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Hybrid Model of Morphometric Analysis and Statistical Correlation for Hydrological Units Prioritization

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Abstract: Watershed and natural resources management of the large-scale drainage networks is of utmost importance for sustainable development. In this research, seven morphometric parameters including area, drainage density, bifurcation ratio, mean weighted slope, net and gross slope of the main stream, and mean weighted elevation are obtained through digital elevation model (DEM). In order to determine the proportion relationship between watersheds morphometric parameters and erosion, Pearson's correlation and multivariate stepwise regression were applied. It was found that erosion rate has the most correlation with the area factor in the following, the factor of area and drainage density were introduced into the multivariate stepwise regression model. In order to prioritizing hydrologic units using the method of sediment yield index (SYI) and Combined method of morphometric analysis and statistical correlation (CMS). The results showed that according to the SYI, B1 hydrologic unit was the highest priority and according to CMS determined that the B2 unit has the highest priority in terms of water and soil conservation. In morphometric analysis uses variables that include morphological characteristics, physiography and hydrology, which experience shows that the results of statistical analysis and modeling will be improved when a combination of these variables is introduced into the model. Using a morphometric analysis method is very suitable method for better access and stability in watershed with associated information constraints.

Keywords: Prioritization; statistical modeling; hydrological modeling; hydraulics; sediment yield index (SYI); morphometric analysis

1. Introduction

Since natural resource development projects are mainly carried out in watersheds, their prioritization is essential for the proper planning and management of natural resources for sustainable development (Jang et al., 2013). There are several methods for prioritizing sub-watershed, which revealed that out of 25 research studies, 11 cases have been applied, the morphometric analysis method (Biswas et al., 1999; Patel et al., 2012; Patel et al., 2013; Gajbhiye et al., 2014; Makwana&Tiwari, 2016; Farhan et al, 2017; Chandniha& Kansal,2017). While 14 other studies also used the morphometric analysis method in combination with other methods such as the Sediment yield Index (SYI) (Nooka Ratnam et al., 2005; Biswas et al., 1999) Fuzzy Analytical Hierarchy Process (Fallah et al, 2016; Rahaman et al, 2015) The Snyder's method relate to unit hydrograph, land use and vegetation (Singh, N & Singh, K.K, 2017) had adapted. Methods that are not in the form of morphometric analysis require information and data of appropriate quality and varied information from the watershed. Therefore, their use in areas with information constraints will be problematic. Several studies have used morphometric analysis to prioritize sub-watershed, Malik et al. (2019) use the morphometric analysis and remote sensing approach to prioritized the 14 sub-watershed in the hilly watershed in the upper Ramganga River basin in India, using different morphometric parameters and weighting the effect of each parameter, Using the Weighted sum Analysis (WSA) method, it was finally determined that 20.3% of the sub-watershed required soil and water conservation measures. Mohammed et al. (2018) also investigated 61 sub-watershed of the Gibe watershed in the southwest of Ethiopia and used morphometric analysis to prioritize sub-watershed. Using DEM, The morphometric parameters were obtained in the GIS by using DEM, and finally, based on the combined value of the parameters, they performed the prioritization of the sub-watershed, so that the highest score was attributed to the sub-watershed that received less combined factor. Poongodi and Venkateswaran (2018) also used the morphometric analysis to prioritize sub-watershed in the Vasishta watershed from the Vellar River Basin. Several empirical models based on geomorphologic parameters have been developed to quantify the sediment yield from the erosion in the watershed, as well as methods such as the Sediment yield Index (SYI) developed by Bali and Karale (1977) Have been used extensively to prioritize watersheds(Naqvi et al, 2015). Given to the lack of hydrometric station in the Kashkamir watershed, erosion and sediment studies as well as the use of sediment yield index(SYI), which even dosen't requires rainfall information, as well as the prioritization of hydrological units on this basis, is very important. Naqvi et al. (2015) evaluated the erosion performance in the 24 sub-watersheds of Nun Nadi watershed in India, using the weighting of soil parameters, topography, rainfall erosion and land use, and based on this Prioritized sub-watersheds. Various factors affect the transport of river sediment, which recognizes the role of each in the amount and sediment transport, are considered as essential steps in determining the sediment load of the rivers (Fryirs, 2013). Also, the correlation between morphometric parameters of the watershed decreases the errors (Melton, 1958). In Kashkamir watershed, we tried firstly to prioritize the sub-watersheds according to the SYI, which is itself influenced by morphometric parameters and sediment transport ratio. Further, the combination of morphometric characteristics with statistical correlation and we measured the weight of each parameter. In fact, in the combination of morphometric analysis and statistical correlation, prioritization is based on the information obtained from the GIS layers, the factors affecting the watershed and the correlation between the parameters (Aher et al., 2014). Rahmati et al. (2019) used automated prioritization methods using morphometric characteristics analysis in GIS and topo-hydrographic indexes and also statistical correlation using Python under Golestan watersheds. Using the digital elevation model and the characteristics of Golestan Watershed drainage system, 9 parameters of morphometric and 3 topo-hydrographic parameters were used, Using WSA, the weights of the impact of each parameter were determined Finally, it was found that in terms of parameters Topo-hydrographic sub-watersheds of Nos. 17, 8 and 7 were the highest values respectively. In the automatic method of prioritization, based on morphometric analysis and statistical correlation, sub-watersheds 13 and also 9 and 5 have priority for control measures. Considering the economic problems and saving more time and energy, as well as the lack of a hydrometric station in the field of study, it is very important to provide a method that minimizes the problems, in this regard, prioritizing the hydrological units in the Kashkamir watershed using the SYI and the morphometric analysis and statistical correlation method are the purpose of this study.

2. Material and methods

2.1 Study area

The Kashkamir watershed located in Kermanshah province of Iran with an area of 55.50 square kilometers and in the geographical position 47˚3' to 47˚9' east longitude and 34° 47' to 34 ° 53' north latitude. The whole area is divided into 13 units, of which 9 are hydrological or independent and 3 units are non-hydrological or dependent (N). The largest hydrological unit, unit (NA5) with an area of 729.6 square kilometers and the smallest hydrological unit, unit (A6) is 228.1 square kilometers. Kashkamir watershed has a mean weighted elevation of 2098 meters and a mean weighted slope of 31.7 percent. In terms of climatic categorization, according to Demarton method has a semi-humid cluster on a general scale. The length of the Kashkamir River is close to 14 km, with a net slope of 2.9% and gross slope of 4.5% (Figure 1). In this study, due to the lack of a hydrometric station and sediment gauge in Kashkamir watershed, in order to estimate the erosion rate and sediment yield, as a prerequisite for performing other methods, the MPSIAC model has been used that the BLM model is considered as a prerequisite for the applied MPSIAC model.

2.2 MPSIAC model

The original version of this model was presented in 1968 by the Pacific Southeast Inter Agency in America to estimate soil erosion in watersheds lacking sediment gauges. This model is based on the assessment of 9 factors of geology, soil, climate, runoff, topography, vegetation, land use, present erosion of the watershed, and gully erosion is applied to each factor. Johnson and Gembhart (1982) modifications in this model and they are called MPSIAC.

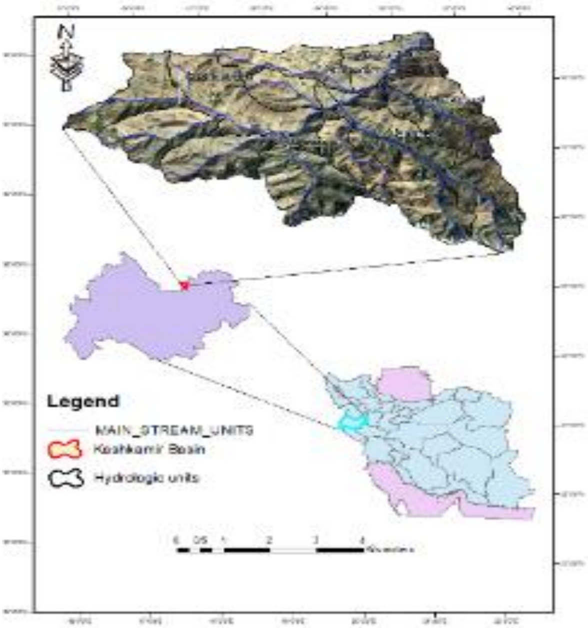

Figure 1 . Geographic location of Kashkamir watershed and its Hydrological units. Entire divided to 13 hydrological units

The table (1) specifies the factors proposed in this method and how to score them. The annual sedimentation rate in this method is calculated by the equation (1).

$$Q_s = 0.253 e^{0.036R} \qquad (1)$$

Where: Qs= annual sedimentation yield (ton/ha/year), R= sediment yield degree, e = 2.718.

The relationship between soil erosion and sedimentation in MPSIAC model and the specific erosion in MPSIAC model is calculated by SDR Coefficient (Sediment Delivery Ratio) by the equation(2).

$$\text{Log (SDR)} = 1.8768 - 0.14191 \log (10A) \qquad (2)$$

A is the area of the watershed ($mail^2$).

Parameters 8 and 9 are presented in Table (b) using the BLM method. The BLM model is based on 7 factors, soil movement, presence of litter on the surface, consolidated rock masses, existence of rill erosion, form of streams and the existence of gully erosion and giving a score of 0 to 15 in terms of their impact on erosion. And the total points of the various factors in this section reaches 100.

Table 1 the effective factors and their point's calculation formula in MPSIAC model

The effective factors	The points calculation formula	Explanation Parameter

Geology	Y1=X1	X1: stone sensitive point
soil	Y2=26.67K	K : erodibility factor in USLE
climate	Y3=0.2X3	X3 : precipitation intensity with 2 year interval return
Runoff	Y4=0.006R+10Qp	R : annual runoff depth (mm), Qp:annual specific discharge
Topography	Y5=0.33S	S: average watershed slope (%)
Vegetation	Y6=0.2X6	X6: bare soil (%)
Land use	Y7=20-0.2X7	X7: canopy cover (%)
Present soil erosion	Y8=0.25X8	X8 : points summation in BLM model
Gully erosion	Y9=1.67X9	X9 : point of Gully erosion in BLM model

In the next step, a digital elevation model (DEM) was prepared in GIS and used as the basic map for determining other morphometric and physiographic characteristics. The morphometric analysis is in fact a systematic description of the geometric conditions of the watershed, the characteristics of the streams and its related measurements in order to know more about the linear characteristics of the drainage network, the regional and landural characteristics of the watershed, as well as the characteristics of the network flow(Strahler, 1964). Also, morphometric analysis is one of the important tools for prioritizing sub-watersheds without the need for a regional soil map (Pandey et al, 2007). In this study, 7 parameters of morphological and physiographic characteristics of the watershed were selected. The drainage density (Dd), which according to equation (3) is equal to the total length of the streams (ΣL) to the watershed area (A), (Horton, 1945). Kumar et al. (2012) find that the drainage density, information relate to the amount of the development of the streams, as well as the amount of the space between the streams in the watershed. Suresh (2007) states that low drainage densities indicate a high penetration of the surface and bottom structures, as well as dense vegetation and lesser roughness, while the high value of this parameter shows a low penetration, dispersed vegetation and more rugged surface. Gives.

$$D_d = \frac{\sum_{i=1}^{i=n} L_i}{A} \qquad (3)$$

The bifurcation ratio (Rb) according to equation (4) is the ratio of the average number of streams of a class (N_a) to the number of next-order streams (N_{a+1}) in a watershed (Horton, 1932), based on which The degree of strength of the building materials of the bedrock against erosion is recognized, because the lower bifurcation ratio, Indicates the lower flow capacity of the bed digging and the formation of derivative streams and the potential for flash flooding and severe storms. In contrast, the lower bifurcation ratio indicates more resistance to erosion (Kanth &Hassan, 2012).

$$Rb = \frac{N_a}{N_{a+1}} \qquad (4)$$

The gross slope of the main stream is the ratio of the difference between the initial points at the outlet of the watershed and the highest point at the end of watershed to the horizontal distance of the two points. While the real or net slope, the tangent of the angle of the triangle is which it's area is equal to the area of the surface below longitudinal profile of the river curve and its base is equal to the overall length of the river, which is obtained according to equation (5).

$$Tan\,\alpha = b^{\frac{2s}{2}} \tag{5}$$

Which (s) is the area equal to surface below longitudinal profile of the river curve, and (b) the height of the right angel triangular that it's area is equal to the area below the longitudinal profile of the river curve and its base is equal to the overall length of the river. The mean slope of the watershed plays a major role in runoff, penetration, flood intensity and erosion. Elevation also plays an important role in the amount and type of rainfall, evapotranspiration and vegetation status of the watershed, and as a result, affect the runoff coefficient and erosion, that obtained using DEM (Figure2).

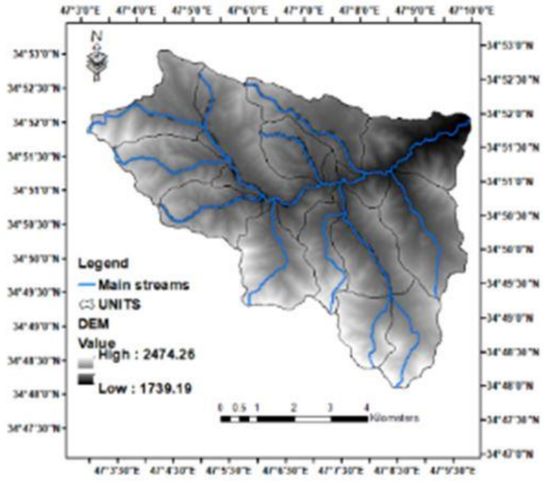

Figure 2 Digital elevation model (DEM) and main streams of Kashkamir watershed

Finally, the factor of the area, which is the most important physical factor, depends on it, the minimum, maximum, and average annual discharge, as well as the shape of the hydrograph, and its effect is influenced by the effect on runoff and sediment transport in the watershed. In order to measure the morphometric characteristics was also using of the DEM drainage network analysis and ranking the streams, by using strahler method in GIS 10.2.

3.2 Multivariate regression model

In this step, in order to investigate the relationship between the erosion rate as a dependent variable and morphometric characteristics as independent variables, the stepwise method (step by step) was used which variables with higher significance level are step-by-step introduce to the model, and this condition has been continue until the test error level reaches 5%. One of the terms of using the multivariate regression method is that there are no multiple collinearity between independed variable, in order to evaluate the multiple collinearity between variables used Variance inflation Factor (VIF), if values greater than 10 represents the probability of multiple collinearity between variables and the occurrence of a problem.

4.2 Prioritization of hydrological units

4.2.1 Sediment yield index (SYI)

An effective method for prioritizing sub-watershed is the use of the Sediment yield index(SYI) based on the effect of erosion (Naqvi et al., 2015).The effective parameters in the calculation of this index include land use, soil, vegetation and slope. In this study, using the output information from the MPSIAC model, using the sediment delivery ratio (SDR. Equation (6) presented for the calculation of the SYI index, the values of this index were calculated for each hydrological unit and then, using table (2), the priority of each hydrological unit was determined. The sediment yield index is used to prioritize sub-watersheds, even without rainfall data. The equation of this index has two main input parameters: the sediment delivery ratio (SDR) and erodibility factor calculated according to equation (6)(Kashy, 2011).

$$E = \frac{\Sigma(A_i * W_i)}{A_w} , \qquad SYI = E * SDR * 10 \qquad (6)$$

Where E: watershed erodibility, A_i: the area of each sub-watershed or hydrological unit, A_w: total watershed area, W_i: specific weight to the erosion rate in each sub-watershed or hydrological unit, SDR: Sediment Delivery Ratio and SDR, also indicator Annual sediment production. This index can be sorted as Table (2).

Table 2 Prioritize SYI values

SYI	priorization	Mark
<5	slight	G
10-5	low	F
15-10	Very low	E
20-15	mediate	D
25-20	high	C

4.2.2 CMS index

In order to prioritize the hydrological units, a morphometric analysis combined with coefficients derived from Pearson correlation were used. Thus, the impact weight (W_i) of each of the morphometric parameters was first obtained using the WSA method according to equation (7).

$$W_i = \frac{\Sigma C_i}{\Sigma T} \qquad (7)$$

Where ΣC_i is the sum of the correlation coefficient of the i-th parameter and ΣT is the sum of the coefficients of the correlation matrix. Having the impact weight for each of the parameters and entering it in the linear equation for the CMS index in accordance to equation (8) as a Weighted Linear Composite (WLC) the values for this index were obtained for each hydrologic unit in GIS.

$$\text{CMS}=W_i A_u + W_i D_d + W_i R_b + W_i S_w + W_i S_p + W_i S_n + W_i H_w \qquad (8)$$

In this equation, W_i: the impact weight for each of the parameters, and A_u: the area of each hydrological unit, D_d:dranage density, R_b : bifurcation ratio, S_w: weighted mean slope, S_p: net slope of the main stream, S_n: gross slope of the main stream and H_w: mean weighted elevation for each hydrological unit. Finally, according to the values obtained for this indicator, the hydrological units are classified for control and management measures. The greater the value of this index shows the situation is more critical for control measures.

5 Results and discussion

Table (3) shows the soil surface factor and soil erosion condition using the BLM model in Kashkamir watershed. Thus, erosion rate in sub-watershed 3 and some hydrological units in sub-watershed 1 in compared to other units are more estimated. Among the seven factors related to the BLM model, the score for the litter agent is higher than the others, which indicates a very low level of surface litter. In this case, the erosion situation is higher in the third sub-watershed. The table (4) indicate the 9th factor and the sediment yield degree of the MPSIAC model in the Kashkamir watershed. According to table (4), we also see that the C2 unit has the highest sediment yield degree, as well as among the 9th factor of the MPSIAC model, the current state of erosion in the watershed has the highest score. In table (5) sediment yield and erosion rate for each of hydrological units is presented.

Table 3. Score of soil surface factors and erosion condition using BLM model in Kashkamir watershed

Hydrological units	Soil movement	Litter	Rock cover	Degradation effects	Surface rill	Stream shape	Gully erosion	ssf	Erosion condition
A1	10	12	5	7	8	10	5	57	moderate
A2	10	12	5	8	8	10	6	59	moderate
A3	10	12	5	8	8	10	3	56	moderate
A4	9	12	4	8	9	11	7	60	moderate
NA5	11	12	4	8	9	11	6	61	high
A6	11	12	3	9	9	11	6	61	high
B1	11	13	3	10	10	12	9	68	high
B2	10	12	4	8	7	10	3	54	moderate
B3	10	12	5	8	7	10	4	56	moderate
NB4	11	12	4	9	9	12	3	60	moderate
C1	11	13	5	10	9	11	6	65	high
C2	11	12	5	12	12	12	10	74	high
NC3	11	12	5	11	11	10	5	65	high
total	10	12	4	9	9	11	6	61	high

Table 4. 9th factors and sediment yield degree of MPSIAC model in Kashkamir watershed

Hydrological units	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	SEDIMENT YIELD DEGREE
A1	3.6	4.6	3.2	5.7	14	3.9	8.3	14.2	8.2	66.06
A2	3.8	4.1	3.2	4.9	15.5	5.2	10.7	14.7	10	72.26
A3	3.8	5.2	3.2	5.2	12.2	7	12.3	14	5	69.05
A4	4.6	4.7	3.2	5.1	7.9	8.5	14	15	11.7	74.73
NA5	5.9	4.5	3.2	3.9	8.5	9.1	14.2	15.2	10	74.57
A6	4	4.8	3.2	3.9	8.6	9.9	15	15.2	10	74.83
B1	2.7	4.6	3.2	6.2	9.9	6.1	9.7	17	15	74.56
B2	2.5	4.5	3.2	6.8	10	3.7	8.1	13.5	5	59.38
B3	3.9	4.6	3.2	5.1	11.2	4.1	8.9	14	6.7	61.95
NB4	4.2	4.5	3.2	4.1	11.1	4.9	9	15	5	61.08
C1	4.5	4.5	3.2	4	8.2	9.1	14.6	16.2	10.1	74.46
C2	2.9	4.8	3.2	4	9	8.2	11.4	18.5	16.7	78.72
NC3	4.4	4.7	3.2	2.7	10.9	8.6	13.1	16.2	8.3	72.19
ALL WATERSHED	4.1	4.6	3.2	4.5	10.5	7.1	11.8	15.3	9.4	70.56

Table 5 Sediment yield and erosion rate in Kashkamir watershed

Hydrological units	Area (km^2)	specific sediment (ton/ha/yea)	Total sediment(ton/year)	SDR	Specific Erosion(ton/ha/year)	Total erosion(ton/year)
A1	4.14	2.73	1130.2	0.40	6.83	2827.6
A2	3.25	3.41	1111.1	0.42	8.18	2665.2
A3	3.49	3.04	1062.0	0.41	7.38	2519.0
A4	4.15	3.73	1547.2	0.40	9.33	3872.1
NA5	6.79	3.71	2517.4	0.37	10.11	6868.5
A6	2.28	3.74	853.6	0.44	8.43	1923.5
B1	3.21	3.71	1192.0	0.45	8.30	2669.7
B2	2.50	2.15	536.5	0.44	4.91	1228.8
B3	2.34	2.35	551.5	0.44	5.33	1248.9
NB4	4.09	2.28	933.1	0.40	5.69	2329.4
C1	3.66	3.69	1351.5	0.41	9.04	2308.8
C2	5.15	4.30	2216.8	0.38	11.19	5161.9
NC3	5.47	3.40	1861.4	0.38	8.94	4889.9
ALL WATERSHED	50.55	3.21	16.217.9	0.25	12.71	64259.1

5.1 Physiographic characteristic of hydrological units

The area is the most important geometric factor of a watershed, which different parameters including maximum, minimum and average annual discharge, as well as the shape of hydrographs and the volume runoff directly depends on it. In the Kashkamir watershed the area under the A sub-watershed has more area, and the range of the area between hydrological units varies from 2. 2 km2 to 6.7 km2, which the hydrologic unit A6 the lowest level and unit NA5 has the largest area. Table (6). Relate to the drainage density, we also see that the B1 unit has the highest level and the lowest drainage density is in the A1 unit figure (3(D)). Relate to the bifurcation ratio, we also see that the lowest ratio there is in NC3 unit and its highest level is in C1 unit, as shown in the table (6) and the order of streams show in figure 3(C). In fact, no matter how much the bifurcation ratio and drainage density is lower, it shows greater resistance and less degradation rate that in terms of drainage density the least degradation is in A1 units, and in terms of the bifurcation ratio, which is actually the ratio between actual degradation by the river and its potential from the base level is showing (Pal et al., 2012). The lowest degradation rate is in the NC3 unit. As shown in Table (6), units A2 have the highest mean weighted slope. It should be noted that in the whole sub-watershed C mean weighted slope is more that causes this sub-watershed to be erosive It is a priority and this condition has an acute condition, figure(3(B)). On this basis, the A2 unit has the highest net and gross slopes of main stream, table (6).In terms of engineering measures, priority is given to control, naturally, whatever the value of the main stream slope is higher, its erodibility will be greater for the erode of the bed and sides, especially in the upstream, which is more slope, and the flow will move more quickly and flow has been transported bed load. The highest elevation in Kashkamir watershed with an mean weighted elevation of

2268 meters upper than sea surface in the southern part and in B2 units and the lowest point in the NC3 unit with an mean weighted elevation of 1929 meters upper than sea surface In the northern part of Kashkamir watershed, figure(3(A)). The maximum average elevation difference is 339 meters upper than sea surface, Table (6).

Table 6. Physiographic characteristics divided by hydrological units

Hydrological units	**Area (km^2)**	**drainage density(km/km^2)**	**Bifurcation ratio**	**Net slope (%)**	**Gross slope (%)**	**Mean weighted slope (%)**	**Mean weighted elevation(m)**
A1	4.14	2.57	3.48	8.7	11.9	42.5	2195
A2	3.25	6.10	3.56	6.8	9.7	47.1	2127
A3	3.49	5.86	3.58	6.3	8.4	37	2150
A4	4.15	6.31	3.80	6.2	10.1	24	2144
NA5	6.79	5.99	2.87	2.4	4.1	25.7	2051
A6	2.28	6.23	2.88	8.6	10.2	26.1	2049
B1	3.21	7.39	3.50	8.6	13.7	30	2231
B2	2.50	5.96	3	11.9	18.1	33.3	2268
B3	2.34	6.75	3.11	11.5	12.9	34.2	2149
NB4	4.09	5.75	2.50	3.9	4.2	33.6	2063
C1	3.66	5.06	5.92	7.4	11.9	24.9	2058
C2	5.15	7.28	4.12	6.1	10.4	27.4	2054
NC3	5.47	5.74	2.22	3.1	3.1	33	1929
ALL WATERSHED	50.55	6.17	3.58	2.9	4.5	31.7	2098

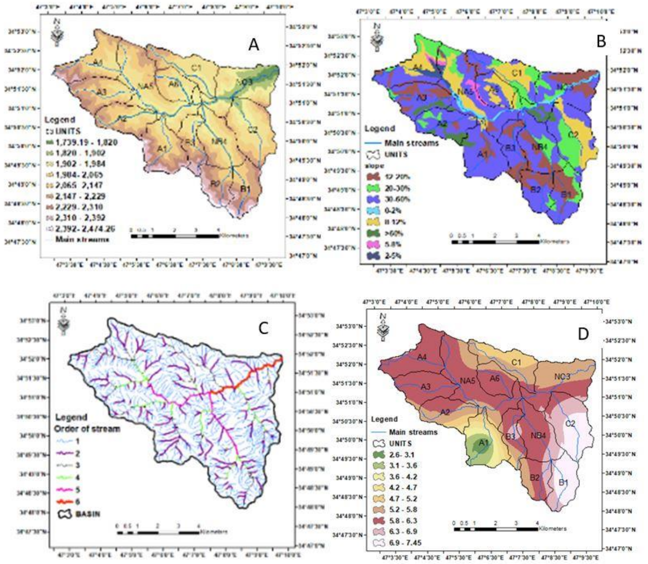

Figure 3 Elevation (A), Slope (B), order of streams (C), Drainage density (D) maps to calculate physiographic characteristics in hydrological units of Kashkamir watershed.

5.2 Correlation between variables

The results of Pearson correlation between erosion and physiographic variables showed that there is a significant correlation between erosion with physiographic variables with area and net slope of the main stream at 1% level and with the gross slope of the main stream at a level of 5%. The highest correlation is between erosion and area factor, which has a positive and strong correlation, and the low and high value of area has a significant effect on erosion, has the lowest correlation with the drainage density factor and this problem On a general scale, The area is one of the indicators that has an indirect effect on erosion, and its effect is influenced by the impact on runoff and sediment transport in the watershed. Given that the Kashkamir watershed is considered to be a small area and not a large area, we can expect more uniformity of rainstorm in the watershed, as well as the possibility of disturbance in transportation the sediment is more precipitated in the watershed with large area. In this watershed, there should normally be less evidence of this. The study area shows a relatively good resistance to erosion in terms of rock structure and geological layers. Also, the drainage density and its low correlation with the erosion factor are related to the time of concentration and drainage of watershed, because the low correlation of the drainage density with the erosion indicates the time of concentration and drainage of the area, in areas where the layer Underlying soil has less penetration, high water drainage. With high flow rate, the amount of flood discharge is much higher, the bedrock is weaker than erosion. Kashkamir watershed in terms of erosion has - resistant lithology structure, which is more due to shale, limestone and sandstone, which has a low sedimentation yield allocate. Erosion rate and sediment yield are more pronounced on alluvial deposits, which in these areas, more drainage density and bifurcation ratio allocate. The factor of drainage density and bifurcation ratio, respectively, have the highest correlation with the mean weighted slope and gross slope of the main stream. The net and gross slope of the main stream had the highest correlation respectively with the gross slope of main stream and the mean weighted elevation, which was significant at 1% level. Mean weighted slope and elevation were also the highest correlation respectively with the factor of drainage density and gross slope of the main stream, table (7).

For this purpose, we use stepwise multivariate regression method that considers the two factors of area and drainage density as independent variables that affect the erosion rate that as a dependent variable. This method provides two models for input parameters by default. In table (8) correlation coefficients relate to regression equations is observed, with the input of the area factor to the model, R^2 coefficient reaches 0.905 and with the input of the drainage density factor, the model has reached this value of 0.939. The modified R^2coefficient in model 2, it is more than 0.927, indicating that two factors affect the area and drainage density of 92.7% of the erosion and control it. Among the models presented, there is a higher efficiency model that has a higher level of R^2 coefficient and lower level of standard error. According to table (8), model 2 has a higher R^2coefficient and a lower standard error. The regression coefficients were significant in Table (9) and the proposed models were evaluated. The significance of a coefficient in the regression equation is that the independent variable can express a part of the variation of the dependent variable (Motamedi & Azari, 2018).

Table 7 Pearson correlation between erosion and physiographic characteristics

	Erosion (ton/year)	**Area (km^2)**	**drainage density($\mathrm{km}/\mathrm{km}^2$)**	**Bifurcation ratio**	**Net slope (%)**	**Gross slope (%)**	**Mean weighted slope (%)**	**Mean weighted elevation(m)**
Erosion (ton/year)	1	0.951 **	-0.090	0.108	-0.783 **	-0.629 *	-0.319	-0.534
Area (km^2)	0.951 **	1	-0.100	-0.106	-0.838 **	-0.698 **	-0.236	-0.548
drainage density($\mathrm{km}/\mathrm{km}^2$)	-0.090	-0.100	1	-0.094	0.003	0.044	-0.394	-0.053
Bifurcation ratio	0.108	-0.106	-0.094	1	0.185	0.380	-0.229	0.114
Net slope (%)	-0.783 **	-0.838 **	0.003	0.185	1	0.927 **	0.174	0.723 **
Gross slope (%)	-0.629 *	-0.698 *	0.044	0.380	0.927 **	1	0.058	0.798 **
Mean weighted slope (%)	-0.319	-0.236	-0.394	-0.229	0.174	0.058	1	0.289
Mean weighted elevation(m)	-0.534	-0.548	-0.053	0.114	0.723 **	0.798 **	0.289	1
Total	-0.296	-0.575	0.316	1.358	1.391	1.880	0.343	1.789

5.3 Regression analysis

Before writing the regression equations, we must test the H_0that the regression coefficients are equal to zero according to the t test, according to Table (9) and the regression correlation significance level for the model 2, which is the final model, It is known that 95% of these coefficients are unequal to H_0 and equal to the estimated value in table (9). At the end of the table (9) there are values of VIF (variance Inflation Factor) which, given values that are less than 10, It can be stated that there is no collinearity between the variables and these variables are suitable for determining the regression coefficients. Finally, model 2 as the final model for the sub-watersheds was selected. In morphometric analysis, we tried to use variables that include morphological characteristics, physiography and hydrology, which experience shows that when the combination of these variables is introduced into the model, the results of statistical analysis and modeling will be improved, thus, with The existence of these parameters in the correlation analysis of data introduced two factors of area and drainage density into a regression model with favorable results.

Table 8 Correlations coefficient in regression equations

Model	R	R^2	MR^2	SE
1	0.951	0.905	0.869	530.7
2	0.969	0.939	0.927	444.2

Table 9 Significant test of coefficients of regression equations

Model	Independent variable	Beta	t	Significant level (%)	VIF	Tolerance
1	Constant		-3.19	0.009		
	Area	0.951	10.22	0.000	1	1
2	Constant		-3.99	0.003		
	Area	0.970	12.39	0.000	1.01	0.990
	Drainage density	0.187	2.38	0.038	1.01	0.990

5.4 Prioritization of hydrological units

According to the equation (6), the factors needed to calculate SYI, including the area of each hydrological unit, the total area of the watershed and the sediment delivery ratio (SDR), derived from the output data from the MPSIAC model. By putting these values in the final SYI formula, the sediment values in each hydrological unit were calculated. Table (10) shows the effective parameters for the SYI and the final values for this indicator in each hydrological unit, and in finally, according to Table (2), the prioritization of each hydrological unit is determined accordingly. The higher SYI values, indicate the greater erosion rate and sediment yield, and therefore the hydrological units has a more critical situation and a higher priority. According to table (10), we see that the B1 unit is in critical condition in terms of SYI, and it is the priority of management measures of erosion and sediment control. Prioritization of hydrological units according to SYI show in figure (4). The Kashkamir watershed has a totally resistance structure and also has a much lower SDR value than other areas, and lime and sandstone structures have high percentage of the area, and more sediment yield, pay attationed to the quaternary structures and alluvial structures in the field in hydrological units. Similarly, Naqvi et al. (2015) used the Sediment yield Index (SYI) to prioritize sub-watersheds in the Nun Nadi watershed in India to identify critical areas for erosion performance. Relate to sediment yield and erosion methods, Shivhare et al. (2017) stated that these types of methods need to use data of soil erosion and sediment from hydrometric and sediment gauge stations at the outlet of each sub-watershed which access and use of this data are subject to limitations in many countries. Therefore, finding and controlling problems in this context can be considered as one of the critical issues in understanding the best complex mechanisms associated with sediment yield studies in the watershed (Adhami and Sadeghi, 2016). The disadvantages of different periodization methods such as lack of an accurate knowledge of criteria, relationship among the criteria, and complexity of these methods are the reasons for developing a new rational, objective and convenient solution to overcome these challenges (Toosi and Samani, 2017; Wu, 2018).

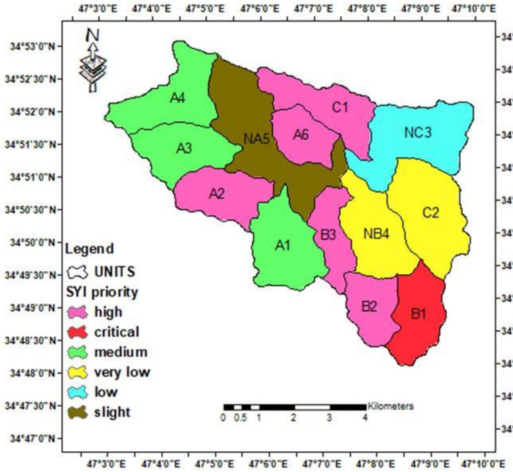

Figure 4 Prioritization of Hydrological units according to SYI in Kashkamir watershed

morphometric parameters such as area, drainage density, bifurcation ratio, net and gross slope of main stream and mean weighted of slope and elevation, using drainage network analysis and DEM of Kashkamir watershed for each hydrologic unit according to Table () in GIS. The Pearson method was used to obtain a correlation between these parameters. In the next step, we used the morphometric analysis and statistical correlation index to prioritize the hydrological units. For this purpose, we first used the Weighted sum Analysis (WSA) method to determine the impact weight (W_i) of each parameter in accordance with table (11). We brought. We observe that the average weighted elevation has the highest impact weight.

Table 10 Prioritization of hydrological units according to SYI

Hydrological units	**Area (km^2)**	**SDR**	W_t	**SYI**	**Class**
A1	4.14	0.40	5	16.3	Moderate
A2	3.25	0.42	9	24.3	High
A3	3.49	0.41	7	19.8	Moderate
A4	4.15	0.40	6	19.7	Moderate
NA5	6.79	0.37	1	4.9	Slight
A6	2.28	0.44	12	23.8	High
B1	3.21	0.45	13	37.1	Critical
B2	2.50	0.44	10	21.7	High
B3	2.34	0.44	11	22.4	High
NB4	4.09	0.40	4	12.9	very low
C1	3.66	0.41	8	23.7	High
C2	5.15	0.38	3	11.6	very low
NC3	5.47	0.38	2	8.23	Low
ALL WATERSHED	50.55	0.25			

Table 11 the impact weight (W_i) according to WSA for each morphometric parameters

Parameter	**Area** $(\mathbf{km^2})$	**drainage density(** $\mathbf{km/km^2}$**)**	**Bifurcation ratio**	**Net slope (%)**	**Gross slope (%)**	**Mean weighted slope (%)**	**Mean weighted elevation(m)**
$\mathbf{W_1}$	-0.092	0.050	0.218	0.224	0.302	0.055	0.228

In the following, using the morphometric analysis and statistical correlation, the hydrologic units prioritize according to the table (12) to carry out control measures, prevent flooding and erosion control. According to Table (12) we find that based on the indicator (CMS) whatever higher value appropriated, shows priority of that hydrological unit to carry out control measures. In this case, it became clear that the B2 unit had the highest priority and then the A2 unit was the next priority, figure (5). The basis of this method is to establish a relationship between the impact weights of morphometric parameters by WSA with morphometric parameters through the establishment of a linear relationship. The method WSA is a dynamic, effective and stable method in usual methods which is used to prioritize the watersheds which a significant or in other words, the impact weight of the parameters is considered (Malik et al., 2019). One of the benefits of the combination of morphometric analysis and statistical correlation is that the analyzes carried out are closer to reality and based on statistical methods, resulting in the errors due to theoretical comparisons of managers in prioritizing the watersheds It does not interfere, and prioritization is closer to reality (Aher et al., 2014). Kadam et al. (2019), based on the response to the erosion process in the basaltic areas of India, fourteen sub-watershed were prioritized based on the WSA ,Remote Sensing Approach and GIS, in terms of methods, The work is consistent with our research, which in fact we combine the morphometric analysis performed by the GIS with statistical correlation and WSA methods, as well as the contribution of sediment yield through the SYI , in their research, they are almost used the same approach With this difference that the morphometric indices used are different and also the amount of sediment production rate (SPR) is included in the equation, but in general the basis of the analyzes is based on morphometric characteristics, in researchs such as Said et al. (2018), Rahaman et al. (2015), Chandniha and Kansal (2017) have provided different morphometric parameters as the basis for prioritizing sub-watersheds.

Table 12 Prioritization of hydrological units according to CMS Index

Hydrological units	CMS	Priority	Hydrological units	CMS	priority
A1	8.88	5	B2	20.66	1
A2	14.17	2	B3	9.64	3
A3	7.22	10	NB4	4.91	12
A4	7	11	C1	8.29	7
NA5	3.95	13	C2	7.72	8

A6	7.63	9	NC3	8.33	6
B1	9.05	4			

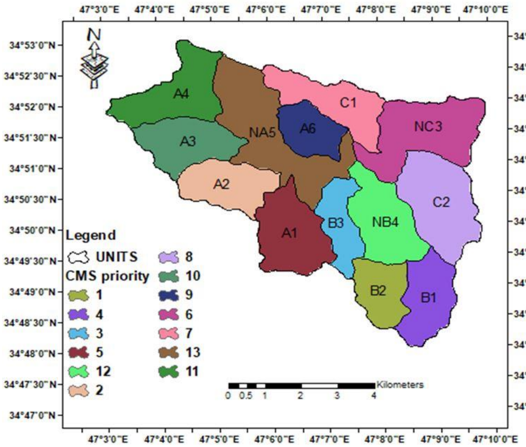

Figure 5 Prioritization of hydrological units of Kashkamir watershed according to the combined method of morphometric and statistical correlation (CMS)

Prioritizing the watersheds based on morphometric parameters is a necessary method for sustainable management of the watershed (Mohammed et al., 2018). To prioritize sub-watersheds, different techniques have been used which have weaknesses, including the number of limited parameters and the involvement of the expert opinion in weighting the parameters. In this research, the basis of prioritization of hydrological units based on the morphometric characteristics and we used the SYI and CMS indexes to prioritize sub-watersheds. Analyzes based on morphometric characteristics are always available and reliable due to the constant morphometric and physiographic characteristics of the watersheds. Therefore, it is possible to prioritize sub-watersheds on this basis (Aher et al., 2014).

Conclusion

In this study, morphometric characteristics were analyzed based on correlation analysis and stepwise multivariate regression. It was found that among the morphometric characteristics of the watershed, the area factor had the highest correlation with erosion. Kashkamir watershed does not have a high area and is in fact considered as a minor watershed, which is less associated with such things as disruption of sediment transport and sediment trapping, and is associated with more uniformity rainfall, with the largest increasing and decreasing in area had an efficiently impact on erosion. The results of the prioritization based on the SYI showed that the B1 hydrological unit has a more impact weight and higher SDR, and has a critical situation according to the SYI. Kashkamir watershed has a resistance structure in terms of erosion and does not actually high sediment yields. In continue morphometric analysis and statistical correlation method were used to prioritize the sub-watersheds. The results showed that for the CMS index, the NA5 hydrological unit is the priority of control measures, and Units NB4 and A4 are the next priorities. In the methods used, it is based more on morphometric analysis, so the results are closer to reality, and there are no theoretical comparisons between managers and the limitations of other methods. It is therefore advisable to use methods based on morphometric analysis in areas that are subject to information constraints or lacking a measurement station, since they have more stable and accessible data and can based on this, the priority was given to the watersheds. In order to carry out further research, it is recommended that the methods used for hydrologic modeling be linked to the morphometric analysis in order to prioritize sub-watersheds and be used in a hybrid method.

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