large set of morphometric parameters.

STUDY AREA

Nandiyar basin is located in the central Tamil Nadu plains and lies between 10°53’-11°84’ N latitudes and 78°48’-78°57’ E longitudes covering an area of nearly 291 sq. km (Fig. 1). It is covered in the Survey of India (SoI) toposheets Nos. 58 I/16 and 58 J/13 on 1:50 000 scale. The river Nandiyar originates in the northwestern corner of the study area at an elevation of 345 m and runs for nearly 100 km before its confluence with the River Cauvery. The study area has semiarid climate and receives an average annual rainfall of 750 mm of which more than 60 % falls during the northeast monsoon months (October-December).

Nandiyar basin owing to its location at the existing crystalline-sedimentary contact zone is underlined by diverse lithological formations ranging in age from precambrian to cretaceous. Sedimentary rocks of the cretaceous period cover a major part of the study area and are represented by marls, coralline limestones, shales, sands and sandstones, whereas crystalline rocks like fissile hornblende biotite gneiss and granites cover a minor portion. Geomorphologically, the study area is mostly covered by pediments and along the stream courses these pediments are buried under unconsolidated materials. In addition, severe development of gully erosion is a peculiar phenomenon observed in the study area. As a consequence, considerable area in the northeastern corner of the Nandiyar basin had been converted into bad lands.

MATERIALS AND METHODS

Initially, basin boundary was demarcated by tracing all the tributaries of the Nandiyar river from the toposheets, and stream ordering was carried out based on Strahler's classification. The same has indicated Nandiyar to be a sixth order river. Later, sub basins and inter basinal areas of the Nandiyar basin were found out. For demarcating the sub basins, only those streams which confluence directly into the principal river of the basin (Nandiyar river) and having a stream order of three and above were taken for consideration. Accordingly, 11 sub basins were demarcated (Fig.1). The rest of the study area, falling outside the margin of these sub basins and drained by streams having a stream order of below three were marked as inter basinal areas.

Subsequently, to understand the dimensional characteristics of these 11 sub basins, the linear, relief and areal aspects of the Nandiyar basin were calculated following the methods of Chorley (1957), Chorley et al. (1957), Horton (1932, 1945), Melton (1959), Miller (1953), Schumm (1956), Strahler (1952) and 14 important morphometric parameters were derived (Table 1). Using the same, correlation matrix was computed (Table 2) to understand the existing interrelationship among these 14 morphometric parameters (variables) and also as a first step towards factor analysis. Later, factor extraction was carried out with a minimum acceptable eigen value as greater than one. From the original 14 variables, three factors were extracted. The factor loading matrix was rotated to an orthogonal simple structure according to varimax rotation and a new set of rotated factor matrix

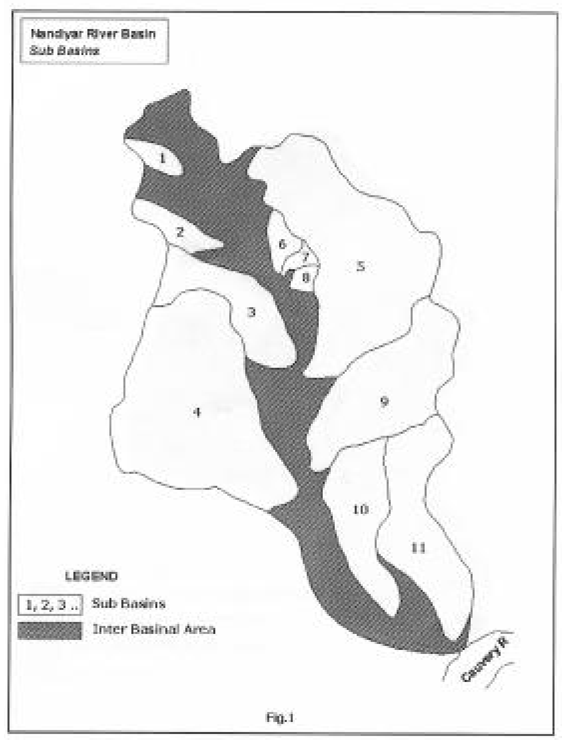

Fig. 1 Sub basins of Nandiyar river basin.

was derived (Table 3). Finally, using factor scores, which is a measure of the influence of each factor on each case, these 11 sub basins were studied to find out the factor having much influence on it. On the basis of the same, a morphometric model was prepared for the entire Nandiyar basin (Fig.2).

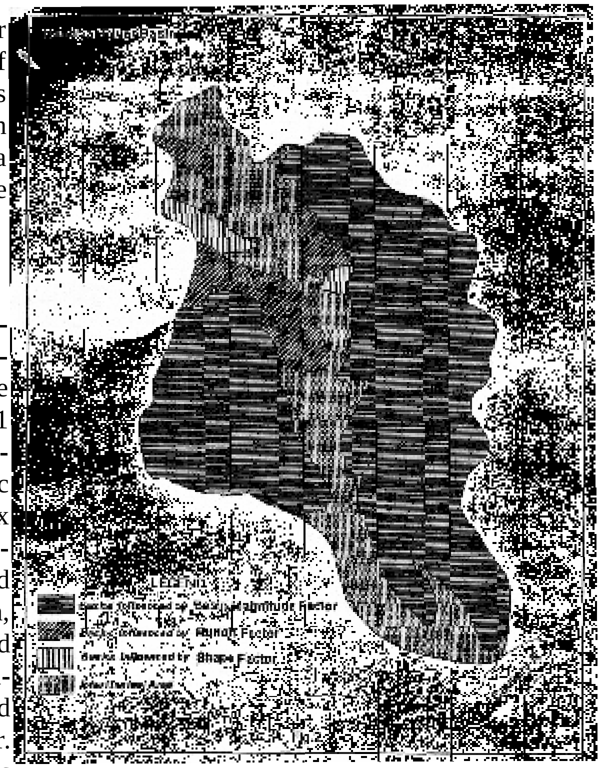

Fig. 2 Morphometry model for entire Nandiyar river basin.

RESULTS AND DISCUSSION

In the present study, the data matrix used consisted of 14 morphometric parameters (variables), which were derived after applying the linear, relief and areal characteristics of the 11 sub basins (observations) of the Nandiyar basin. Initially, when these 14 morphometric variables were subjected to correlation matrix it was observed that there exits a strong positive correlation among the basin area and stream length, basin area and basin length, basin area and elongation ratio, basin area and basin perimeter, basin length and basin perimeter, basin perimeter and elongation ratio, and maximum basin relief and ruggedness number. It is worth to mention here that morphometric parameters like basin area, basin length, basin perimeter and total stream length usually have strong correlation in regions of homogenous climatic conditions like the present study area.

On the contrary, strong negative correlation was observed between channel maintenance and

Table 1: Forteen important morphometric parameters (data matrix).

Sub Basins	Stream Order	SL	LG	DD	CM	SF	A	L	P	RE	RF	KA	H	RH	RN
1	3	5.75	1.15	2.30	0.43	3.20	2.50	3.25	7.50	0.49	0.24	0.56	0.024	0.010	0.11
2	3	7.50	0.76	1.51	0.66	1.81	4.97	4.50	11.0	0.70	0.19	0.52	0.033	0.010	0.10
3	4	35.5	1.29	2.58	0.39	2.18	13.74	8.0	22.0	1.09	0.25	0.41	0.042	0.010	0.18
4	5	111.5	0.94	1.87	0.53	2.45	59.50	17.0	33.0	2.23	0.41	0.69	0.053	0.003	0.20
5	4	115.0	1.06	2.12	0.47	2.80	54.30	13.0	36.0	2.66	0.32	0.53	0.049	0.004	0.21
6	3	8.50	1.46	2.91	0.34	4.45	2.92	3.0	7.50	0.62	0.28	0.65	0.016	0.005	0.09
7	3	4.50	1.63	3.26	0.31	6.52	1.38	2.0	6.00	0.44	0.31	0.48	0.008	0.004	0.05
8	3	3.55	1.32	2.63	0.38	7.41	1.35	1.75	4.50	0.49	0.44	0.84	0.006	0.003	0.03
9	4	78.0	1.29	2.58	0.39	4.20	30.27	11.0	25.0	1.75	0.42	0.61	0.040	0.004	0.21
10	4	39.5	1.10	2.20	0.45	2.06	17.96	9.0	22.0	1.27	0.25	0.47	0.025	0.010	0.11
11	3	45.5	0.88	1.76	0.57	1.78	25.81	12.0	28.0	1.36	0.21	0.41	0.046	0.004	0.16

SL-Total stream length, LG-Length of overland flow, DD-Drainage density, SF-Stream frequency, A-Basin area, L-Basin length, P-Basin perimeter, RE-Elongation ratio, RF-Form factor, KA-Circulatory ratio, H-Maximum basin relief, RH-Relief ratio, RN-Ruggedness number, CM-Channel maintenance

Table 2: Correlation matrix among the 14 morphometric parameters.

	SL	LG	DD	CM	SF	A	L	P	RE	RF	KA	H	RH	RN
SL	1.000													
LG	-0.357	1.000												
DD	-0.354	1.000	1.000											
CM	0.242	-0.969	-0.970	1.000										
SF	-0.390	0.761	0.758	-0.703	1.000									
A	0.987	-0.435	-0.434	0.330	-0.423	1.000								
L	0.929	-0.533	-0.530	0.426	-0.594	0.946	1.000							
P	0.932	-0.497	-0.494	0.385	-0.613	0.930	0.969	1.000						
RE	0.989	-0.410	-0.407	0.295	-0.447	0.975	0.922	0.953	1.000					
RF	0.391	0.340	0.337	-0.402	0.602	0.350	0.196	0.114	0.302	1.000				
KA	-0.001	0.176	0.169	-0.213	0.605	0.008	-0.164	-0.281	-0.068	0.764	1.000			
H	0.813	-0.657	-0.654	0.576	-0.770	0.824	0.902	0.908	0.826	-0.068	-0.337	1.000		
RH	-0.395	-0.237	-0.235	0.220	-0.514	-0.410	-0.271	-0.217	-0.345	-0.706	-0.496	-0.027	1.000	
RN	0.862	-0.407	-0.404	0.296	-0.632	0.824	0.875	0.900	0.861	0.093	-0.337	0.937	-0.086	1.000

Table 3: Rotated factor matrix.

Parameters	Factor 1	Factor 2	Factor 3	Communality
Total stream length	0.962	-0.117	0.206	0.981
Length of overland flow	-0.290	0.942	0.154	0.995
Drainage density	-0.286	0.944	0.148	0.996
Channel maintenance	0.177	-0.950	-0.170	0.963
Stream frequency	-0.475	0.565	0.641	0.955
Basin area	0.936	-0.213	0.222	0.970
Basin length	0.936	-0.285	0.038	0.959
Basin perimeter	0.961	-0.214	-0.068	0.975
Elongation ratio	0.955	-0.160	0.138	0.958
Form factor	0.254	0.299	0.874	0.918
Circulatory ratio	-0.212	-0.035	0.912	0.879
Maximum basin relief	0.860	-0.405	-0.205	0.945
Relief ratio	-0.311	-0.221	-0.768	0.735
Ruggedness number	0.929	-0.123	-0.164	0.906
Total variance explained				
Total	7.943	3.707	1.483	
% of Variance	56.737	26.479	10.595	
Cumulative %			93.811	

drainage density, and channel maintenance and length ratio. In addition, it was also noticed that the correlation between stream length and circulatory ratio, basin area and circulatory ratio, maximum basin height and relief ratio, and maximum basin height and elongation ratio are near zero.

Subsequently, after applying the rotated varimax factor, three factors were derived (Table 3). The first factor has an eigen value of 7.943 and explains nearly 57 % of variance. The second factor has an eigen value of 3.787 and the variance explained by it accounts to 26.5%. The third factor was noticed to have an eigen value of 1.483 and it explains 10.6 % of variance. Overall, cumulatively these three factors explain nearly 94% of the variance and the variability among these 11 sample points (sub basin) lies in three dimensions. Factor loadings, which show the degree of closeness existing between the variables and factors when studied has shown the presence of three classes, viz., 1. low (close to zero), 2. medium, and 3. high (approaching one).

Table 4: Factor scores.

Sub basin no.	Factor 1	Factor 2	Factor 3
1	-0.84459	- 1.7576	-0.61428
2	-1.0292	-1.98405	-0.576613
3	0.39247	0.81628	-1.45170
4	1.36216	-0.82782	-1.20592
5	1.55008	0.04705	0.16516
6	-0.69561	0.81839	-1.3863
7	-0.74398	1.64578	-0.06674
8	-1.31798	-0.04910	2.05912
9	0.92781	0.69958	0.59046
10	-0.02456	-0.09624	-0.86227
11	0.42341	-0.89411	-0.58818

Rotated factor 1: It is emphasized as the prime factor in Nandiyar basin as it accounts for nearly 57 % of the total variance. Under this factor, important morphometric parameters like total stream length, basin area, basin length, basin perimeter, elongation ratio, maximum basin relief and ruggedness no. were found to have significant positive loadings. The occurrence of all positive loadings indicates that all the morphometric parameters loaded under this factor act in the same direction. This means, either the increase or decrease of the value of any selected morphometric parameter loaded under this factor would lead to the development of similar trend in the remaining morphometric parameters. For example, with the increase of basin area other morphometric parameters like basin length, basin perimeter and the total stream length too obviously increase and vice versa. The increase of maximum basin relief and ruggedness no. with the increase of total stream length can be explained as wherever the terrain is rugged and is of higher elevation, runoff will be more compared to infiltration. As a consequence, such areas will have a very dense (fine) stream network that automatically leads to the increase of total stream length of the basin.

The morphometric parameters loaded under this factor generally explain the characteristics of "basin magnitude" as with the increase of the basin area all the other remaining morphometric parameters are expected to increase. Hence, this factor was termed as "basin magnitude factor".

Rotated factor 2: It is the second major factor in Nandiyar basin and explains 26 % of the total variance. Under this factor, three high loadings were observed. Length of overland flow and drainage density were found to have significant positive loadings whereas channel maintenance has significant negative loading. The same indicates that channel maintenance decreases with the increase of value for length of overland flow and drainage density. On the contrary, length of overland flow and drainage density act in the same direction. Generally, length of overland flow defines the path that surface runoff follows from its origin to the point where it enters a concentrated flow area (channel). Obviously, more the length of overland flow naturally results in the increase of the overall drainage density of the area whereas constant channel maintenance, being the inverse of drainage density decreases with the increase of drainage density values. The morphometric parameters loaded under this factor generally have greater control over the drainage characteristics and runoff conditions of the basin, and hence, this factor was termed as "runoff factor".

Rotated factor 3: This factor was observed to explain nearly 11 % of the total variance. Under this factor, stream frequency, form factor and circulatory ratio were found to have significant positive loadings whereas relief ratio was negatively loaded. This indicates that stream frequency, circulatory ratio and form factor act in the same direction whereas relief ratio has an inverse relationship with all the above morphometric parameters. In general, relief ratio is a measure of overall steepness of the basin and in the present study it indicates that basins with high values of relief ratio have low values of stream frequency, form factor and circulatory ratio. The morphometeric parameters loaded under this factor generally define the areal aspects and shape characteristics of the basin, and hence, it was grouped under “shape factor”.

Factor scores: Generally, factor scores are estimated to understand a variable’s relative spacing or standing on a particular factor under consideration. In the present study, factor scores (Table 4) were estimated in order to infer which among the above discussed three factors has a significant influence among the 11 sub basins of the Nandiyar river. The results have shown that morphometric parameters grouped under ‘basin magnitude factor’ control the sub basins 4, 5, 9, 10 and 11, whereas sub basins 3, 6 and 7 were found to be under the influence of runoff factor. Finally, shape factor was found to have much influence in the sub basins 2 and 8.

The above inferences were also substantiated by the fact that severe gully erosion observed in the study area was, in fact, noticed to be a major environmental problem in sub basins 6 and 7, which are as per the statistical analysis inferred to be under influence of runoff factor.

CONCLUSION

Morphometric parameters grouped under basin magnitude factor play a major role in Nandiyar basin, as they account for the largest proportion of the variance observed (nearly 57 %). Morphometric parameters grouped under runoff factor come second whereas shape factor comes third. Drainage network in the Nandiyar basin seems to have a strong structural control and exhibits typical dendritic pattern. The severe development of gully erosion indicates that soil erosion and excess runoff are the major environmental problems of the study area. Hence, remedial measures like gully plucks, check dams and waste weirs are warranted in proper places to minimise these problems. Drastic water level fall due to over exploitation is yet another major problem in the study area. Hence, to improve the groundwater conditions, the inter basinal areas which have good infiltration capabilities could be utilised by constructing check dams/ponds/tanks at suitable places.

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