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Prioritizing areas for watershed management activities by preparing soil erosion intensity map (Case study: Safaroud River watershed, Northern Iran)

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ABSTRACT

An awareness of the state of erosion in watersheds seems to be necessary for planning and prioritizing management and conservation activities. The purpose of the present study is to prioritize areas for watershed conservation and management activities by preparing a soil erosion intensity map using a geomorphological model and the AHP technique in the Safaroud River watershed, which is located in Mazandaran Province, Northern Iran. So, criteria in the geomorphological model, such as physiographic, climatic, geological, vegetation and land use criteria were used for the erosion intensity mapping. The studied criteria were weighted using the AHP technique. The erosion facies map was prepared, and the weight of each facies for erosion incidence was calculated. By combining the raster map of each criteria weight with the raster map of the facies weight together in GIS, the raster map of erosion intensity was prepared. The results showed that the land use criterion exhibited the minimum weight (0.045), while the climatic and geological criteria the maximum (0.209). By preparing the homogeneous unit map and calculating the weighted average of the erosion intensity in each homogeneous unit, it was determined that homogeneous units No. 17, 28, 39, 29 and 14 with erosion intensity coefficients of 0.0848, 0.0663, 0.0585, 0.0571 and 0.0476, and a total area of 341.94 hectares had the highest erosion intensity in the area. Hence, these homogeneous units are prioritized for protection and management plans.

Keywords: Geomorphology model, Erosion Intensity, AHP, Safaroud River.
Article type: Research Article.

INTRODUCTION

Soil erosion is one of the most important problems of human communities following climate change (Eswaran *et al*. 2001; Lai 2001; Terranova *et al*. 2009). Thus, it can be considered as one of the most important obstacles to achieve sustainable development of agriculture and natural resources (Schwab *et al*. 1992). Awareness of erosion rate in watersheds makes it possible to identify critical areas and prioritize management and also conservation plans (Erfanian *et al*. 2014). Given the breadth of most watersheds in Iran, as well as the lack of economic and technical credits alongside economic and technical limitations of watersheds, conservation and watershed management plans are not available in all areas. Thus, in order to reduce the associated costs and enhance the performance of watershed management plans, critical areas of a watershed should first be identified and prioritized in terms of soil erosion. Prioritization is generally based on selective criteria and only on a given objective of

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watershed management, such as flooding, soil erosion, etc. (Azami Babaei *et al*. 2018; Dalir *et al.* 2021). In general, the purposes of the study of erosion and sedimentation in the detailed-executive phase of a watershed are to identify the current state, determine the extent and intensity of erosion in the study area, and precisely identify the priorities for basin conservation measures (Bayat & Rostami 2016). One of the major problems in estimating erosion is the lack of statistics, as lack of data incalculating erosion rate for many basins of the country necessitates the use of empirical methods for estimating soil erosion (Mokhtari *et al*. 2016). In general, using native models in each area based on the conditions of that area can lead to better results for identifying erosion-sensitive areas and prioritizing areas for conservation and watershed management activities. One model for estimating water erosion in Iran is the geomorphology method (Ahmadi *et al*. 2009). This method has been studied and confirmed by various investigators, including Angabini (2014) and Mohammad Khan (2009). In this model, by determining the effective criteria and indices of erosion and weighting them at a homogeneous unit level, an erosion intensity map can be prepared. Many investigators have prioritized hydrological units in watersheds. Rezaei (2017) prepared erosion risk map using AHP technique for Semnan drainage Basin, Central Iran and identified erosion-sensitive areas with a conservation priority. Rajabzadeh Saee *et al*. (2013) prepared the erosion intensity map of the Godarchai watershed in Naghadeh, West Iran using AHP technique and EPM model, identified the erosion-sensitive sub-basins, and prioritized the areas, suggesting that rock erosion sensitivity is the most important cause of sub-basin erosion. Nit Yananda *et al*. (2016) were able to map sensitivity to erosion in India with the AHP technique and the frequency ratio model, considering 16 factors affecting erosion. The investigators stated that the proposed method is able to identify areas with high erosion sensitivity to prioritize conservation plans in such areas. According to this study, comprehensive management strategies for erosion-sensitive areas can predict the current and future conditions of those areas. Rajish *et al*. (2016) identified critical focuses of water erosion using the universal soil loss equation (USLE) and AHP for erosion-affected areas in the Jomati River watershed, India. Aserat and Afera (2019) used multi-criteria decision-making systems and GIS in Ethiopia's southern Gondar area. Afera *et al*. (2018) prepared a map of erosion sensitivity using multi-criteria decision-making systems and GIS for upstream of the Nile River in Ethiopia. They stated that 1.13% of areas had high erosion risk and priority of conservation and management activities. Erosion intensity mapping using native models and new techniques can be crucial for decision-makers and planners working in the field of soil conservation in Iran, since erosion intensity mapping can identify critical and priority areas for soil conservation and watershed management activities. Accordingly, in the present study, using the geomorphological model and the AHP technique, the soil erosion intensity map of the Safaroud River watershed (in Mazandaran Province, Northern Iran) was prepared. This method evaluated the state of different areas in the region in terms of erosion, as well as highly sensitive and critical homogeneous units for specific conservation activities.

MATERIALS AND METHODS

Study area

The Safaroud River watershed with an area of 13551 hectares is located in the geographical range of 50° 24' 53" to 50° 37' 56" east longitude and 36° 48' 35" to 36° 55' 16" north latitude, Western Mazandaran Province, Northern Iran. This basin, which is one of the upstream watersheds to Ramsar City, has 9500 hectares of forests and 4051 hectares of rangelands (Fig1).

Method

In the present study, in order to determine the priority areas for watershed management activities in the Safaroud River watershed, the erosion intensity map was prepared using AHP and GIS techniques via geomorphological method. So, the layers of information used in the geomorphology model were provided for erosion intensity mapping followed by preparing the erosion intensity map in each homogeneous unit. By comparing the erosion intensity in homogeneous units and their differences from the average weight of the erosion intensity in the area, sensitive and critical homogeneous units were identified.

Preparation of information layer for erosion intensity map by geomorphology method

In the present study, the following criteria and indices were used in order to prepare the erosion intensity map through a geomorphology model: physiographic criteria (slope and aspect indices), climatic criteria (precipitation and its form indices), soil criteria (soil texture and infiltration indices), vegetation criteria (indices of vegetation coverage percentage and generation form), geology criteria, land use criteria, and the intensity of utilization.

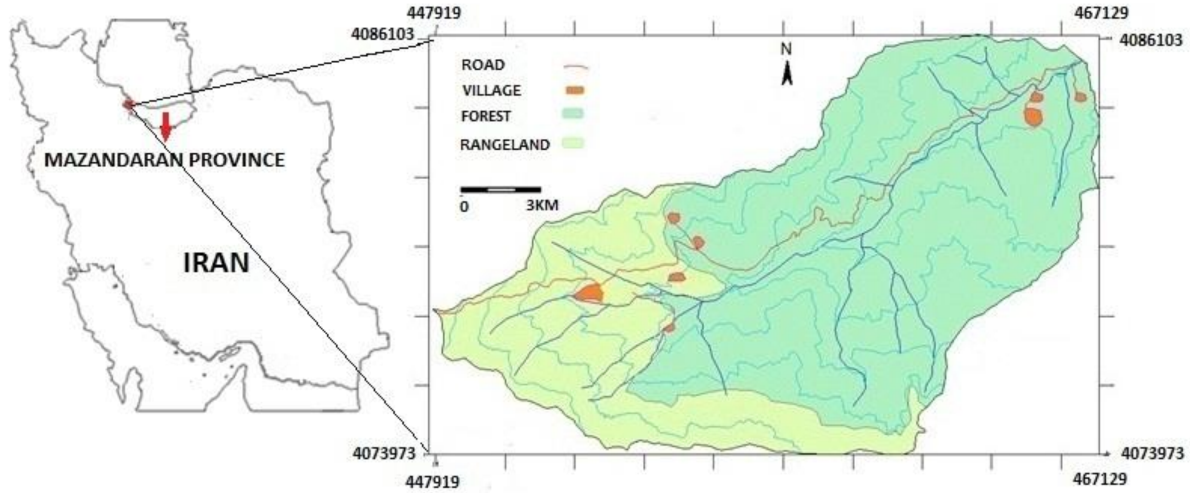

Fig. 1. Geographical location map of the study area.

Preparation of physiographic criterion information layer

In this study, the physiographic criteria of slope and aspect indices were studied. In order to prepare these information layers, digital elevation model (DEM) was used.

Preparation of climatic criteria information layer

Among the climatic indices used in the geomorphology model, the precipitation rate and form indices were used in this study. Ramsar weather station and stations within watershed (Mianlat and Javaherdeh) data were used to prepare precipitation index information layer and regional precipitation regression (Eq. 1).

$$Y=-0.155X+1163 \quad \textbf{(1)}$$

By applying the digital elevation map of the area instead of the independent variable **x** in the above equation, the dependent variable **y** was prepared as precipitation raster map.

The study area has two precipitation forms of snow and rain. Due to incomplete temperature data in the region, according to the opinion of experts, a 2700-meters line was considered as a snow line (Kavyani & Alijani 2010).

Preparation of geological criterion information layer

In order to prepare this information layer, a geological map of Ramsar and Javaherdeh sheets on $\frac{1}{100/000}$ scale prepared by Geological Survey of Iran was used.

Preparation of soil criterion information layer

Among the soil criterion indices in the geomorphologic model, the soil texture and infiltration indices were studied based on available data. The soil texture map was extracted from available data of soil reports and maps. We used the raster map of soil texture and permeability related to different soil texture types presented in different references in order to prepare this information layer (Mahdavi 2010).

Vegetation criterion information layer

In this study, vegetation coverage percentage and generation form indices of vegetation criterion were studied in the geomorphological model. For this purpose, at first, the forest and rangeland vegetation coverage percentage map was prepared separately through analysis of satellite images (Land sat 8). This study used bands, vegetation indices, and image integration through HIS color space conversion command to use and compare the data obtained from the classification process. The map of vegetation form (tree, shrub and rangeland) was also extracted using vegetation coverage percentage map and visual interpretation of satellite data.

Preparation of information layer for criteria of land use type and intensity of utilization

In order to prepare the land use information layer, the false color composite (FCC) images were first obtained from satellite images. On these images, different land use was made through a specific visual interpretation and the vector map. This map was modified by field survey. Then, the forest percentage map was used to determine the intensity of forest utilization, where areas with vegetation less than 30% were destructed forest, 30-75% were semi-destructed, and over 75% were good. In order to prepare the map of rangeland utilization intensity, the rangeland type map of the area was first reviewed through a field survey. Thereafter, using the modified map of rangeland type when sampling for vegetation cover percentage, in a plot of 10 plots in each sampling unit, we scored the factors for the rangeland state by a four-factor method including parameters of vegetation state (composition and production) and soil state (land vegetation and erosion state), determined the rangeland state in each type. Finally, we used the criteria of land use type and intensity of utilization in the information layer. By integrating maps of rangelands and forests with the land use maps produced from the false-color images, the final land use and the utilization intensity maps were prepared.

Preparation of information layer of erosion facies

In order to prepare the map of erosion facies, initially false color composite images of different types of facies were identified and the facies vector map was prepared. This map was according to topographic map on $\frac{1}{50/000}$ scale. Then, by field survey and the necessary corrections, the final map of erosion facies was prepared. At the next stage, we determined the weight of each erosion facies through completing the questionnaire by experts.

Weighing criteria and indices used in this study

After preparing the information layers used in this study, the erosion intensity map was prepared via geomorphological method using AHP weighting technique where information layer weighting indices and criteria were prepared by performing the following stages.

Hierarchical development

In AHP, which is practically a graphical representation of real complex problems, at the top lies the main purpose of the problem followed by the criteria, indices, and options. There is basically no fixed rule for drawing hierarchies (Strojny & Hejman 2016; Mohammadi Samani *et al*. 2010). In this study, the aim of the first level is to prepare the erosion intensity map. At the second level, we have the geomorphological facies. At the third level we have criteria examined in this study including the physiography, climatic, geology, soil, vegetation, and land use. At the fourth level we have the tested indices; and at the last level, the options for each index. After drawing the hierarchies, weighting is typically from low to high levels. Thus, first the weight of the options, and then the weight of the indices and finally the weight of the criteria were calculated. The facies were weighted separately because of their importance. In order to the relative preferences of options were specified and their pair-wise comparison matrices were completed through the application of AHP technique, based on the ratio of area under erosion to total area for each option and Equation 2. In the next stage, EXPERT CHOICE was used to calculate the relative weight of each option.

$P = \Delta A \times 0.08 + 1$ (Mohammad Khan 2009) **(2)**

where P: The option preferences used in the pair wise comparison matrix, ΔA: The percentage difference of the area of erosion in each option compared to the other. Options were weighted using approximate weighting and mathematical average methods (Ishizaka & Labib 2011).

For assigning weights to the indices, the erosion-prone options were specified in each index. Then, the ratio of the erosion-prone area in a region where erosion had occurred, to total area of erosion facies, was calculated. Finally, a table was completed for preference of each index, and the weight of each index was calculated. In order to assign weights to the criteria, the corresponding indices to each criterion with the highest percentage of erosion area in the previous stage were selected as the dominant indices. These were then used to complete the pair-wise comparison matrix of criteria, and to finally calculate the weight of each criterion. The combined weight of options was calculated by multiplying the weight of each category by its higher category. Then, the sum of the weights for options of each index was calculated, while the weight of each criterion was calculated by the sum of weights for indices of that criterion. Fig. 2 depicts the hierarchical development stages of this study.

Preparation of raster map of information layers in GIS

After weighting the layers of information used in this study in Expert Choice software, the raster map of the weight of these layers was prepared in software ArcGis and combined with each other to create the erosion intensity raster map.

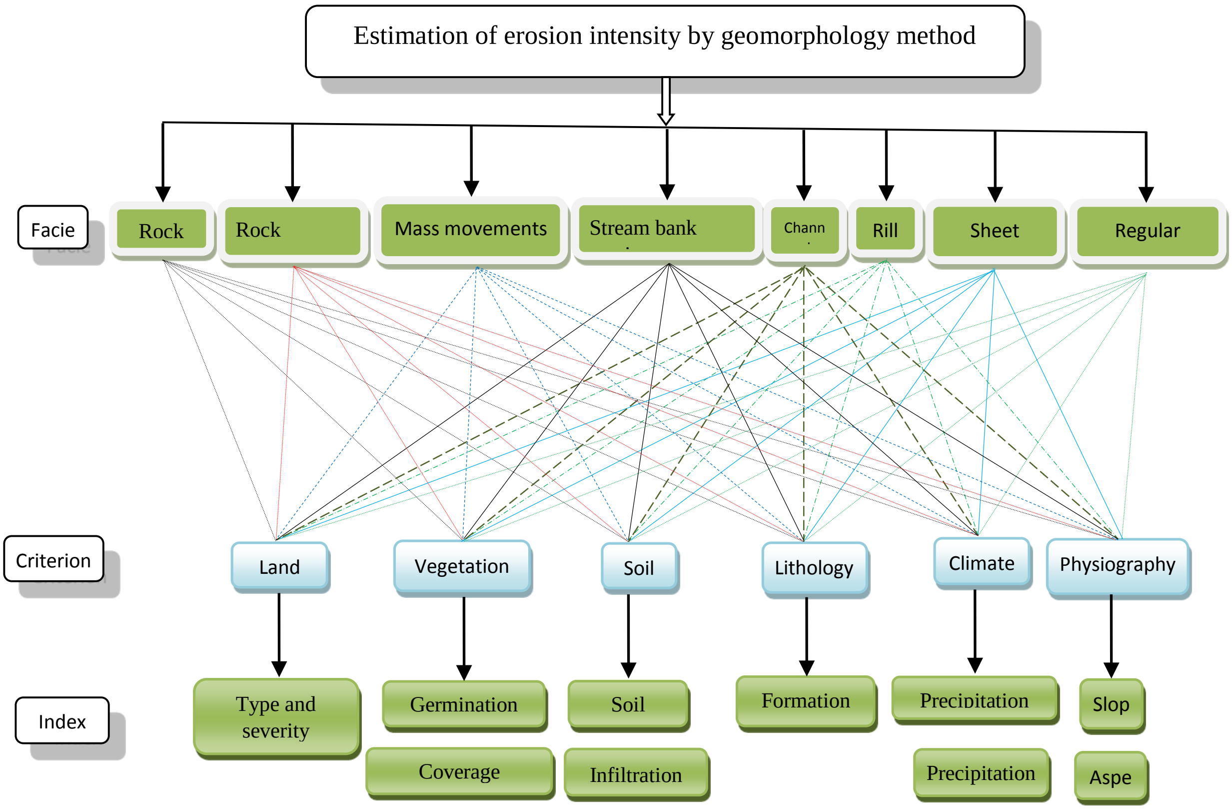

Fig. 2. Hierarchical development stages of the research.

The homogeneous unit map

Using geology maps, geomorphological facies, slope, and aspect, the maps of homogeneous areas were prepared in 39 homogeneous units. After preparing the erosion intensity raster map and the homogeneous unit map, the average weight of erosion intensity in each unit was calculated with the erosion intensity map prepared in each homogeneous unit. By calculating the average weight of erosion intensity in the entire area and average weight of erosion intensity in each homogeneous unit, those with erosion coefficients higher than average were determined.

RESULTS

Information layers used to prepare the erosion intensity map via the geomorphology method

In this study, the layers of information required to map the intensity of erosion were initially prepared through a geomorphological model. Fig. 3 reveals the maps of slope, aspect, precipitation rate, precipitation form, vegetation cover percentage, soil texture, soil infiltration, geology, land use, and erosion facies.

Relative weighting options

In order to determine the weight of each option, the index map with different options was first overlaid with the erosion facies map. Then, the percentage of the area of each of the options lying within the range of erosion facies was obtained to the whole area was the same option. According to the percentage of erosion areas for each option and Eq. 2 the weight for each option was calculated.

Relative weighting to indices

In order to form a matrix of preference for indices, the options included among the erosion-prone options were first determined. Afterward, the percentage of the area of eroded parts for these options was calculated relative to the total area of eroded parts. In this manner, by calculating this percentage and using Equation 2, the preference table of indices was completed, and the weight of each index was then calculated.

Relative weighting criteria

At this stage, criteria binary matrices were formulated, and based on the preference table of indices for eroded areas, the index with the highest percentage of eroded areas was considered to be the representative of that criterion. Thereafter, using Eq. 2, the preference table of the criteria was completed, and the weight of each criterion was calculated. Table 1 reports the relative weight of options, indices, and criteria.

Calculation of the final and combined weights of criteria and indices

To calculate the final and combined weights of the options, the relative weight of each option was multiplied by the relative weight of the category above it. The final and combined weights of each index were obtained from the sum of the combined weights of all options of those indices. Meanwhile, the combined weight of each criterion was obtained from the sum of the combined weight of the indices of the criteria using Equations 3 to 5. Table 2 summarizes the final and combined weights of the studied criteria, indices, and options.

$$W_O = W_1 \times W_2 \times W_3 \quad \textbf{(3)}$$

W_O: Final weight of options, W_1 : Relative weight of options, W_2 : Relative weight of indices W_3 : Relative weight of criteria

$$W_{\mathrm{I}} = \sum_{i=1}^{\mathrm{n}} \mathrm{W_O} \quad \textbf{(4)}$$

W_I: Final weight of indices, W_O : Final weight of options

$$W_{\mathrm{C}} = \sum_{i=1}^{\mathrm{n}} \mathrm{W_I} \quad \textbf{(5)}$$

W_C: Final weight of criteria, W_I: Final weight of indices

Calculation of the inconsistency ratio

Inconsistency ratio (IR) specifies consistency and shows the extent to which comparative priorities can be trusted. Experience has shown that if the inconsistency ratio is less than 0.10, the consistency of the comparisons is acceptable; otherwise, the comparisons should be revised (Alonso & Lamata 2006). In this study, the inconsistency ratio of the indices and criteria was calculated and was lower than 0.10.

Preparation of information layers for thefinal weights of options

After determining the final weight of each option, raster map was prepared for each option. At this stage, by executing the code reclassification command, each option was changed to its final weight.

Determination of relative preference of facies to erosion

To form the paired matrix of erosion facies, we used a questionnaire in which experts were asked to indicate their opinions on the importance of erosion facies in the erosion intensity (responses were given on scales ranging from 1 to 9). A total of 11 questionnaires were completed. The pair-wise comparison matrix of facies was formed by a mathematical method, and the weight of facies was determined. Table 3 provides the relative weight of erosion facies. Through there-coding and relative weighting of each facies to the corresponding code for that facies in GIS, the erosion facies raster map was prepared.

Preparation of erosion intensity map

Equation 6 was used to prepare the erosion intensity map (Mohammad Khan *et al*. 2015).

$$GM = [(WT + WC + WG + WS + WV + WL) \times WF] \quad \textbf{(6)}$$

Where *GM*: Erosion intensity and actually a dimensionless coefficient and number, *WT*: Topographic criterion final weight, *WC*: Climate criterion final weight, *WG*: Geological criterion final weight, *WS*: Soil criterion final weight, *WV*: Vegetation criterion final weight, *WL*: Functional criterion final weight, *WF*: Relative weight or preference of erosion facies.

By applying the above equation in GIS and combining the raster layers with the final weight of criteria together, the raster map of erosion intensity was prepared. Fig. 4 indicates the raster map of erosion intensity.

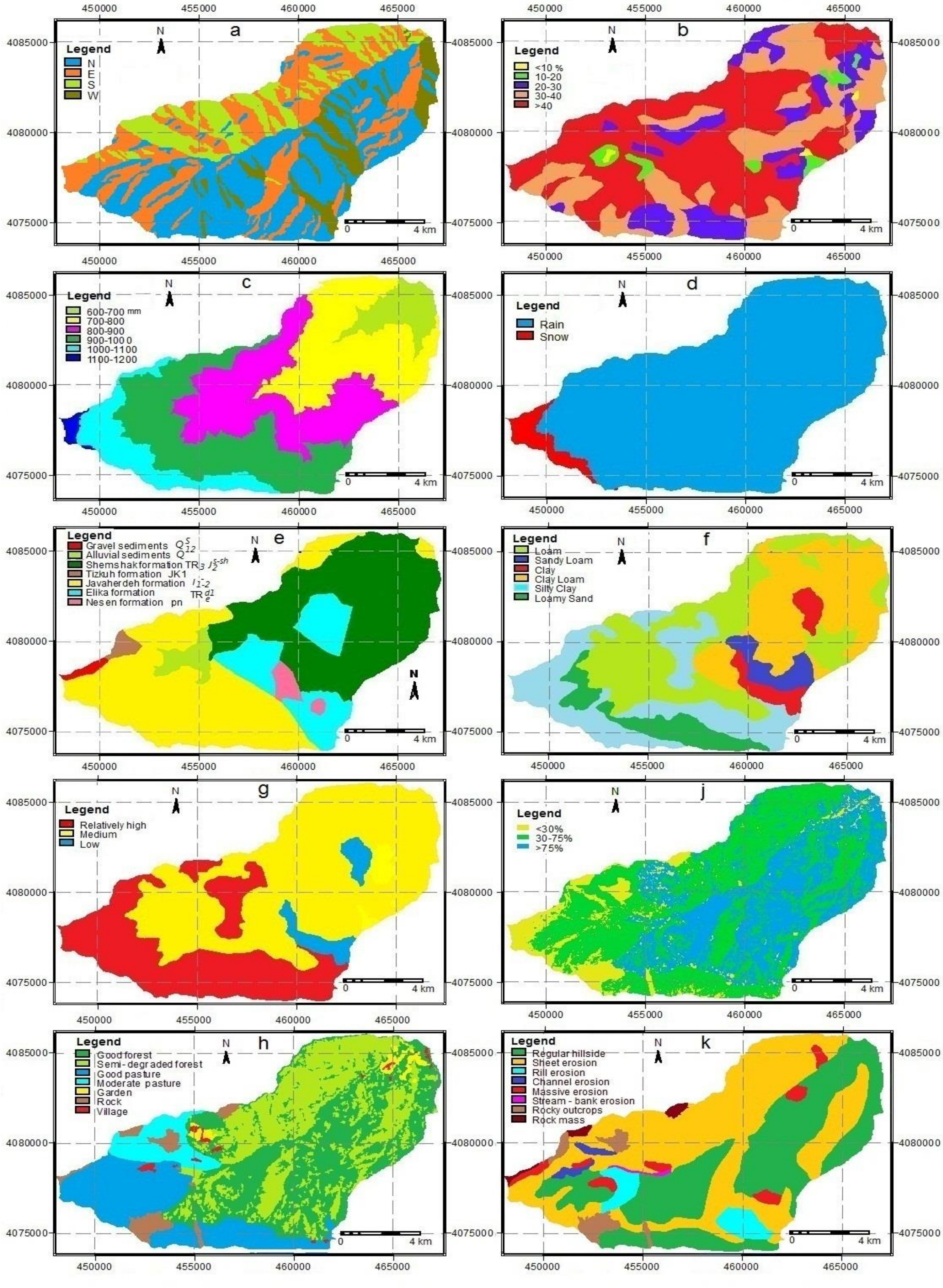

Fig. 3. Map of the Safaroud River watershed showing **(a)** aspect, **(b)** slope, **(c)** precipitation, **(d)** precipitation form, **(e)** geology, **(f)** soil texture, **(g)** intensity of soil infiltration, **(j)** coverage percentage, **(h)** land use and **(k)** erosion facies.

Table 1. Relative weight of the criteria, indices, and options examined in this study.

weight	Options	Index	Criterion	weight	Options	Index	Criterion
0.518	<10	Slope 0.784	Topography 0.26	0.358	Loam	0.5 Soil texture	Soil 0.066
0.093	10-20			0.248	Loam-Sandy		
0.093	20-30			0.141	Clay Loam		
0.093	30-40			0.126	Clay		
0.203	>40			0.053	Silty Clay		
0.103	N	Aspect 0.216		0.073	Loamy Sand		
0.389	E			0.35	Relatively high	Infiltration 0.5	
0.456	S			0.453	Moderate		
0.05	W			0.197	low		
0.374	600-700	Precipitation 0.697	Climate 0.269	0.222	Tree	Germination form 0.216	Vegetation 0.089
0.078	700-800			0.513	Shrub		
0.167	800-900			0.265	Grass		
0.186	900-1000			0.259	< 30	Coverage percentage 0.784	
0.148	1000-1100			0.601	30-75		
0.048	1100-1200			0.14	> 75		
0.254	Rain	Precipitation form 0.303		0.064	good forest	Type and severity of exploitation 1	Land use 0.046
0.746	Snow			0.229	semi- degraded forest		
0.129	Q2	Formation type 1	Geology 0.269	0.111	Good pasture		
0.308	Qs			0.371	Moderate pasture		
0.062	Tizkooh			0.15	village		
0.063	Javaherdeh			0.051	garden		
0.082	Shemshak			0.024	rock		
0.078	Elika						
0.279	Nesen						

Table 2. Final and combined weight of the studied criteria, indices, and options.

weight	Options	Index	Criterion	weight	Options	Index	Criterion
0. 1	<10	Slope 0.2	Topography 0.256	0.012	Loam	Soil texture 0.034	Soil 0.066
0.02	10-20			0.008	Loam-Sandy		
0.02	20-30			0.005	Clay Loam		
0.02	30-40			0.004	Clay		
0.04	>40			0.002	Silty Clay		
0.006	N	Aspect 0.056		0.003	Loamy Sand		
0.022	E			0.011	Relatively high	Infiltration 0.032	
0.025	S			0.015	Moderate		
0.003	W			0.006	low		
0009	600-700	Precipitation 0.189	Climate 0.269	0.004	Tree	Germination form 0.019	Vegetation 0.089
0.03	700-800			0.01	Shrub		
0.035	800-900			0.005	Grass		
0.03	900-1000			0.018	< 30	Coverae percentage 0.07	
0.015	1000-1100			0.042	30-75		
0.07	1100-1200			0.01	> 75		
0.02	Rain	Precipitation form 0.08		0.003	good forest	Type and severity of exploitation 0.045	Land use 0.045
0.06	Snow			0.01	semi- degraded forest		
0.035	Q2	Formation type 0.269	Geology 0.269	0.005	Good pasture		
0.083	Qs			0.017	Moderate pasture		
0.017	Tizkooh			0.007	village		
0.017	Javaherdeh			0.002	garden		
0.022	Shemshak			0.001	rock		
0.02	Elika						
0.075	Nesen						

Table 3. Relative weight of facies.

Facies	Regular hillside	Sheet erosion	Rill erosion	channel erosion	Massive erosion	Stream – bank erosion	Rocky outcrops	Rock mass
weight	0.03	0.063	0.087	0.221	0.388	0.129	0.05	0.028

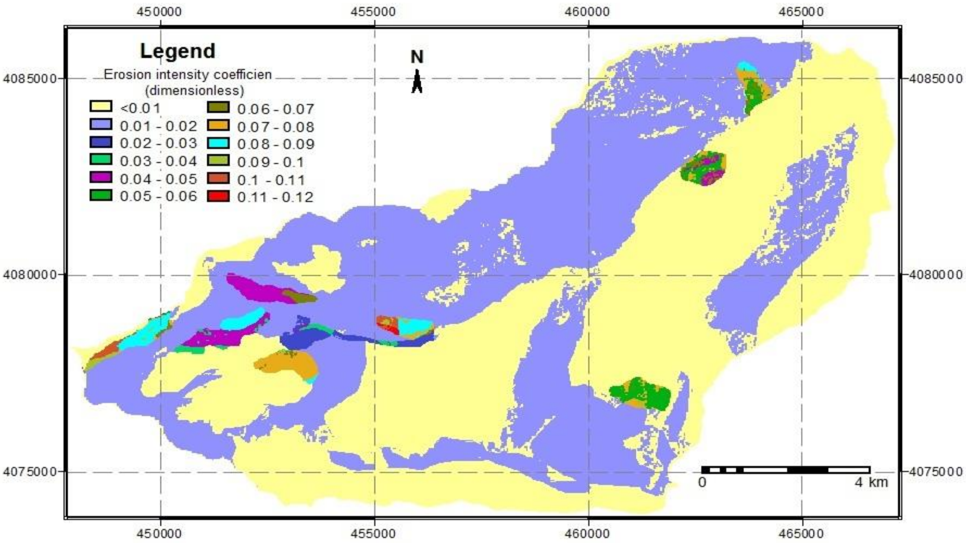

Fig. 4. Erosion intensity map of the study area.

Preparation of erosion intensity map foreach homogeneous unit

According to the erosion intensity raster map and the homogeneous unit map, the erosion intensity map was prepared for each homogeneous unit. The intensity of erosion was calculated as the average weight per homogeneous unit. Fig. 5 reveals the erosion intensity map for each homogeneous unit, and Fig. 6 depicts the changes in erosion intensity for each homogeneous unit.

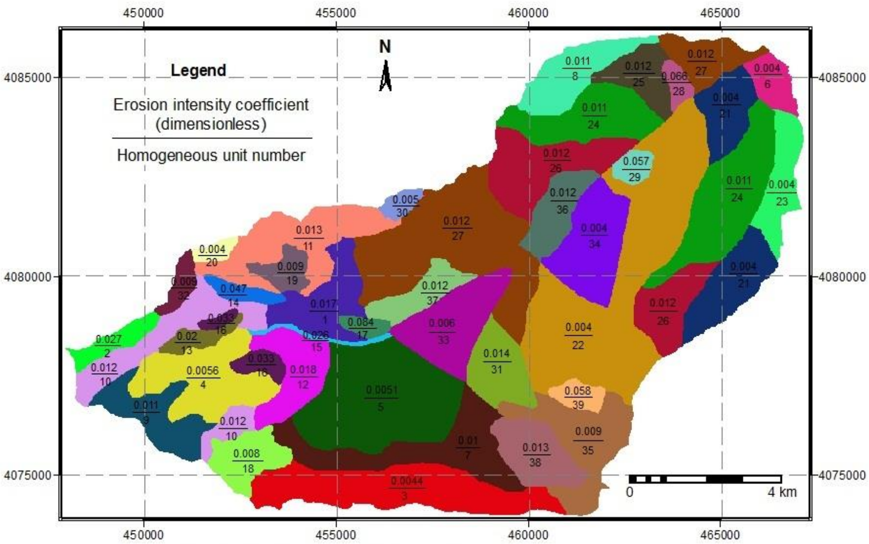

Fig. 5. Erosion intensity map in each homogeneous unit.

According to the difference between the information provided in the erosion intensity map and the average weight of erosion intensity for the entire study area (0.01094), the erosion intensity state of each unit relative to the average was determined. Table 4 depicts the erosion intensity coefficient for each homogeneous unit, and Fig. 7 presents the changes in these coefficients with respect to the total average.

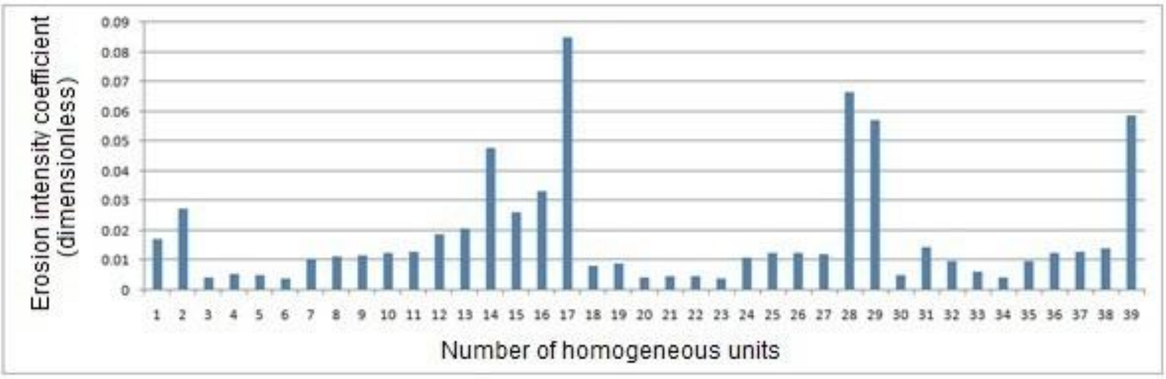

Fig. 6. Erosion intensity changes per homogeneous unit.

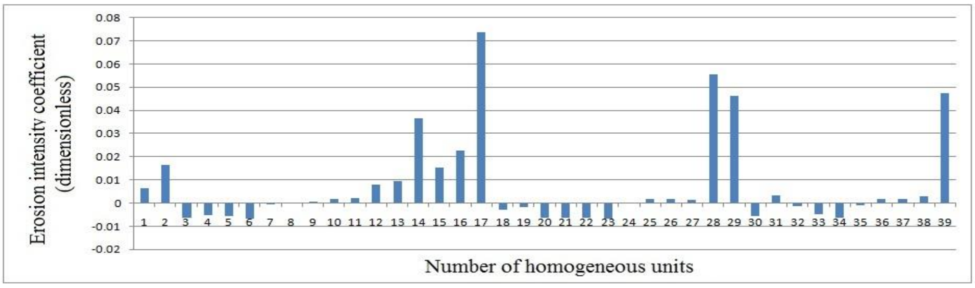

Fig. 7. Erosion intensity changes per homogeneous unit from the average.

Table 4. Erosion intensity coefficient per homogeneous unit.

Homogeneous unit number	Area- ha	Erosion intensity coefficient	Difference erosion intensity coefficient with mean	Homogeneous unit number	Area- ha	Erosion intensity coefficient	Difference erosion intensity coefficient with mean
1	321.07	0.01719	0.00625	21	633.53	0.00456	-0.00638
2	111.83	0.02753	0.01659	22	1428.78	0.0046	-0.00634
3	694.28	0.0044	-0.00654	23	133.97	0.00409	-0.00685
4	482.23	0.oo564	-0.0053	24	957.79	0.01104	0.000105
5	896.96	0.00513	-0.00581	25	198.7	0.01256	0.00162
6	117.79	0.00408	-0.00686	26	684.39	0.0127	0.00176
7	528.24	0.0105	-0.00044	27	1131.18	0.0123	0.00136
8	299.46	0.01123	0.00029	28	59.09	0.06638	0.05544
9	297.48	0.01166	0.00072	29	70.8	0.05712	0.04618
10	432.35	0.01268	0.00174	30	57.03	0.00512	-0.00582
11	499.82	0.0129	0.00196	31	264.9	0.01431	0.00337
12	289.23	0.01885	0.00791	32	79.15	0.0096	-0.00134
13	84.6	0.02058	0.00964	33	404.8	0.00608	-0.00486
14	75.18	0.04763	0.03669	34	416.03	0.0044	-0.00654
15	41.05	0.02614	0.0152	35	438.12	0.0098	-0.00114
16	104.81	0.03342	0.02248	36	220.72	0.01252	0.00158
17	54.55	0.08484	0.0739	37	178.8	0.01279	0.00185
18	220.72	0.00803	-0.00291	38	284.33	0.01397	0.00303
19	110.09	0.00909	-0.00185	39	82.32	0.05856	0.04762
20	46.67	0.00435	-0.00659				

DISCUSSION AND CONCLUSION

According to the results, the land use criterion exhibited the lowest weight (.045), while, the climatic and geological criteria the highest (0.269), followed by the topographic criterion (0.256). Accordingly, it was found that the most important factors of erosion in the area include the three factors of climate, geology and topography, which affect the erosion of the area almost equally. Given that these three factors are somewhat out of our control and given that we cannot make much of a difference, we should pay attention to other factors. Feyznia & Zare Khosh Eghbal (2003) emphasised the three factors of climate, geology, and slope, while Nasiri (2013) mentioned a geological factor and vegetation; Rajabzadeh Saee *et al*. (2013) noted the formation sensitivity factor; Jorge (2009) reported soil slope and soil texture factors; Bathrellos & Skilodimou (2007) referred to atopography factor; and Sameh *et al*. (2015) stated climate as the most important factors in the erosion of their respective study areas. The homogeneous units of 17, 28, 39, 29, and 14 exhibited erosion coefficients of 0.084840, 0.066380, 0.058560, 0.057120 and 0.047630, respectively. Also, the total area of 341.94 hectares displayed the highest erosion intensity in the area. The profile of these units is given in Table 5.

Table 5. Profile of units with the highest erosion coefficient.

Homogeneous unit number	Formation type	Erosion facies	Slope %	Aspect	Land use	Area-ha	Erosion coefficient
17	Javaherdeh	Massive erosion	>40	s	Mostly semi-destructed forest	54.55	0.08484
28	Shemahak	Massive erosion	30-40	s	Mostly semi-destructed forest	59.09	0.06638
39	Elika	Massive erosion	>40	n	Mostly semi-destructed forest	82.32	0.05856
29	Shemahak	Massive erosion	>40	n	Good and semi-destructed forest	70.8	0.05712
14	Javaherdeh	channel erosion	>40	s	Medium rangeland	75.18	0.04763

All of these areas exhibited erosion-sensitive formations and erosion facies of mass movements, as well as channel erosion. Mass movements erosion with weight of 0.388 and channel erosion with weight of 0.221 displayed the highest weight, respectively. Regarding the climatic and edaphic conditions of the area, mass movements are among the most important natural hazards of the Safaroud River watershed and have been studied by various authors, such as Eshaghi *et al*. (2010) and Jokar Sarhangi *et al*. (2010). These homogeneous units are located close to the road, by considering it as the most important factor in mass movements in the study area. Hence, construction activities, such as road construction (without observing environmental principles) can be one of the most important causes of erosion in the area. Sidle (2010) and Zemke (2016) identified road construction as an effective parameter in producing runoff and erosion in their study areas. None of the homogeneous units with the highest erosion coefficients lay within the range of destructed forest areas and/or poor rangelands. The results related to the weights of the criteria also indicated that the land use criterion (which had a weight of .045) exhibited the weakest effect on erosion incidence in the region. The most important erosion facies affecting the erosion coefficient in this study was mass movements. Meanwhile, according to the results obtained by Eshaghi *et al*. (2010) in the study area, land use did not play a decisive role in the occurrence of mass movements in the area, which is consistent with our study results, as well as identification of the minimum weight and effect of the land use criterion on erosion. The correct estimation of erosion and the correct identification of erosion-sensitive areas play important roles in improving land management recommendations and erosion control via different methods (Mokhtari *et al*. 2016). Although mapping erosion facies can partially identify eroded critical areas, it is very important to identify all eroded areas and/or priority homogeneous units. By preparing a quantitative map of erosion intensity for each area, priority areas for conservation activities can be identified. In the Safaroud River watershed, homogeneous units No. 17, 28, 39, 29, and 14 exhibit the highest erosion intensity in the area. Hence, these homogeneous units are a priority for any soil conservation and watershed management activities. The dominant erosion facies in these areas are mass movements. Thus, the most important conservation and watershed management activities in the area should be in line with mass erosion control.

REFERENCES

Afera, H, Aserat, T, Ermias, S & Mihret, D 2018, Erosion sensitivity mapping using GIS and multi-criteria decision approach in Rib Watershed upper Blue Nile, Ethiopia, *International Journal Of Energy And Environmental Science*, 6: 99-111.

Ahmadi, H, Maleki, M, Jafari, M, Ghodusi, J, Azarnivand, H & Mosayebi, M 2009, Quantification of qualitative geomorphology method for water erosion estimation (case study: three sub-watersheds of Latian Dam basin), *Iranian Journal of Natural Resources*, 61: 775-795.

Alemi Safaval, P, Kheirkhah Zarkesh, M, Neshaei, SA & Ejlali, F 2018, Morphological changes in the southern coasts of the Caspian Sea using remote sensing and GIS. *Caspian Journal of Environmental Sciences*, 16: 271-285.

Alonso, JA & Lamata, MT 2006, Consistency in the analytic hierarchy process: A new approach, *International Journal of Uncertainty, Fuzziness and Knowledge-Based Systems*, 14: 445-459.

Angabini, S 2014, A new model of regional erosion and sediment at Jegin Watershed by comparing experimental models, geomorphology and intelligent systems (fuzzy logic, neural network), PhD Dissertation, Science and Research Branch of tehran, Iran, 250 p.

Aserat, T & Afera, H 2019, Mapping of soil erosion hotspot areas using GIS based–MCDA techniques in South Gondar Zone, Amhara Region, Ethiopia. *Word News of Natural Sciences, an International Scientific Journal WNOFNS*, 24: 216-239.

Azami Babaei, B, Mumipour, M & azari, A 2018, Prioritization flood risk of hydrologic units (Case study: Pole Shah Catchment). *Geography and Development Iranian Journal*, 53: 69-84.

Bathrellos, G & Skilodimou, H 2007, Using the analytic hierarchy process to create an erosion risk map — Case study in Malakasiotiko Stream, Trikala Prefecture. *Bulletin of the Geological Society of Greece*, 40: 1904-1915.

Bayat, R & Rostami, M 2016, Assessment of soil erosion and watershed prioritization using empirical models EPM and MPSIAC (Case Study: Aro watershed), 1: 19-32.

Dalir, P, Naghdi, R, Gholami, V 2021, Assessing the rice straw effects on the soil erosion rate in forest road cut slope embankments. *Caspian Journal of Environmental Sciences*, 19: 325-339.

Erfanian, M, Ghahramani, P & Saadat, H 2014, Mapping of Potential Soil Erosion Hazard using Fuzzy Logic in Gharnave Waetershed, Golestan Province, *Iranian Journal of Watershed Management Science and Engineering*. 23: 43-52.

Eshaghi, A, Motamedvaziri, B & Feiznia, S 2010, Landslides Hazard Zonation Using Logistic Regression Method (Case Study: Safaroud Watershed), territory, 6: 67-77.

Eswaran, H, Lai, R & Reich, P 2001, Land degradation: An overview in: Bridge Em, Hannam Id, Oldeman Lr, Penning de Vries Ewt, Scherr Sj, Sombatpanit S (eds.) Response to land degradation, *Science Enfield*, 4: 20-35.

Feyznia, S & Zare Khosh Eghbal, M 2003, Investigation of geological formation sensitivity to erosion and sediment production in Latian Watershed. *Iranian Journal of Natural Resources*, 4: 365-381.

Ishizaka, A & Labib, A 2011, Review of the main developments in the analytic hierarchy process. *Expert Systems with Applications*, 38: 14336-14345.

Jokar SarhangiI, A, Amir Ahmadi, A & Salmaliyan, H 2010, Landslide hazard zonation in Safaroud watershed using GIS, *Journal of Geography and Regional Development*, 5: 79-93.

Jorge, LAB 2009, Soil Erosion Fragility Assessment Using an Impact Model and Geographic Information System. *Sciatica Agricola*, 66: 658-666.

Kavyani, MR & Alijani, B 2010, The Foundations of climatology, 16th Ed, Samt Publication, Tehran, Iran, pp. 257-259.

Lai, R 2001, Soil Degradation By Erosion, Land Degrad Dev, 12: 519-539.

Mahdavi, M 2010, Applied Hydrology, 7th Ed, Vol: 2, Tehran, Iran, pp. 149-150.

Mohammad Khan, SH 2009, Quantitative estimation of erosion and sediment through GIS; case study of Latian Watershed, PhD Dissertation, University of Tehran, Iran, 190p.

Mohammad Khan, SH, Ahmadi, H, Jafari, M, Feizenia, S, Salajagheh, A & Aznarvand, H 2015, Quantitative geomorphology modeling using hierarchical systems analysis (Case study: Latian Watershed', *Watershed Management Researches Journal*, 28: 92-110.

Mohammadi Samani, k, Hosseiny, S, A, Lotfalian, M & Najafi, A 2010, Planning road network in mountain forests using GIS and Analytic Hierarchical Process (AHP), *Caspian Journal of Environmental Sciences*, 8: 151-162.

Mokhtari, D, Mohammazadeh Golani, F, Nikjoo, M & Asghari, S 2016, Estimates of Erosion Sediment of Gavi River Catchment Using Mpsiac Method in GIS Environment, *Hydrogeomorphology*, 6: 1-16.

Nasiri, M 2013, GIS modelling for locating the risk zone of soil erosion in a deciduous forest, Journal of Forest Science, 59: 87-91.

Nit Yananda, S, Ansar, K, Soumendu, Ch, Arosikha, D & Bijay, SM 2016, Coupling of analytical hierarchy process and frequency ratio based spatial prediction of soil erosion susceptibility in Keleghai River Basin, India, *International Soil and Water Conservation Research*, 4: 1-21.

Rajabzadeh Saee, HR, Ahmadi, H & Aghazadeh, N 2013, Preparation of AHP erosion susceptibility map and estimation of sedimentation rate of Goddacha basin in Naghadeh using EPM model, 8th Iranian Society of Engineering Geology and Environment, Mashhad, pp. 2215-2223.

Rajish, Ch, Dibyendu, D, Rabindar, NB & Uttam Kumar, M 2016, Analytic Hierarchy Process and Multi–Criteria Decision-Making approach for selecting the most effective soil erosion zone in Gomati River Basin, *International Journal of Engineering Research & Technology*, 5: 595-600.

Rezaei, K 2017, Evoluation of erosion risk map based on hierarchical decision tree method: A case study: Semnan drainage basin, *Journal of Stratigraphy and Sedimentology Researches*, 34: 47-66.

Sameh, K, Hammadi, Habib,A & Samir, B 2015, Soil erosion hazard mapping using Analytic Hierarchy Process and logistic regression: A case study of Haffouz watershed, central Tunisia, *Arabian Journal of Geosciences*, 8: 4257-4268.

Schwab GO, Fangmeier DD, Elliot WI & Frevert RK 1992, Soil and water conservation engineering, 4th ed., John Wiley and Sons Inc., New York, pp: 52-59.

Sidle, RC 2010, Hydrogeomorphic Processes in Temperate and Tropical Forests: Effects of Land Use and Scale. *Geography Compass*, 4: 1115-1132.

Strojny, J & Hejman, W 2016, AHP Based Multicriteria Comparative Analysis of Regions of Eastern Poland, International *Journal of the Analytic Hierarchy Process*, 8: 53-76.

Terranova, O, Antronico, L, Coscarelli, R & Iaqunita, P 2009, Soil erosion risk scenarios in the Mediterranean using RUSLE and GIS: an Application Model for Calabria (Southern Italy), Geomorphology, 112: 228-245.

Zemke, JJ 2016, Runoff and soil erosion assessment on forest roads using a small scale rainfall simulator, *Hydrology*, 3: 1- 25.

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