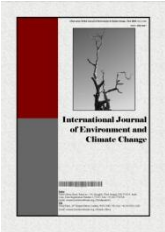

International Journal of Environment and Climate Change

12(11): 1541-1551, 2022; Article no.IJECC.89818
ISSN: 2581-8627
(Past name: British Journal of Environment & Climate Change, Past ISSN: 2231–4784)

Identification of Influential Geomorphologic Parameters on Runoff Characteristics of the Thuthapuzha River Basin in Kerala, India

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJECC/2022/v12i1131137

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here:
https://www.sdiarticle5.com/review-history/89818

Original Research Article

Received 18 May 2022
Accepted 29 July 2022
Published 16 August 2022

ABSTRACT

Aims: Geomorphological parameters are signature for the conversion of rainfall into runoff. The morphometric analysis using GIS gives platform for deriving the geomorphological parameter of the river basin. Due to intercourse between stream network and landscape, geomorphological parameters are driving force for the conversion of rainfall into runoff. For finding parameter which is more significant contribution to runoff, statistical analysis gives better solution. The morphological parameters of the watershed are derived and then use landform equation for getting geomorphological parameters. Derived parameters are subjected for the factor analysis using Minitab 18 software.

Place and Duration of Study: Study is conducted on Thuthapuzha River basin which is tributary of Bharathapuzha River located in Kerala, India has been selected and it is conducted on Department of Soil and water Conservation Engineering, Kelappaji College of Agricultural Engineering (KCAET), Tavanur, between June 2017 and July 2018.

Methodology: From seventeen Micro-watershed the geomorphological parameters are derived and subjected to factor analysis. Interpretation of factor loadings, communalities, variance, % variance, factor score gibes more influencing parameters on runoff.

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Results: The total percentage variance explained by all the factors is about 83.9%, which gives the analysis is a good approach. Runoff factor exhibits the highest percentage variance of about 37% among the percentage variance explained by each factor. The highest correlation coefficient is obtained between runoff factor and the length of overland flow, and the constant of channel maintenance which are more significant parameters of river basin. Total variance explained by all three factors is 11.247 where runoff factor exhibits the highest variance of 5.192. Highest factor score is obtained from length of overland flow having factor score 0.190 followed by elongation ratio, form factor having factor score of 0.165 and 0.152 respectively which can be used as independent variable in case of regression models.

Keywords: Geomorphological parameters; GIS; factor analysis; minitab 18; factor score.

1. INTRODUCTION

Geomorphological parameters are parameters defined by stream network, surrounding landscape and topography using mathematical equation [1]. Now a days it is easy to understand the concept of hydrogeomorphology through geomorphometry because terrain analysis and surface modelling are easy with modern tools and software. The basic idea behind the geomorphometry is that relationship is developed among the geography and topography [2]. The parameters are derived from geomorphometry hence it is also called as geomorphometrical parameter. The morphological parameters of the river basin are derived with the help of GIS software. Using landform equation the derived morphological parameters used for obtaining geomorphological parameters which can be considered as reflect of the surface roughness [3]. Due to intercourse between stream network and landscape, geomorphological parameters are driving force for the conversion of rainfall into runoff [4,5]. The parameters are stream frequency, bifurcation ratio, elongation ratio, drainage density etc. which exhibits the characteristics of the watershed geomorphology. These parameters are strongly related to the rainfall and streamflow in the watershed. In other words, geomorphological characteristics are signature of hydrologic response. The study of response and influential geomorphological parameter on runoff involves, finding which parameter is more significant contribution to streamflow, various statistical analysis are applied [6]. If the large number of data exist, then factor analysis can be better solution for the analysis of this kind of data. Factor analysis is a statistical analysis which uses continuous data and it is a kind of multivariate analysis where large number of variable can be analyzed statistically to bring down fewer ones [7,6]. Foremost purpose of factor analysis is to identify hidden dimensions called factors, and these factors are used to represent relationships among interrelate variables. Here variables means geomorphological parameters. The relationship reveals that correlation matrix is computed between factors and geomorphological parameter so that correlation between the parameter and the factor can be easily identified

2. MATERIALS AND METHODS

For the present study Thuthapuzha River basin located in the central part of Kerala, India has been selected. The basin having area of 1005 Km2 with a perimeter of 240 Km and length of the main channel is about 99.64 Km. Thuthapuzha is a one of main tributary of Bharathapuzha river, which is flowing towards west and finally reaches Arabian Sea near Ponnani. The Bharathapuzha river basin having total catchment area of 5,397 km2 in which 1593 km2 area lies in Tamil Nadu and remaining area lies in Kerala. The flow in river is strongly depend by south west monsoon. This river water is the lifeline source for water for almost one-eighth of Kerala's population residing in the districts of Malappuram, Thrissur, and Palakkad. The location of Thuthapuzha River is which lies between 10° 50^1 to 11°15^1 North latitude and 76° 5^1 to 76°40^1 East longitude.

For identifying influential parameters, the first step to derive geomorphological parameters. It is derived from landform equation which can be considered to reflect the surface roughness. The morphological parameters of the watershed are derived and then use landform equation for getting geomorphological parameters. In this study, morphological parameters are extracted from Digital elevation model (DEM) with the help of ArcGIS software. Cartosat-1: DEM - Version-3R1 1 arc sec (~ 32 m) resolution was used for this study.

The morphometric parameters of sub basin such as stream parameters like number of stream segments, stream order, sub basin length, and areal parameters like drainage pattern area and perimeter were delineated from this DEM within the GIS environment. Obtained parameters are further used in computing the geomorphological parameters such as stream frequency, bifurcation ratio, drainage density, form factor, circulatory ratio etc. using mathematical equations. The extraction of stream network and watershed parameters can be done under separate categories [8].

From single watershed it is difficult to conclude influential parameters. For this purpose entire Thuthapuzha River basin is divided into small microwatershed. In this study, river basin is divided into nineteen micro watershed using catchment grid delineation in ArcGIS out of nineteen micro watersheds, seventeen micro watershed are used in this study. From all seventeen microwatershed the geomorphological parameters are derived and then make these parameters into tables in Microsoft excel. Finally the table is imported into the Minitab worksheet and subjected for the factor analysis. In this study Minitab 18 trial version software was used for conducting factor analysis.

The study of influential parameter on runoff involves, finding which parameter is more significant contribution to runoff. Identification significant parameter can be done by application of statistical analysis. Since the large number of data (fourteen parameters from seventeen micro watersheds), factor analysis can be better solution for the analysis of this kind of data [9]. Factor analysis involves relation between geomorphological parameters and internal attribute (also called as factors) and the basic principle involved in factor analysis is that, factors influences these parameters in systematic pattern [10]. This underlying factors measurement is the main objective for the finding influential parameter. Here factors are linear composite of the variables. The entire factor analysis procedure are done in Minitab 18 software and step by step procedure is shown in Fig. 1.

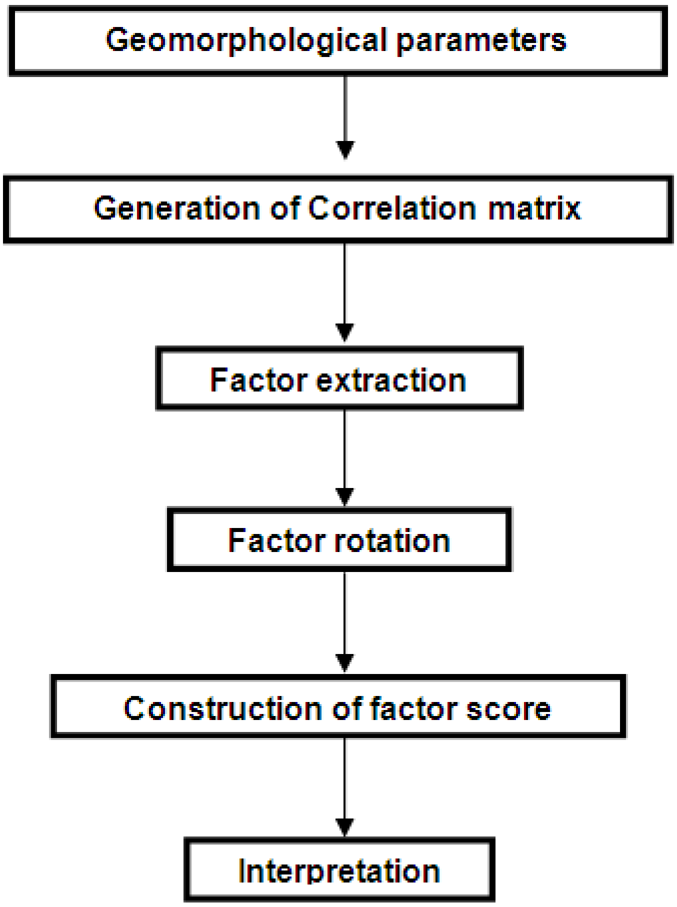


Fig. 1. Flow chart for the conducting factor analysis in Minitab

2.1 Steps in Conducting a Factor Analysis

There are five basic steps that have to be considered for a Factor analysis experiment are discussed below:

2.1.1 Geomorphological parameters

In this step the identified 14 geomorphological parameters from seventeen micro watershed are worked out for statistical analysis are put it in excel and make into a table.

2.1.2 Generation of correlation matrix

In this step correlation matrix for all variables are generated. It is also called loadings in factor analysis. Loadings are nothing but correlation of the variables with the factor. Loadings are main factor for identify the variables not related to other variables. Factor loadings to indicate up to what extent the factor can explain the variance and it is given by correlation coefficient which ranges from -1 to 1. Square the loading and multiply by 100 gives the cofficient. The coefficients of correlation approaches the degree of linear relationship between the row and column variables of the correlation matrix [11].

2.1.3 Factor extraction from correlation matrix

In this step the number of factors are to be extracted. Since purpose of the study is to create new variables as a linear combination with existing variables so Principle Component Analysis (PCA) method is used in this study. PCA is the mathematical procedure where huge number of correlated variables are transformed into smaller uncorrelated variables (called principal component (PC)) [12]. The analysis used for the elimination of the insignificant parameters. The analysis of PCA is to explain maximum amount of variance with less number or few number of principal components [13]. The first principal component accounts largest variance in the geomorphological data (1st extracted factor) and successive components explains progressively smaller portions of the total sample variance.

Based on the screen plot and Eigen values, the number of factors are selected for the factor analysis. Eigen values is defined by sum of the square of the loadings across the factor where values greater than one is considered for the accepting the number of factors. Scree plot is the graph of number of factors versus its corresponding Eigen values and generally it is steep curve followed by bent and then a straight line. Scree plot shows bent at each factor and slope of this line basically gives the more variance. First factor explains highest amount of variance, second factor explains little bit less variance compare to first one and goes on decreasing order.

2.1.4 Rotation

Most of the variables are loaded at one factor for many times, in this condition rotation provides a structure of loadings and a pattern matrix of partial weights. From the rotating the matrix, the distribution of the variables is made much better across the factor. Rotation doesn't change the results of PCA but the pattern of loadings can easier for interpretation of the results. Varimax is method of orthogonal rotation method in which, factor loading matrix is rotated to orthogonal simple structure. Varimax rotation attempts to maximize the dispersion of loadings between factors, maximization of variance of the factor loadings of the variables on the factor matrix and also varimax is good for simple factor analysis. The unrotated factor matrix and rotated factor matrix is obtained while doing factor analsis. For the interpretation, results from the rotated matrix is considered.

2.1.5 Construction of factor score

Factor score is defined by numerical value that indicates one individual's standing on a given factor and this score can be used as dependent and independent variables for regression analysis [14]. Factor coefficients are used to calculate the factor scores in minitab, which are the estimated values of the factors. The larger the value of factor coefficient, the more important the corresponding variable.

2.1.6 Interpretation results from factor analysis

2.1.6.1 Interpretation of factor loadings

Factor loadings indicates the what extent the factor can explain the variance and it is given by correlation coefficient which ranges from -1 to 1. The value -1 to nearer to this gives negative relationship (less influencing), whereas the +1 or nearer value indicates the positive relationship (more influencing). Correlation coefficient closer to zero accounts, lesser the relationship, where as the correlation coefficient closer to 1 indicates for the greater the relationship. A negative sign indicates that the variables are inversely related in other word negative influencing parameter and positive sign indicates positively influencing parameter. Correlation coefficient greater than 0.7 in absolute value are indicative of acceptable correlation.

2.1.6.2 Interpretation of communalities

The variable contribution to each factor is given by communality. It is the square of the loading or correlation coefficient of variable with respect to factor and it is same in both rotated and unrotated factor matrix. It explains variability that is explained by the factor and it is always less than one. If the communality value is nearer to 1 than better the variable explained by the factor.

2.1.6.3 Interpretation of variance

Variance is squared deviation of the variable from its mean in each factor. If the variance is more, than the factor explains more variability and better will be the result.

2.1.6.4 Interpretation of % variance

The percentage variance of each factor is directly proportional to the variability explained by the factor and it ranges from 0 to 1(0% to 100%). From the factor analysis, at least 60% of variance can be determined. When the variance is explained by the variable is small which is very less than 10%, then neglect that factor.

2.1.6.5 Interpretation of factor score

It is the rank wise order of the variables within the factor in other words the important variable in each factor is given by factor score. The larger the value of variable, more important corresponding variable and that variable is used as independent variables in regression analysis [15].

3. RESULTS AND DISCUSSION

3.1 Morphometric Evaluation of Thuthapuzha Sub-basin

The morphometric parameters were measured in terms of quantitatively. For the present study,Cartosat-1: DEM - Version-3R1 1 arc sec (~ 32 m) which freely downloaded is used for the deriving morphological parameters. The morphometric data are obtained with the help of attribute data in GIS. From that attribute data, basin having area of 1005 Km^2 with a perimeter of 240 Km and length of the main channel is about 99.64 Km were obtained. The streams in the basin exhibits dendritic in nature which means the basin having many streams which are then joined which is called the tributaries of the river and this nature of drainage pattern develop where river channel follows slope of the terrain. The Location and DEM of the study is shown in Fig. 2.

Geomorphologic parameters influences of the Thuthapuzha sub-basin. The entire river basin is divided into 17 micro-watersheds and from all these sub basin, geomorphologic parameters are derived. All 14 parameters are identified and worked out for statistical analysis. Fig. 3 shows micro watershed of Thuthapuzha river basin.

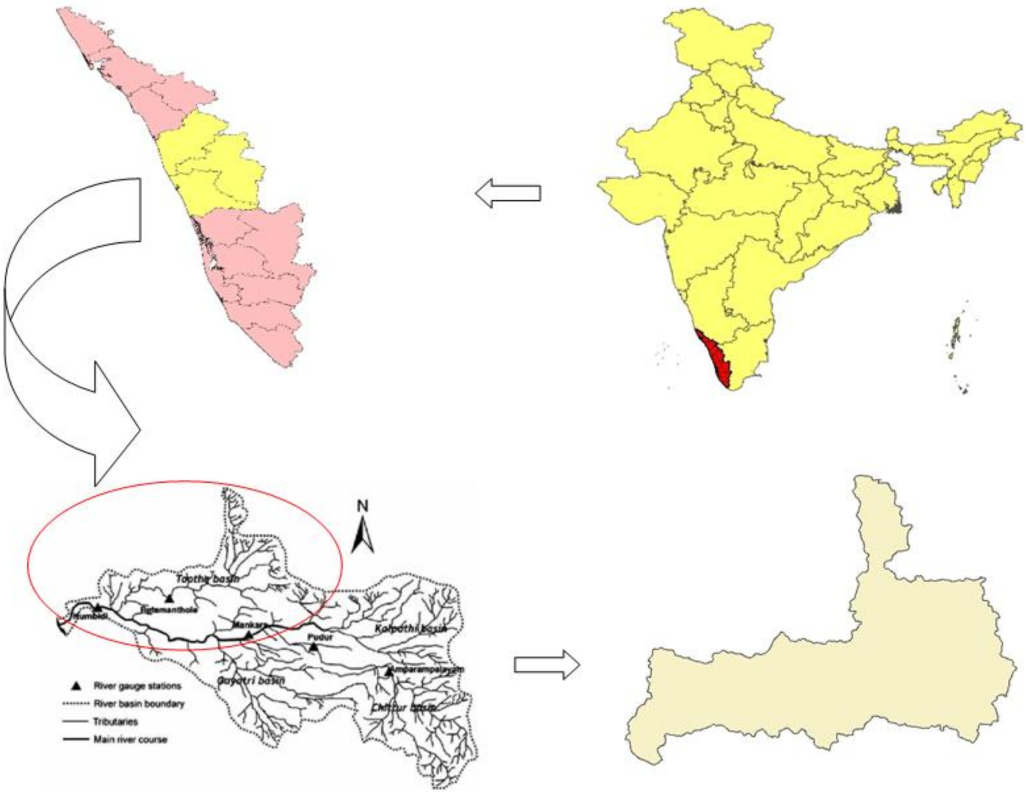
Finding influential parameter from large number of data can be done by applying multivariate analysis especially factor analysis is used for this purpose. Since the data in these case is geomorphological parameters having 14 parameters from 17 Micro-watersheds, the first step is to make these parameters into tables in Microsoft excel and this table is imported into the Minitab worksheet and finally subjected to factor analysis. The results from factor analysis can be interpreted with the correlation matrix, scree plot, Eigen values, variance and factor score.

3.2 Interpretation of Screen Plot

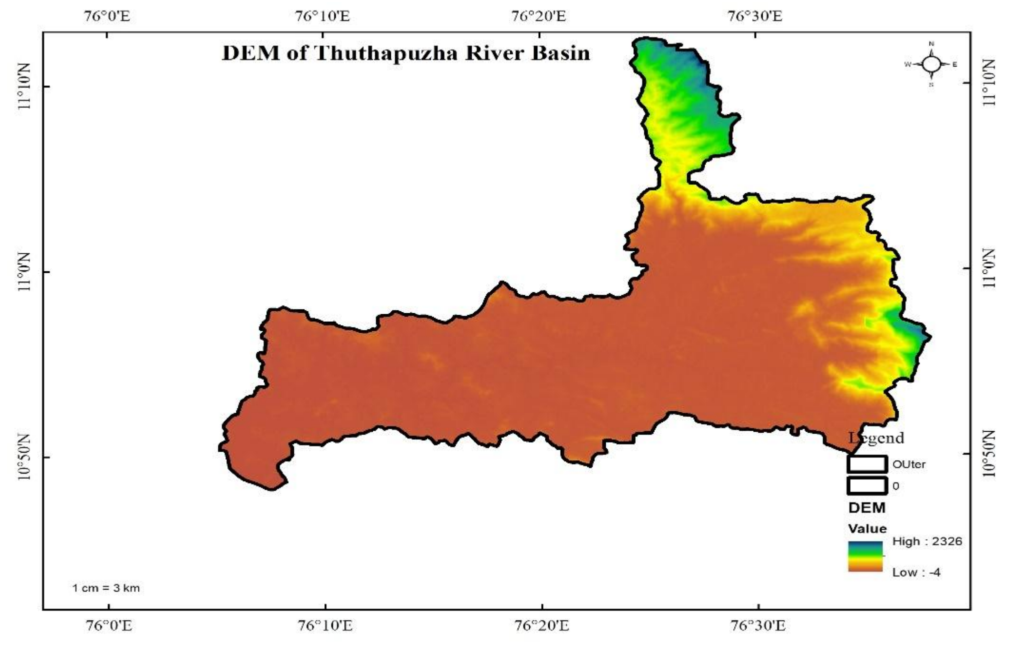
Screen plot accounts to find the number of factors to be selected for the analysis. The plot of Eigen values versus number of factors shows that select the factors. From this graph the bent is obtained at number of factors is at three and this point eigen values is also greater than one. So the number of factor to be selected for the factor analysis is three and it is shown in Fig. 4.

3.3 Interpretation of Factor Loadings

Loadings are nothing but correlation of the variables with the factor. Loadings are main factor to identify the variables not related to other variables. The interpretation of factor loadings can be discussed under two condition *viz.* unrotated factor loadings and rotated factor loadings [6]. Both can be easily differentiated by observing the graphs.



(a)



(b)

Fig. 2. (a) Location of Thuthapuzha river Basin (b)DEM of Thuthapuzha River Basin

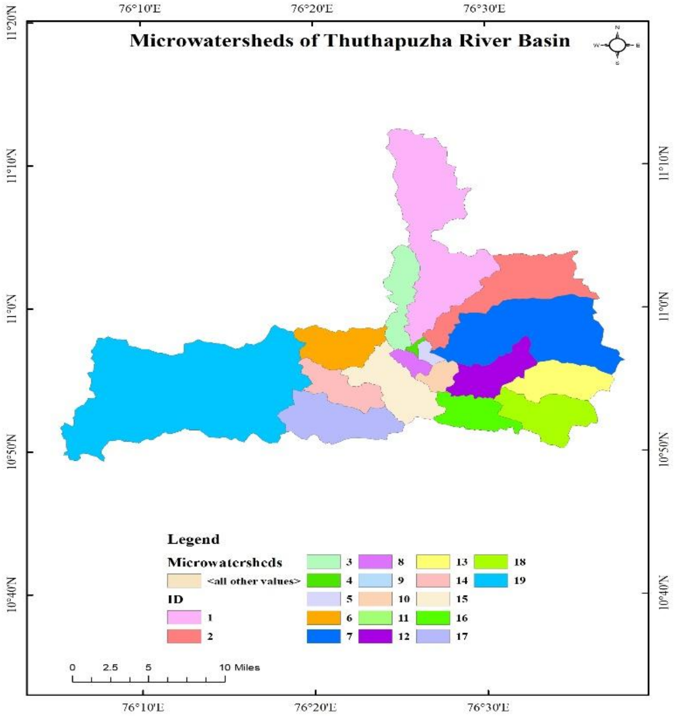


Fig. 3. Micro-watersheds map of the Thuthapuzha river basin

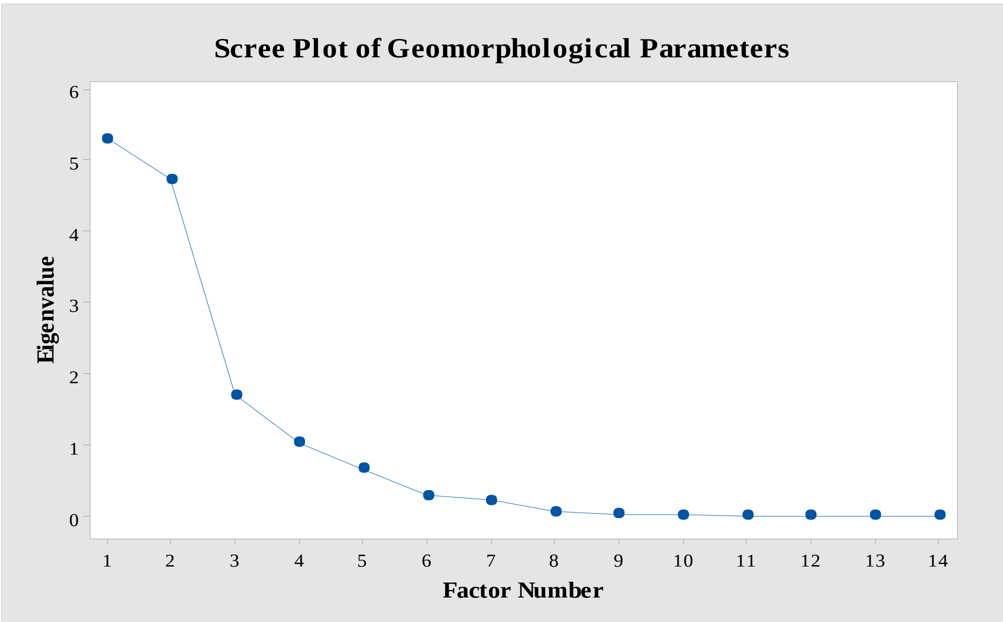


Fig. 4. Screen plot of Geomorphological parameters

The graph loadings in unrotated is obtained to understand the distribution of the variables within the factor. In the Fig. 5 most of the variables are loaded at one factor (factor 1) and more variables meets at same loadings in different factor (loadings at -0.5, 0, -0.1). In this condition, interpretation of loadings is difficult. For avoiding this, the loadings are rotated in order to distribute the variables and pattern of loadings can easier to interpret the results.

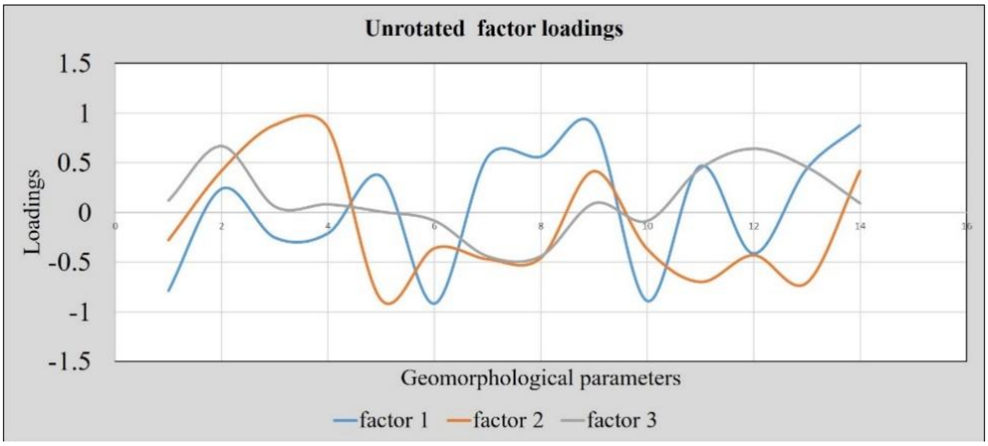


Fig. 5. Unrotated factor loadings for three all factors

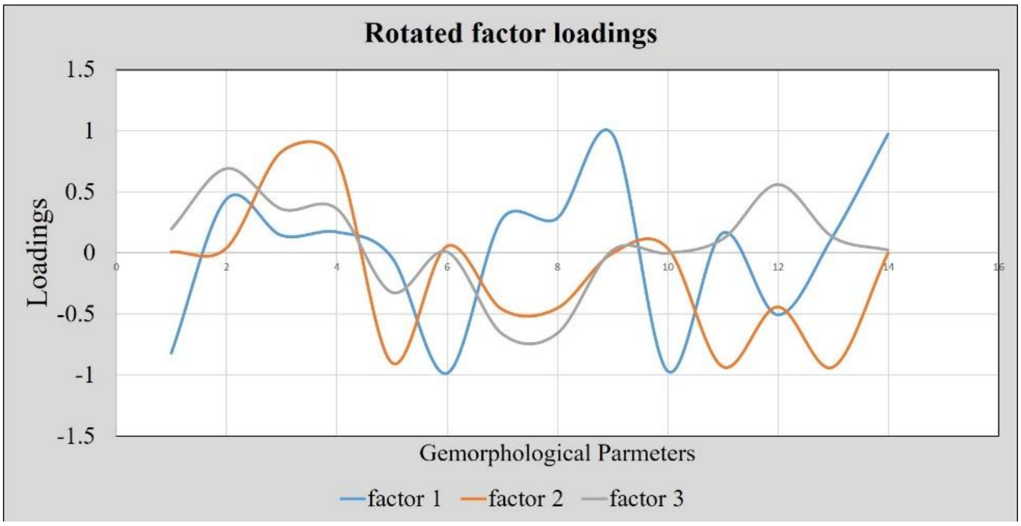


Fig. 6. Rotated factor loadings for all three factors

Table 1. Rotated Factor Loadings and Communalities

Variable	Factor1	Factor2	Factor3	Communality
Stream frequency	-0.822	0.010	0.196	0.714
Bifurcation ratio	0.440	0.042	0.692	0.674
Elongation ratio	0.143	0.831	0.360	0.840
Form factor	0.171	0.780	0.363	0.769
Shape factor	-0.037	-0.897	-0.322	0.909
Drainage density	-0.987	0.057	0.009	0.978
Drainage texture	0.278	-0.460	-0.662	0.728
Circulatory ratio	0.284	-0.451	-0.659	0.718
Length of overland flow	0.974	-0.001	0.022	0.950
Infiltration number	-0.968	0.042	-0.001	0.938
Basin relief(km)	0.163	-0.929	0.114	0.903
Relief ratio	-0.507	-0.440	0.561	0.765
Ruggedness number	0.136	-0.933	0.130	0.905
Constant of channel maintenance	0.974	0.000	0.024	0.950
Variance	5.1901	4.4516	2.1010	11.7427
% Variance	0.371	0.318	0.150	0.839

Varimax method is used for factor rotation. In the Fig. 6, the distribution of variables in different factors and also distribution pattern also changed. The interpretation of loadings in this case easy compare to unrotated loadings which is shown in Table 1.

3.3.1 Factor 1

In this factor the highest positive correlation coefficient is obtained from length of overland flow and constant of channel maintenance. Both of the variables are having correlation coefficient of 0.974. This value indicates two variables exhibits more relationship (influencing) with factor. In case of negative correlation parameters, the highest relationship is obtained from drainage density having correlation coefficient of -0.987. The remaining negative correlation parameters are infiltration number and stream frequency. Both variables having coefficient of -0.968 and -0.822 respectively. Results obtained from both positive and negative correlation variables (length of overland flow, constant of channel maintenance, drainage density, infiltration number and stream frequency) exhibits the characteristics of the runoff. Hence runoff characteristics are more influencing in Thuthapuzha river basin and this factor named as runoff factor.

3.3.2 Factor 2

In this factor the highest positive correlation coefficient is obtained from elongation ratio having correlation coefficient of 0.831. Form factor also exhibits positive correlation with factor 2 having correlation coefficients 0.78. In case of negative correlation parameters, the highest relationship from ruggedness number having correlation coefficient of -0.933. The other less influential (negative correlation) parameters are basin relief and shape factor. Both variables having coefficient of -0.929 and -0.897 respectively. From the above results from both positive and negative correlation variables, the parameters elongation and shape factor exhibits shape characteristic of the basin. Hence shape characteristics are more influencing in Thuthapuzha river basin after the runoff factor.

3.3.3 Factor 3

In this factor the highest positive correlation coefficient is obtained from bifurcation ratio having correlation coefficient of 0.692. Drainage texture and circulatoryratio exhibits negative correlation with factor having correlation coefficient of -0.662 and -0.625 respectively. From all these variables, correlation coefficient less than 0.6 in both case of positive and negative influential parameters hence factor 3 variables are having less influence parameters.

3.4 Interpretation of Variance

The variance also derived through factor analysis to check the variability among the factors. Out of four factors runoff factor (factor 1) exhibits the variance of 5.192. This shows that factor 1 exhibits more variability and gives comparatively good result. The other factors 2 and 3 gives the variance of 4.416 and 2.101 respectively. Total variance explained by all three factors is 11.247.

Table 2. Factor Score Coefficients

Variable	Factor1	Factor2	Factor3
Stream frequency	-0.154	-0.020	0.080
Bifurcation ratio	0.106	-0.076	0.383
Elongation ratio	0.037	0.165	0.096
Form factor	0.043	0.152	0.105
Shape factor	-0.015	-0.187	-0.064
Drainage density	-0.192	0.015	-0.032
Drainage texture	0.035	-0.035	-0.293
Circulatory ratio	0.036	-0.033	-0.292
Length of overland flow	0.190	-0.005	0.041
Infiltration number	-0.188	0.013	-0.035
Basin relief(km)	0.037	-0.250	0.182
Relief ratio	-0.081	-0.180	0.343
Ruggedness number	0.032	-0.253	0.191
Constant of channel maintenance	0.190	-0.005	0.042

3.5 Interpretation of % Variance

The % variance ranges from 0 to 1 (0% to 100%) of which minimum 60% of variance can be determined through factor analysis. In this study the % variance explained by all factors is about 0.839(83.9%). Among all these factors, first factor (runoff) factor exhibits % variance of 0.371. Remaining factors exhibits %variance of 0.318 and 0.150 respectively. This values shows that runoff factors exhibits more % variance compare to all other factors.

3.6 Interpretation of Factor Score

Factor score is the rank wise order of the variables within the factor. From the factor analysis, the highest factor score is obtained from length of overland flow having factor score 0.190 and for all geomorphological parameters factor score is shown in Table 2. Elongation ratio, form factor parameters having factor score of 0.165 and 0.152 respectively and these parameters can be used as independent variables in regression equation for runoff estimation.

4. CONCLUSION

The total percentage variance explained by all the factors in factor analysis is relatively high. The factor analysis is a good approach for finding significant parameters. Among the percentage variance explained by each factor, the runoff factor exhibits more percentage variance. The high correlation coefficient between runoff and geomorphological parameters are more significant. The positive correlation values on runoff factor are length of overland flow and constant of channel maintenance which exhibits more significant parameters, whereas the drainage density exhibits less significance. All these parameters indicate that runoff factor is controlled by these groups of variables.

The results of factor analysis show that the form factor, elongation ratio, and circulatory ratio, exhibit shape characteristics which are more important after considering the runoff factor. The present study is useful in eliminating the relatively insignificant parameters and arranging the remaining significant factors into clearly distinguish groups. The shape parameters are lower values which is given as rank and similarly rank is given for the other parameter also. According to rank highest priority is given for prioritizing the watershed. The results show the significance of factor analysis in hydrologic response studies and also the results from the factor analysis can be used for prioritizing the watershed.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Chethan BJ, Vishnu B. Determination of the geomorphologic parameters of the Thuthapuzha River Basin in central Kerala, India, using GIS and remote sensing. Int J Curr Microbiol Appl Sci. 2018;7(9): 1245-60.
2. Jarrar A, Jayasurya N, Jayyousi A, Othman M. Applicability of the GIUH model to estimate flood peaks from ungauged catchments in arid areas- a case study for the west bank. IAHS Publ Perugia. 2007:346-57.
3. Mark D. Geomorphometric parameters: a review and evaluation. Vancouver: Department of Geogr. 2004:12-25.
4. Bhat SA, Shah AM, Alam A, Sheik AH. Modelling hydrological response of Indus basin as a function of geomorphology and land cover change. Srinagar: University of Kashmir. Srinagar. 2015:1-12.
5. Seldomridge ED, Prestegaard KL. Use of geomorphic, hydrologic, and nitrogen mass balance data to model ecosystem nitrate retention in tidal fresh wetlands. Biogeosciences. 2012;9(7):2661-72.
6. Nikam SP, Purohit RC, Shinde MG. Principal component analysis for morphometric modelling for small watersheds of Tapi river basin in India. Int J Agric Eng. 2014;7(1):186-9.
7. Jayakumar R, Ramesh D, Balaji S. Factor analysis in deducing groundwater level functions. Geoinformatics. 1996;7(1-2): 23-7.
8. Jotish N, Parathasathi C, Nazrin U, Singh KV. Int J Geom Geosci. 2011. A geomorphological based rainfall-runoff model for ungauged watershed;2(2): 676-88.
9. Abrahams A. Factor analysiss of drainage basin properties: evidence for stream abstraction accompaying the degradation of the relief. Water Resour Res. 1972;8(3):1-10.
10. Gavit BK, Purohit RC, Singh PK, Kothari MK. Grouping of geomorphic parameters

in selected watershed using principal component analysis for hydrologic modelling. Int Res J Environ Sci. 2016;5(12):7-13.
11. Bhaskaran G, Kumaraswamy K. Identification of influential gemorphic parameters in hydrologic modelling through numerical analysis. J Appl Hydrol. 2002;15(1):1-8.
12. Meshram SG, Sharma SK. Prioritization of watershed through morphometric parameters: a PCA based approach. Appl Water Sci. 2017;7(3):1505-19.
13. Sharma SK, Tignath S, Gajbhiye S. Application of PCA in grouping geomorphologic parameters in Uttela watershed for hydrologic modelling. Int J Remote Sens Geosci. 2013;2(6): 63-71.
14. Yakuba A, Idahor KO. Using factor scores in multiple linear regression model for predicting the carcass weight of broiler chicken using body measurements. Rev UDO Agric. 2009;9(4): 963-7.
15. Eyduran E, Karakus K, Cengiz F. Usage of factor scores for determining relationships among body weight and some body measurement. Bulg J Agric Sci. 2009; 15(4):373-7.

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