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Original Research

Comparison of EPM and Geomorphology models for erosion and sediment yield assessment in a semi-arid environment

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ABSTRACT:

In the present study, erosion and sedimentation are estimated by the two qualitative (Geomorphology) and quantitative (EPM) methods; the results in Dehbala watershed in Yazd, Iran, were compared with that of observed statistics for sedimentation. Geomorphology presents the intensity of erosion qualitatively; factors such as physiographic, soil and stone type, vegetation coverage and geomorphology facies determine the intensity o the erosion. EPM method quantitatively offers the amount of erosion for each watershed using four factors including current erosion conditions, soil and stone susceptibility coefficient to erosion, utilization coefficient of lands and also calculation of the amount of sedimentation carrying after the calculation of sedimentation coefficient of watershed. In order to improve precision and to create possibility of the better investigation, the accomplishment of the quantitative model, i.e. EPM, at the level of homogenous units was representative of this case that of EPM model because geomorphology considers more efficient factors in erosion and also its application in the specific areas, called homogenous units, which mediates effective elements in destruction, presents better results. However the results differed from the real amount of the watershed sedimentation due to special conditions of the area of study (mountainous, highly inclined). By comparing the results of the above-mentioned methods with observed statistics for sedimentation, we find out that the difference between the amount obtained by geomorphology method and the amount obtained by observed statistics for sedimentation was 48.96%; this difference was 77.22% in the EPM model.

Keywords:

Erosion, Sedimentation, Geomorphology model, EPM model, Facie, Homogenous unit

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INTRODUCTION

Erosion, especially soil erosion by water, apart from morphological kinds of it, is a phenomenon that is as old as the presence of the earth in the globe. Some researchers think that soil erosion consequences are so dangerous that they attribute the extinction of the previous civilization to this phenomenon. Recently it`s believed that soil erosion by water is an important and major factor of prevention of economic and social development because it destroys environmental resources and prevents food security in the world. Although the oldness of soil erosion is equal to the lifetime of the globe, soil destruction is increasingly growing in the twenty-century due to the population growth and the extreme use of land.

In the most inscriptions related to the erosion and soil protection, it's pointed that the first scientific research in the field of erosion was done by Wollny between 1877 and 1895. This German scientist investigated vegetation coverage, soil kind, and land inclination in the production of superficial running water and erosion in order to explain erosion formation. He introduced these factors as the effective elements in the intensity of erosion (Hudson, 1971).

The objective of recognition of the effective elements in soil erosion is to evaluate the hazards of it and determine the areas that are similar in terms of erosion danger; it seemed that the possibility of programming for soil protection and struggle with route erosion is provided in this way. According to these thoughts, the researcher's attention is drawn to the necessity of the awareness of the amount and intensity of erosion for determination of effective strategies of soil protection and struggle with the erosion and sedimentation production; therefore, local condition and the level of erosion danger can be predicted (Morgan, 1996).

Surface erosion and sediment yield are important factors that should be taken into account in planning renewable natural resource projects (Tangestani, 2006).

Among these factors, ecological conditions which are the representative of soil behavior to rainfall, in terms of aqua erosion is the determinant factor. For example, when the weather is rainy and dry, and till the superficial water is not produced, the amount of erosion is limited to the excavation and soil displacement can be like splash erosion; and when the soil is saturated with humidity, the amount and intensity of erosion is much more than that of dry conditions (Morgan, 1974; Satterlund, 1972; Hudson, 1981; Morgan, 1996).

Erosion is the opposite of pedogenes. When the amount of these two is equal, equilibrium exists but when erosion becomes more than pedogenes, it becomes dangerous. Understanding the importance of erosion and sedimentation absorbed researchers of natural resources. In the present time study of the erosion and sedimentation is a key parameter and cannot be separated from studies of a watershed basin; and the methods of struggle with sedimentation and erosion consisting of the framework of the programming of a watershed basin management.

Because of qualitative characteristics of this method, we should use mathematical ways in order to change it, to a quantitative method and increase the validity of it. EPM model is one of these models that is used in this study to estimate erosion and sedimentation and the results of this method are compared with that of geomorphology method. For calculation of soil erosion intensity and forecasting of maximum runoff from the river basin, a programme driven by the Erosion Potential Method (Gavrilovic, 1972).

The Erosion Potential Method (EPM) is a model for qualifying the erosion severity and estimating the total annual sediment yield, developed initially from the investigation of data in Yugoslavia by Gavrilovic in 1972, that involves a parametric distributed model, and is used for predicting annual soil erosion rates and annual coefficient, protection coefficient and erosion sediment

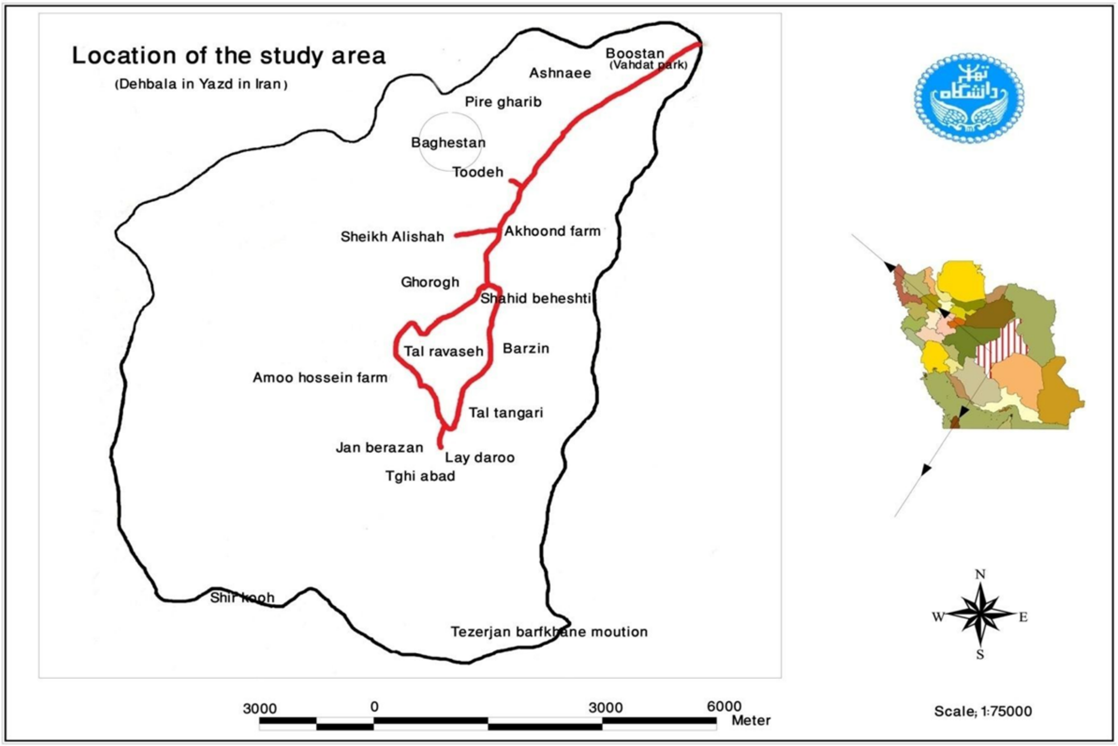

Figure 1. Location of study area

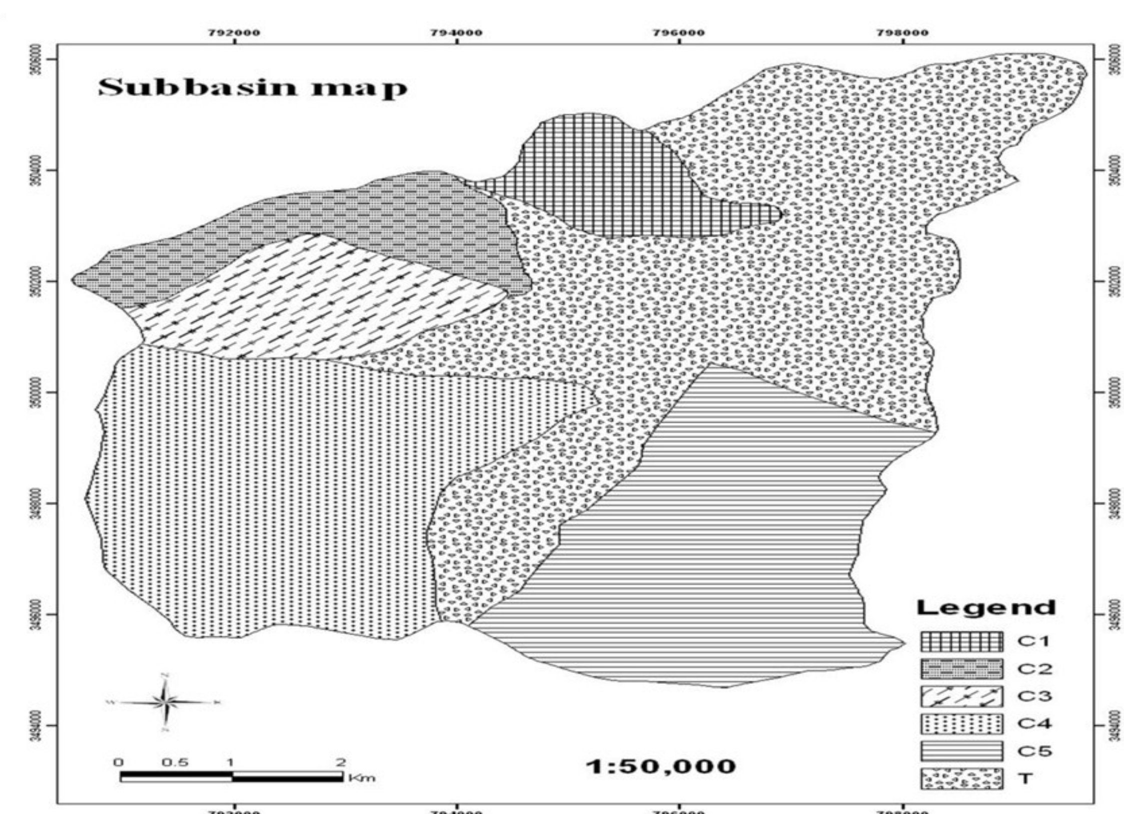

Figure 2. Sub basin map

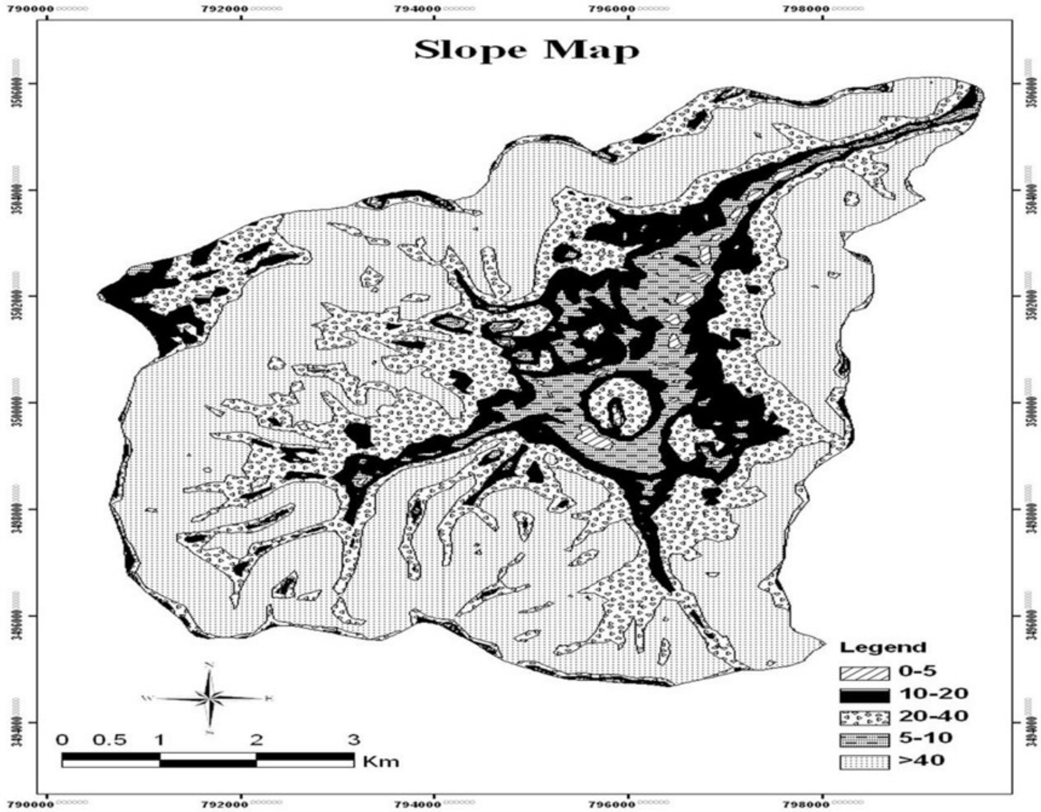

Figure 3. Slope map

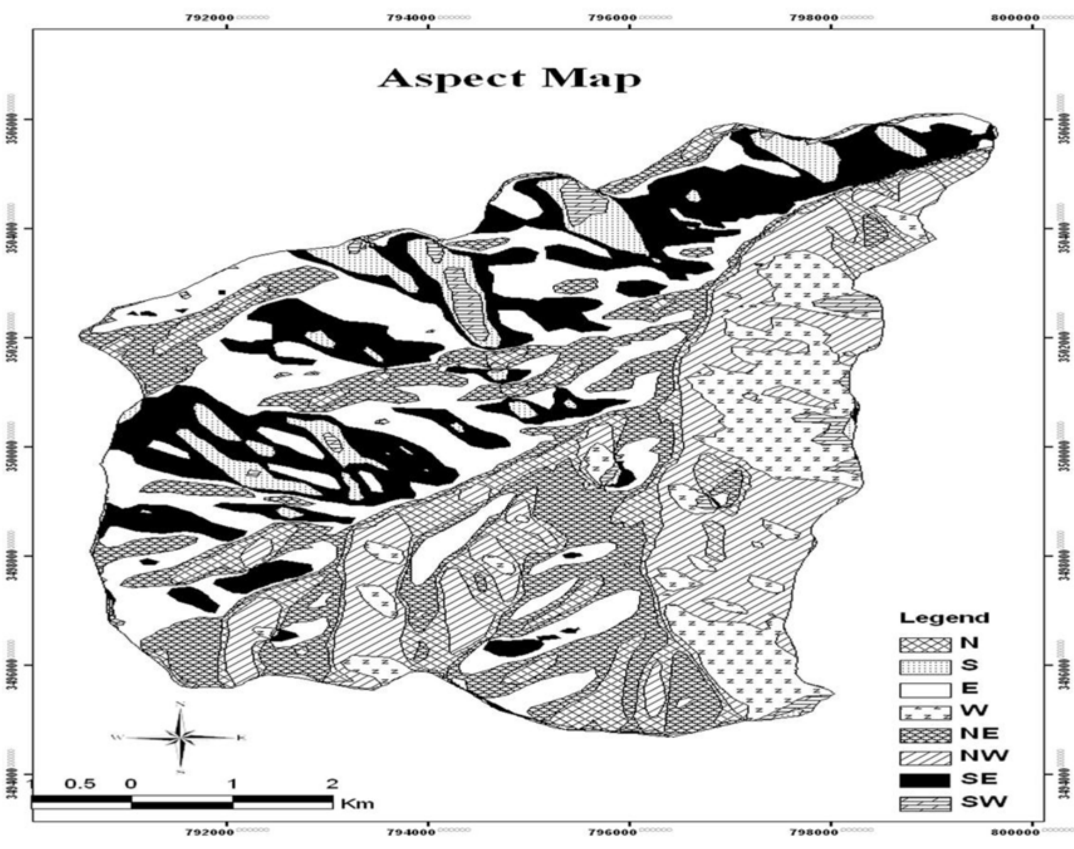

Figure 4. Aspect map

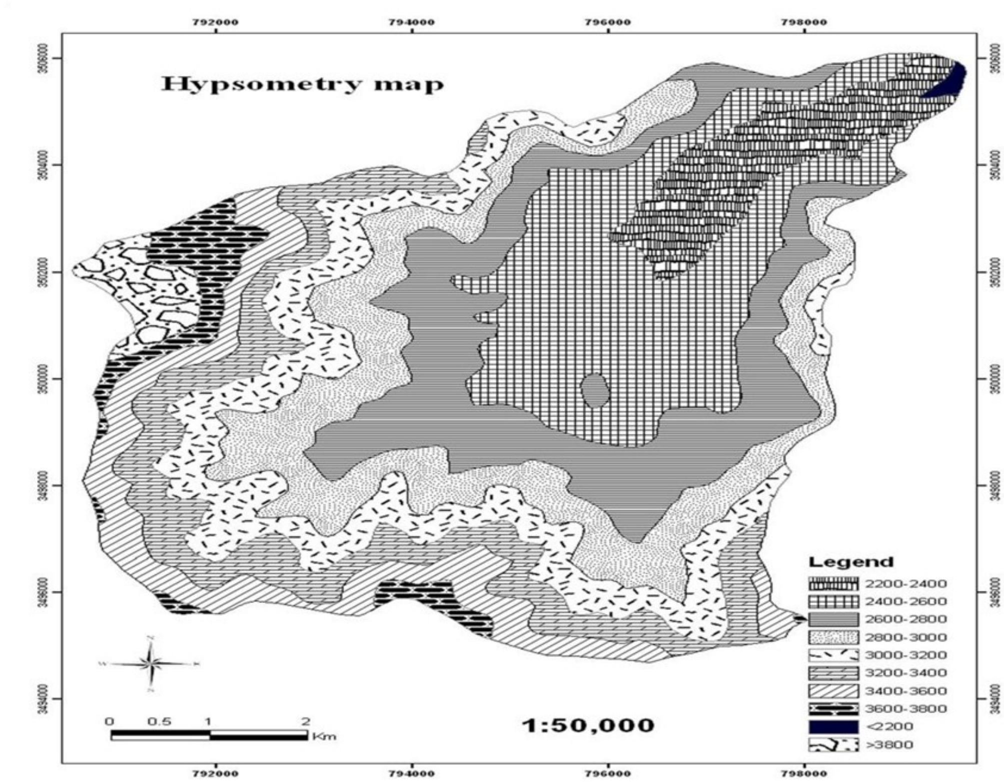

Figure 5. Hypsometry map

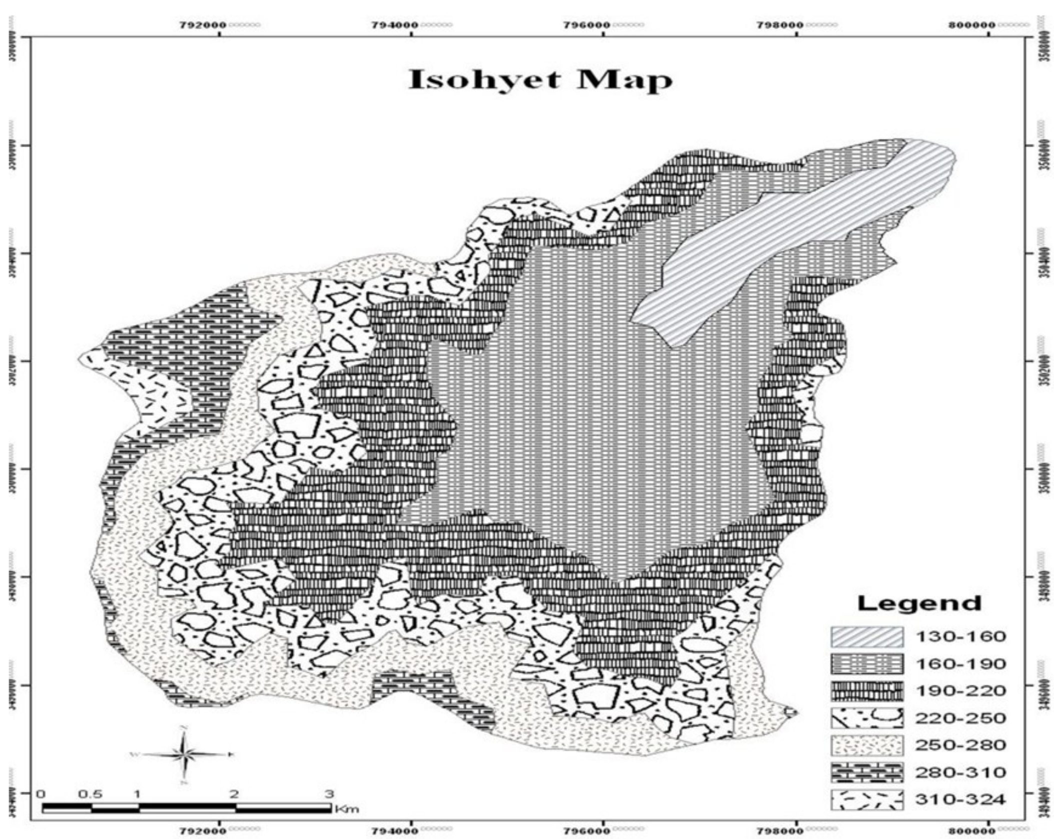

Figure 6. Isohyet map

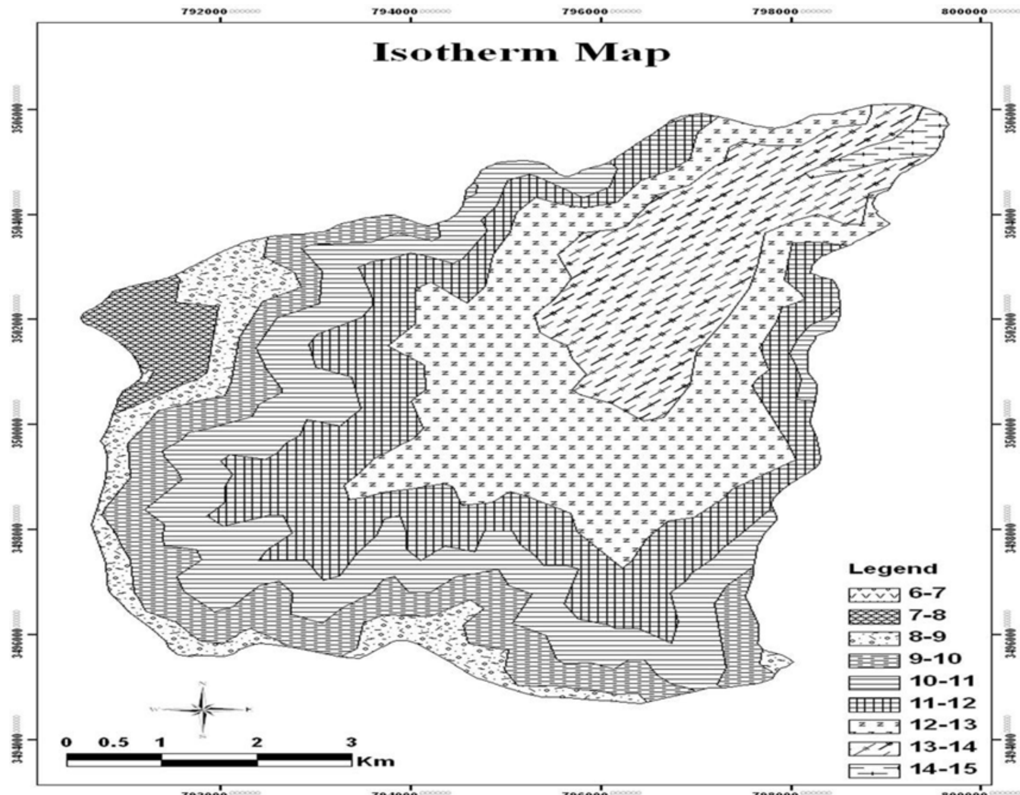

Figure 7. Isotherm map

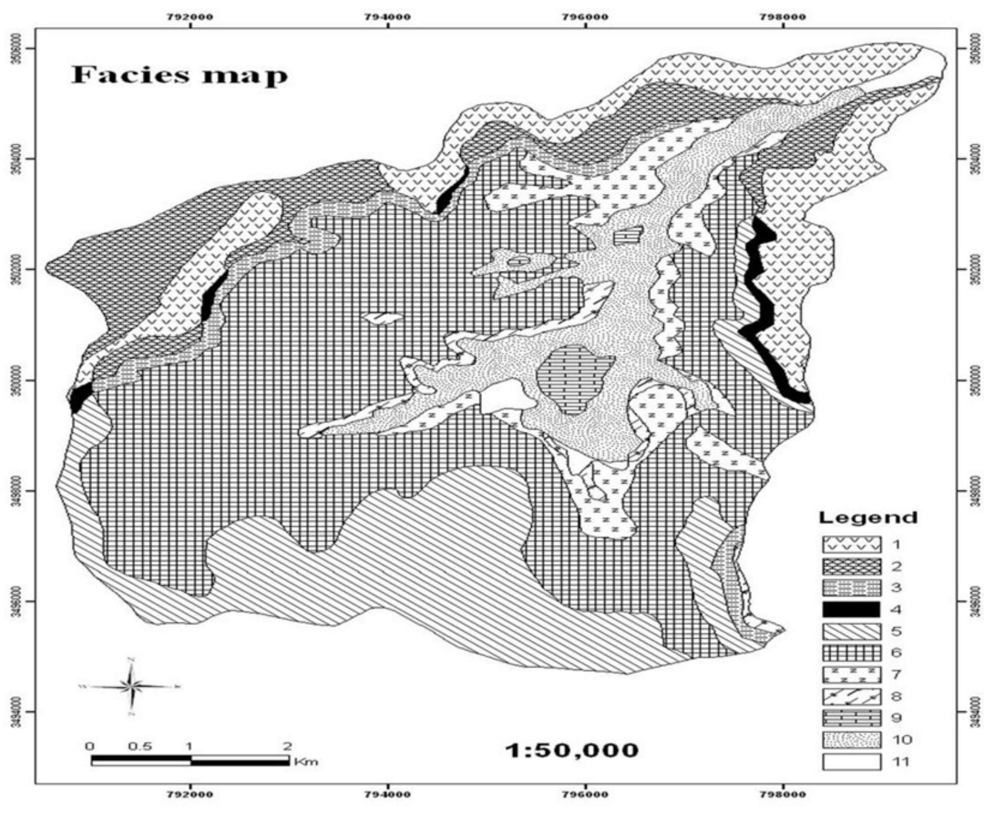

Figure 8. Facies map

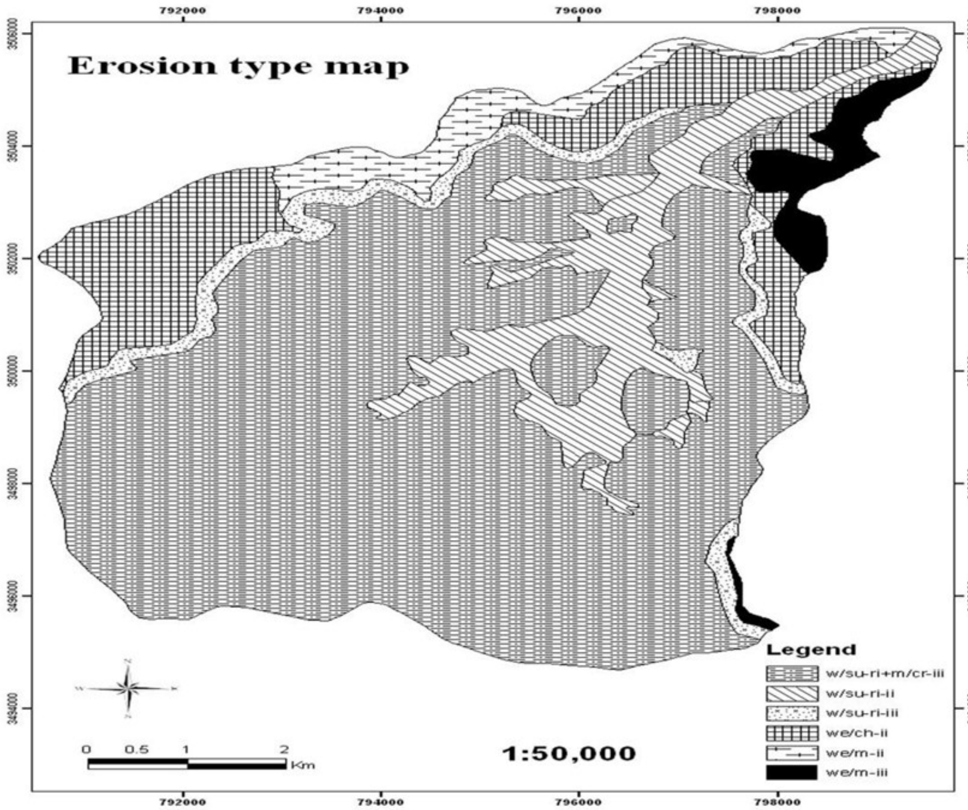

Figure 9. Erosion type map

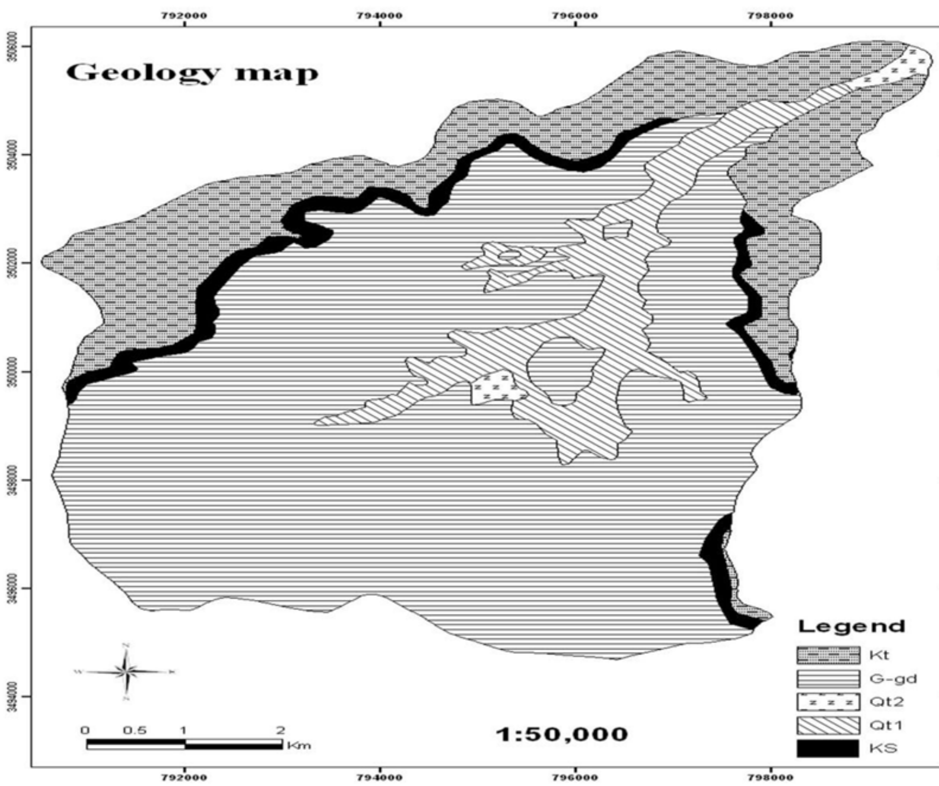

Figure 10. Geology map

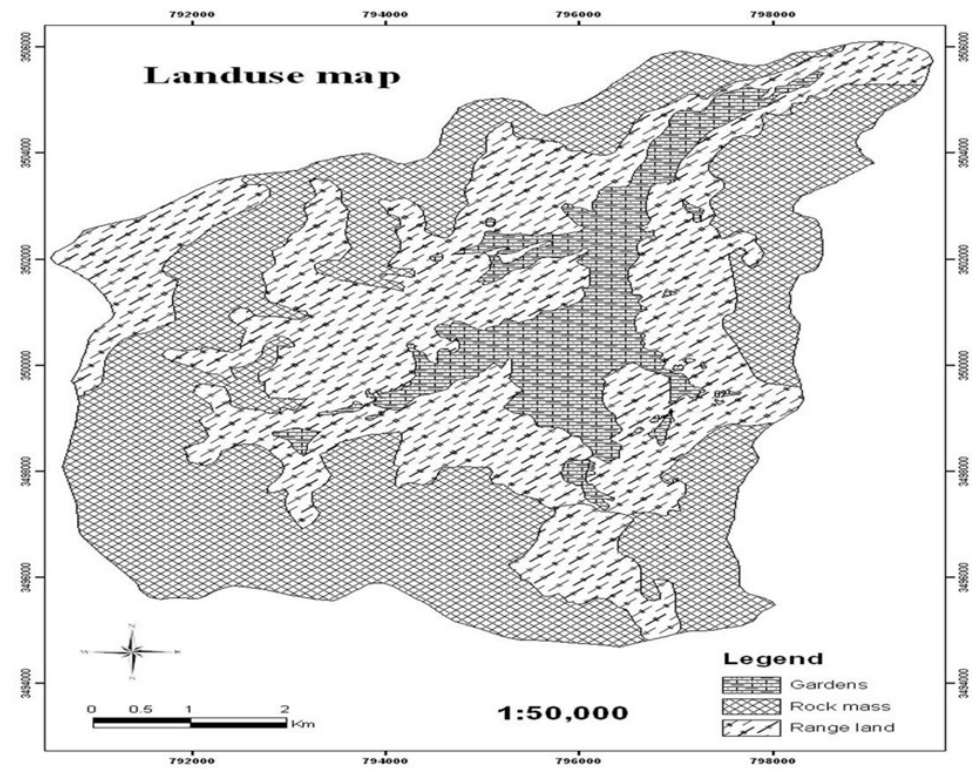

Figure 11. Landuse map

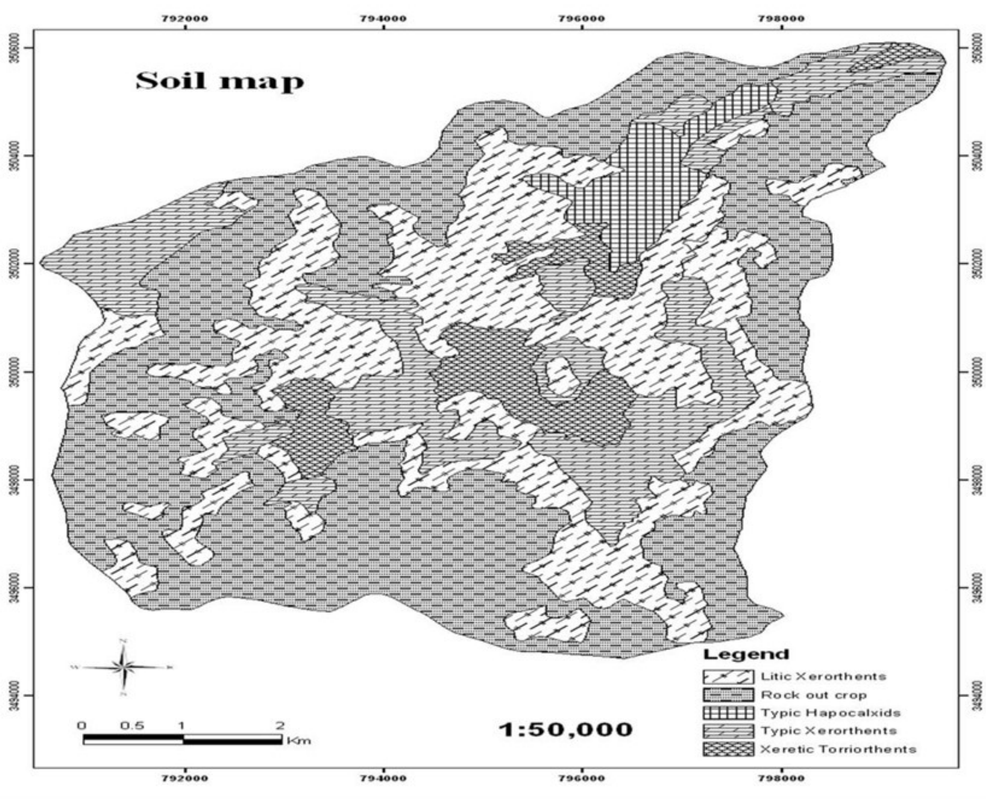

Figure 12. Soil map

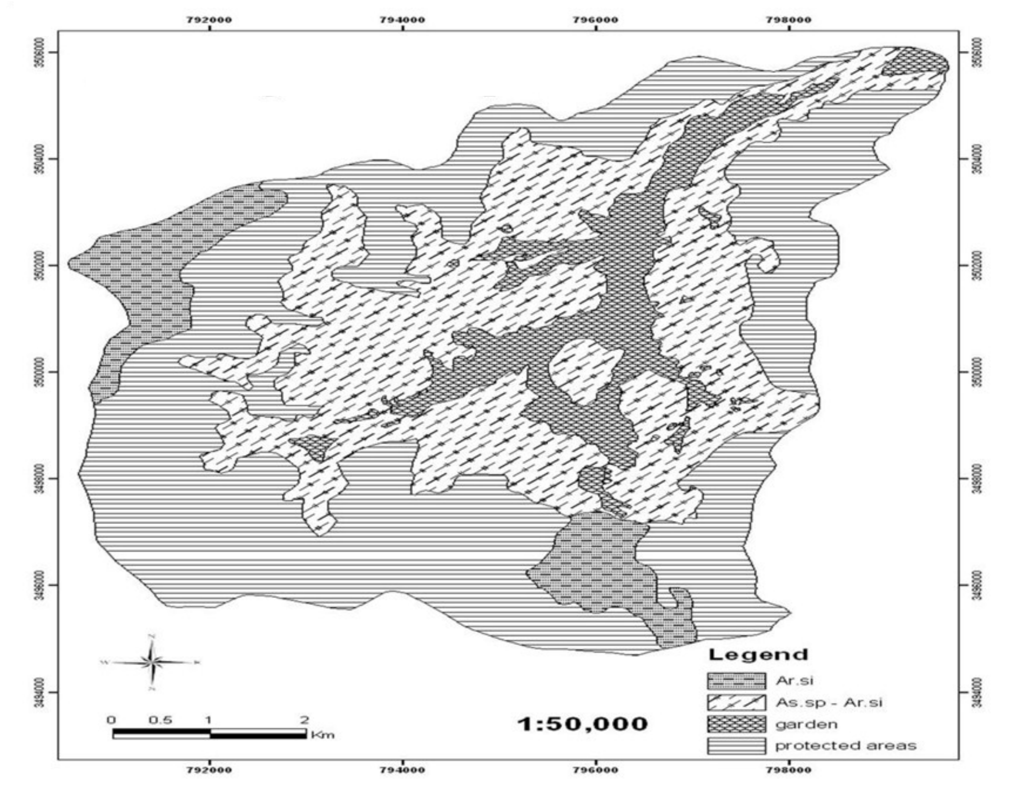

Figure 13. Cover vegetation map

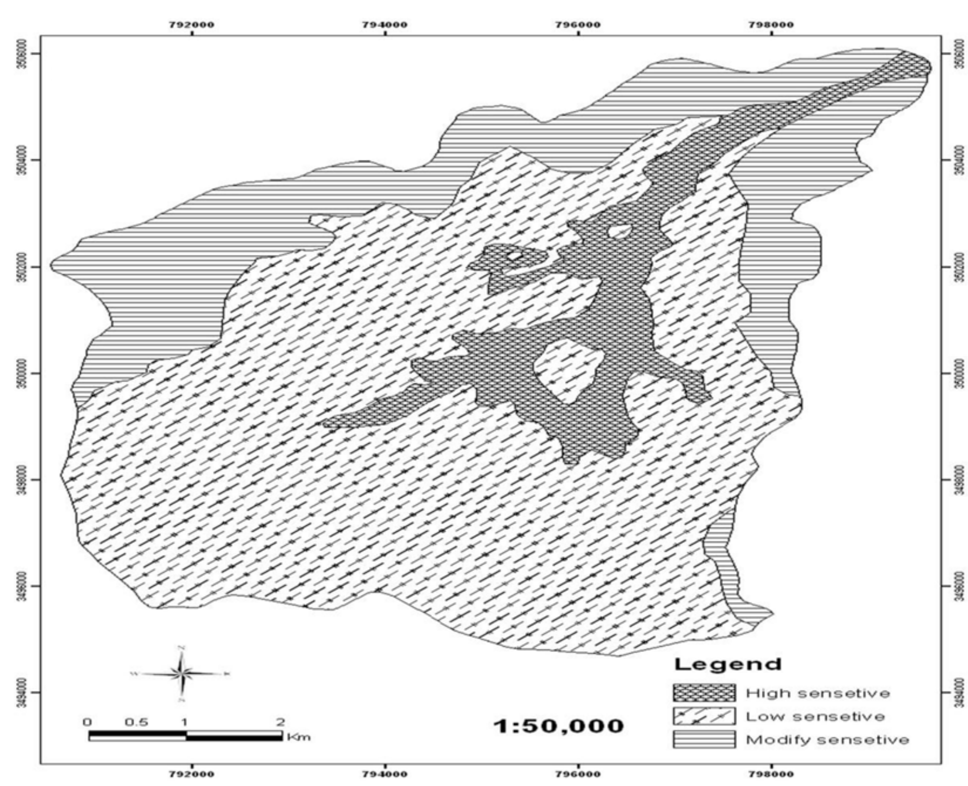

Figure 14. Sensitive to erosion map

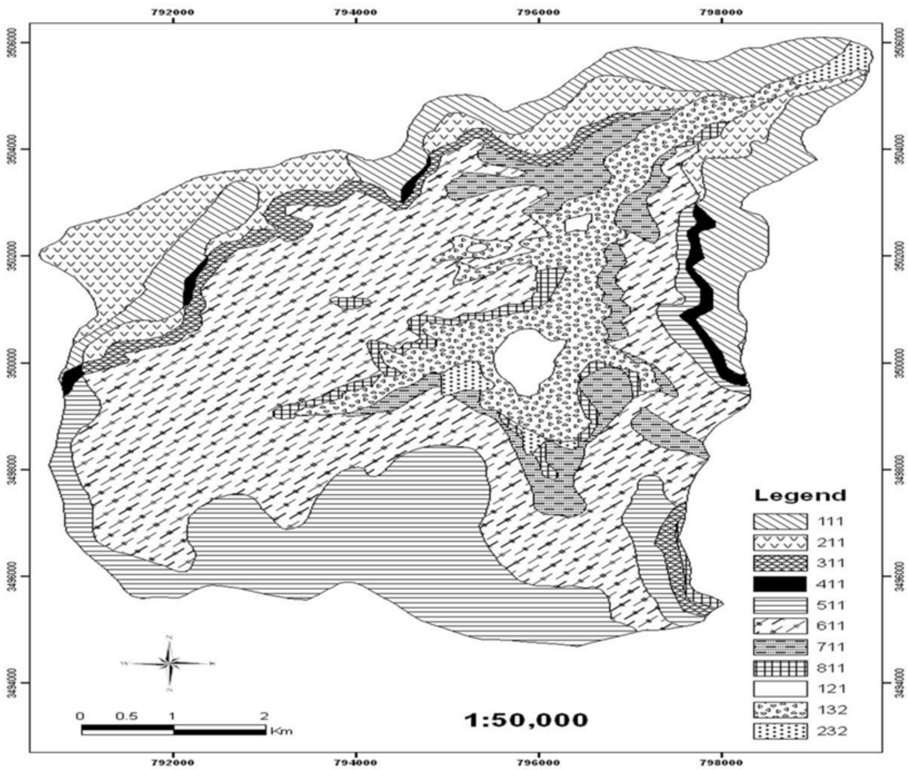

Figure 15. Homogenous map

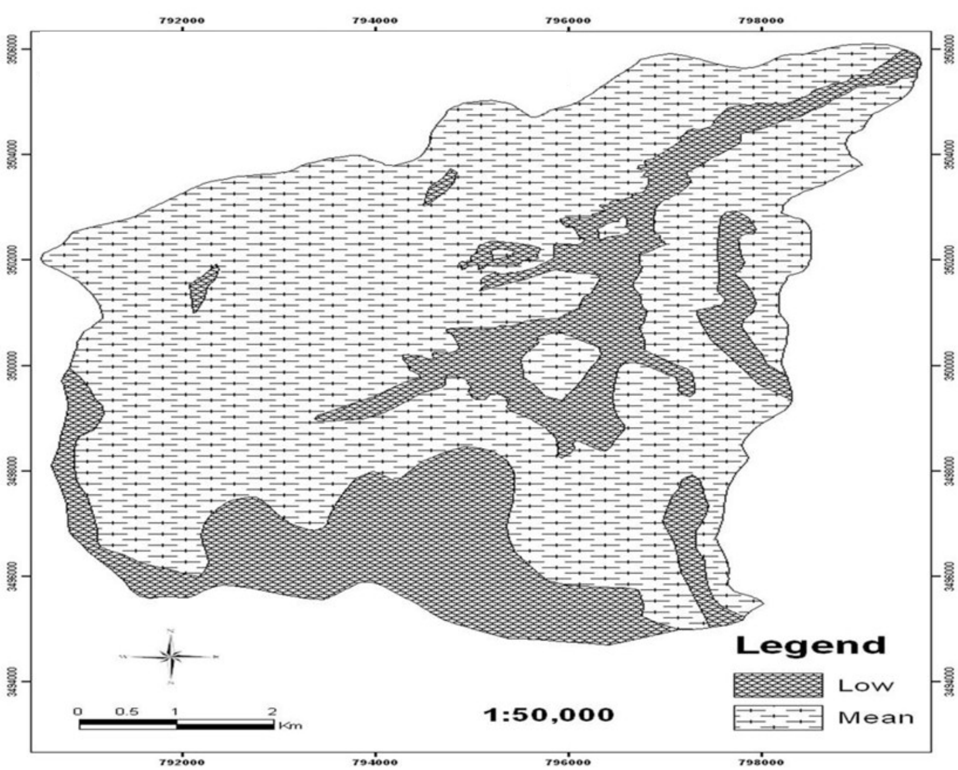

Figure 16. Erosion intensity map using geomorphology method

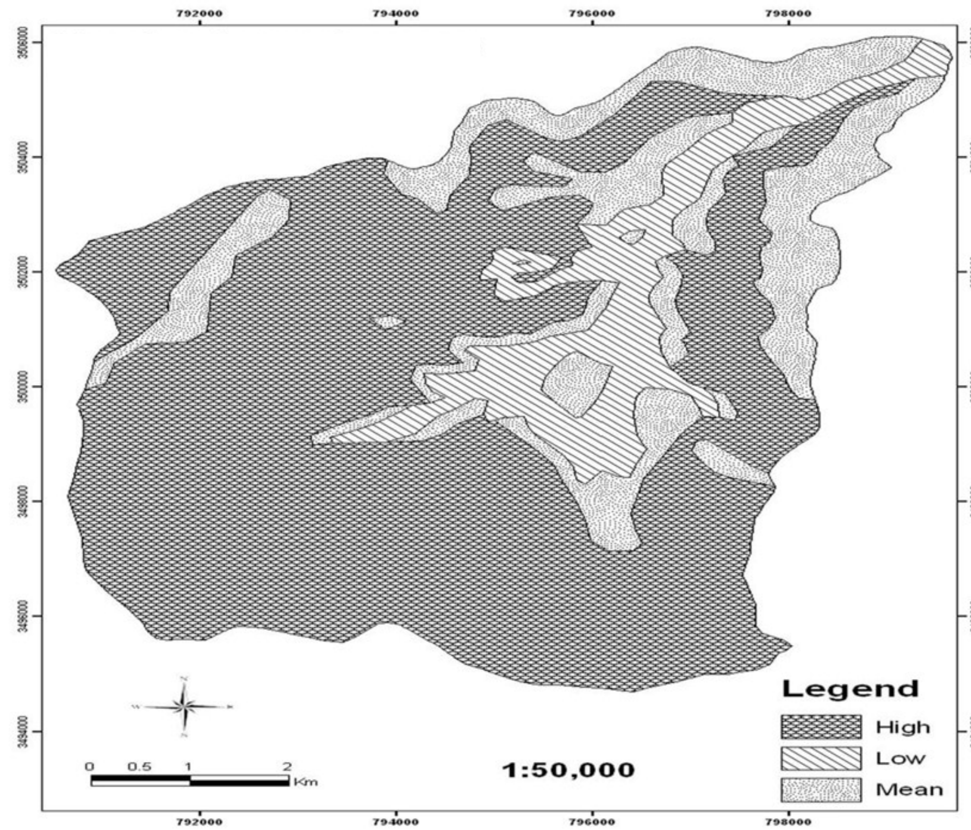

Figure 17. Erosion intensity map using EPM method

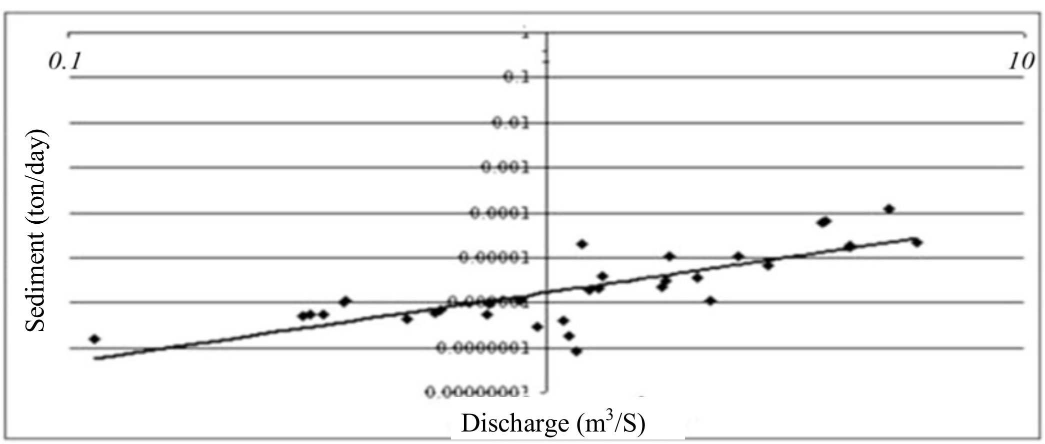

Figure 18. Rating curve of sediment in Baghestan station

yield. It uses empirical coefficients (erodibility coefficient) and the matrix of physical characteristics of the basin. The EPM gives a quantitative estimation of erosion intensity as well as the estimation of sediment yield and transportation (Tangestani, 2006).

In order to estimate and predict the amount and power of being eroded in a watershed basin, quantitative and qualitative model can be used to achieve the desired goal. It`s necessary to investigate and determine confidence limit of the results obtained by applying these models and goal of the present study is achieving an efficient model in dry and semidry area in central Iran and is improving the ability of the investigation of foreign models and optimization of development of them for similar areas in Iran and also investigating and comparing the application of EPM model and

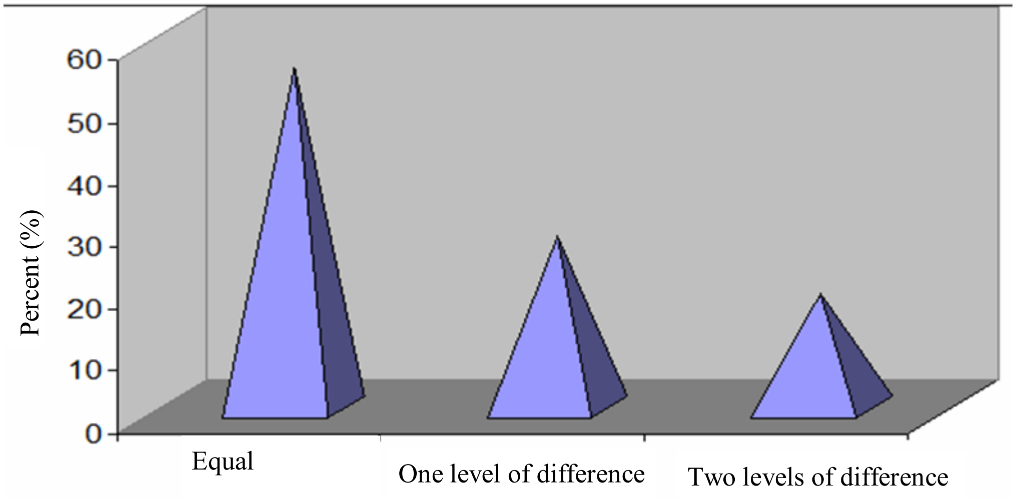

Figure 19. The difference of erosion intensity classes in homogenous units by using geomorphology and EPM methods

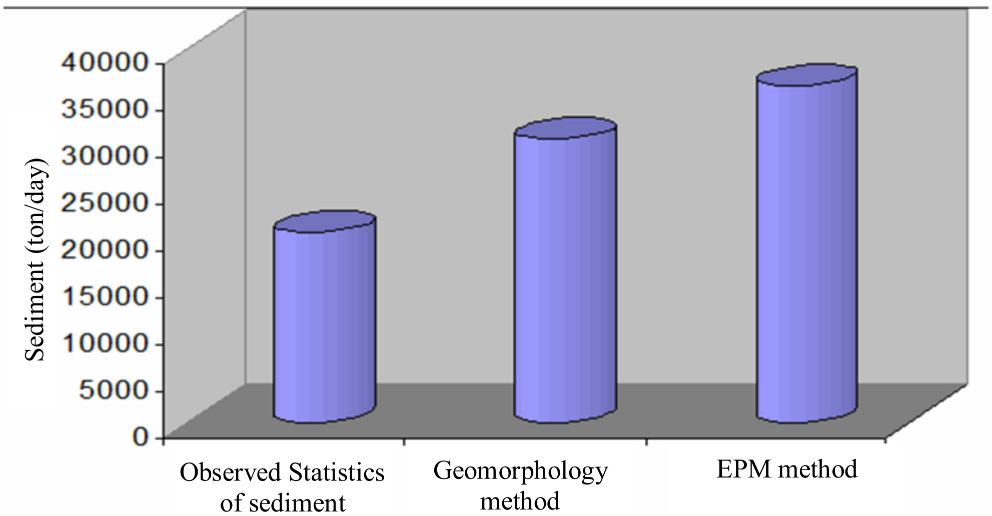

Figure 20. The difference between estimated amount of sediment by EPM and geomorphology with observed statistics of sediment

geomorphology method in estimation and prediction of erosion in watershed basin.

MATERIALS AND METHODS

Study Area

Dehbala area lies at 54° 3' 54"-54° 10' East and 31° 33' 5"-31° 39' 14" North. The area of it is about 67.87 Km^2 (Figure 1). According to information taken from Yazd Regional Water Authority (2005) and Department of Natural Resources of Yazd (2005), Vegetation coverage of this area consisted of dispersed bushes, average annual rain and temperature of it are 281mm and 11.28°c respectively; and according to the Emberger classification is Mediterranean, dry and warm. This area includes quartz, Shirkooh granite, rocky place with lime

Methodology

All maps in the methodologies are provided by the author using ArcView software. To achieve quality and characteristics of the study area, at first, the basin was divided in to sub-basins that are shown in (Figure 2), then geological map of the area is provided (Figure 10), and then morphological facie map of the area is

Table 1. Categorization of erosion intensity in EPM model

Erosion categorization	Limit value of Z	Average value of Z	Erosion intensity
1	Z>1	1.25	Very severe
2	1> Z> 0.71	0.85	Severe
3	0.7> Z>0.41	0.55	Medium
4	0.4> Z>0.2	0.2	Low
5	0.19> Z	0.1	Very low

organized by field inspection and air photography (Figure 8). After the construction of TIN model of Dehbala (triangulated irregular network), Digital Elevation Model (DEM) of Dehbala was designed in ArcView software environment, and then slope, aspect, hypsometry and isohyet maps were determined by the authors (Figures 3,4,5 and 6). Isothermal map of the area was determined by temperature and rain gradient of the area (Figure 7). Map of the application of land in this area was also provided (Figure 11). Map of the soil units and vegetation types of the area were designed by visit of region and according to information taken from Department of Natural Resources of Yazd (2005) (Figure 12,13). In order to estimate erosion and sedimentation by using geomorphology method, first of all, map of the introductory homogeneous units was provided (by overlaying morphological facies map, slop map and lithology), (Figure 15), then topographical elements (slope, Aspect, latitude), vegetation coverage, soil type, type of the erosion facies were investigated (Figure 9); and by using the mentioned factors and according to the basic of geomorphology method, erosion condition of each unit was determined separately and the amount of erosion or sensitive erosion map was defined qualitatively (Figure 14).

The below steps should be followed to calculate sedimentation by EPM method. First, the intensity of erosion is obtained by below equation:

$$Z = X_a . Y (\varphi + I^{1/2}) \quad (1)$$

where 'Z' is the intensity coefficient of erosion, 'X_a' is utilization coefficient of lands, 'Y' is susceptibility coefficient of stone and soil to erosion, 'φ' is erosion coefficient of watershed basin and 'I' is the average intensity of watershed in percentage terms (Gavrilovic, 1988).

The coefficients of the model are obtained by tables related to EPM model and the slope of the area is calculated in average weight using the slope map of desired watershed basin for each watershed and also using the whole watershed basin. After determination of the intensity coefficient of erosion (Z), this coefficient is divided into 5 categories according to Table 1, and we can define the erosion condition in watershed basin as very high, high, average, low, very low.

The second step is the calculation of sedimentation carrying; we can estimate the amount of erosion in area unit of watershed basin (km^2) during a year in terms of m^3/km in year, by using the below equation:

$$WSP = T.\ H.\ Z^{1.5} . \pi \quad (2)$$

where 'WSP' is the amount of annual specific erosion in terms of m^3/km^2 and 'T' is temperature coefficient ands is obtained by:

$$T = \left(\frac{t+0.1}{10}\right)^{0.5} \quad (3)$$

where 't' is the average annual temperature of watershed basin in terms of °c, 'H' is the average annual rain in terms of mm, 'Z' is intensity coefficient of erosion and 'π' is equal to 3.14 (Gavrilovic, 1988).

Calculation of special erosion is done in the area of each watershed basin and then the amount of special erosion for the whole watershed basin is calculated from the sum of them.

In the third step, sedimentation is calculated in each part of the river. Discharge of specific sedimentation is defined as the amount of production in area unit of a watershed basin. To calculate discharge of specific sedimentation, the amount of specific erosion is multiplied by sedimentation coefficient:

$$G_{sp} = W_{sp}.RU \quad (4)$$

where 'G_{sp}' is specific sedimentation in terms of m^3/km^2 in year, 'W_{sp}' is specific erosion in terms of m^2/year and 'RU' is sedimentation coefficient of watershed basin. Discharge of specific sedimentation is multiplied by the total area of watershed basin to calculate discharge of total sedimentation:

$$G_s = G_{sp}.A \quad (5)$$

where 'G_s' is the total sedimentation of each watershed basin in terms of m^3/year, 'G_{sp}' is the specific sedimentation of each watershed basin in terms of m^3/km^2year, and 'A' is the area of each watershed in terms of km^2. It's clear that total sedimentation watershed basin is as follow:

$$GS_t = GS_1+GS_2+\ldots\ldots GS_n \quad (6)$$

After the calculation of erosion by the two mentioned methods, the real amount of watershed`s sedimentation was estimated by using the statistics of daily discharge of suspended sedimentation of Dehbala river and the sedimentation measurement curve.

This curve is obtained by the correlation between suspension current (Q_s) and its discharge counterpart in logarithm coordination plane, after the selection of the best line according to the least square method, the below equation is obtained:

$$Q_s = a\,Q_w^{\,b} \quad (7)$$

where 'Q_s' is suspension current in terms of tone per day, 'Q_w' is discharge of current in terms of m^3/s, 'a and b' are intercepts and the slope of the line (Gavrilovic, 1988).

To obtain curve by the mentioned method, momentary discharge in terms of m^3/s and its sedimentation counterpart in terms of tone per day should be arrange in order in logarithm coordination planes and then the best line with higher amount of R^2 is selected and the equation related to the sedimentation measurement curve is obtained. Finally, the amount of estimated erosion and sedimentation which is obtained by Geomorphology and EPM method is compared with the observed amount of sedimentation.

RESULTS

Erosion condition in each homogeneous unit is determined qualitatively to design erosion map by Geomorphology method using ecological information of the area and investigating them and using geomorphological maps, lithology, vegetation coverage, soil, hypsometry, slope and desert investigation and precise interpretation of air images. This had led to the distinction of two erosion types, low and average, out of five erosion types including very low, low, average, high, very high. After determination of erosion in each unit, units in an erosion type are mixed and erosion map of the area was provided (Figure 16). In most cases, it`s found that some of these units have different stones, vegetation coverage, slope, condensation and soil type, but they have similar erosion shape and erosion emergence and are included in one erosion type. In order to design erosion map by EPM method after the calculation of the intensity coefficient of erosion for all parts of the watershed basin, according to Table 1, the condition of erosion intensity in watershed basin was classified qualitatively and by considering five classes in the table, erosion intensity was determined for the whole watershed (Figure 17). Qualitative amount of erosion and sedimentation in EPM method is calculated according to the procedure and is shown in Table 2 and Table 3.

One-line sedimentation measurement curve-daily discharge, is plotted in logarithm coordination planes using related data of current discharge and the concentration of suspension current; after the best selection of line according to the least square method by using Q_s=203.98$Q_w^{0.3948}$, R^2 obtained 0.61, in logarithm coordination plane suspension current (Q_s) and its

Table 2. Calculation of intensity coefficient of erosion in EPM modle in homogeneous unit

Row	Homogeneous unit code	Average slope of area in %	Susceptibility coefficient of stone and soil to erosion (Y)	Utilization coefficient of lands (Xa)	Erosion coefficient of watershed basin (φ)	Coefficient of erosion intensity (Z)	Erosion intensity (EPM)	Erosion intensity (geomorphology)
1	1-1-1	40.01	0.25	0.41	0.57	0.7	Medium	Medium
2	2-1-1	41.6	0.26	0.45	0.56	0.82	High	Medium
3	3-1-1	52.3	0.25	0.44	0.63	0.86	High	Medium
4	4-1-1	49.94	0.27	0.48	0.53	0.98	High	Low
5	5-1-1	41.02	0.26	0.5	0.6	0.91	High	Low
6	6-1-1	38.09	0.28	0.42	0.55	0.79	High	Medium
7	7-1-1	19.41	0.32	0.41	0.44	0.64	Medium	Medium
8	8-1-1	11.62	0.35	0.41	0.4	0.55	Medium	Medium
9	1-2-1	22.01	0.26	0.51	0.51	0.69	Medium	Medium
10	1-3-2	15.17	0.7	0.12	0.21	0.34	Low	Low
11	2-3-2	17.68	0.51	0.18	0.11	0.39	Low	Low

discharge counterpart (Q_w) are plotted as follows (Figure 18).

According to the result obtained by Geomorphology method in watershed basin of Dehbala we can conclude that 40.86 percent of the total area of watershed has low sensitivity to the erosion and 59.14 percent of it has average sensitivity, five units out of the whole units have average sensitivity and six units of them have low sensitivity to the erosion. The results obtained by the application of EPM method for estimation of the amount of erosion and sedimentation of Dehbala watershed are as followed: 10.28 percent of the watershed area has low sensitivity to erosion and 20.08 percent of it has average sensitivity and 69.63 percent of the total area has high sensitivity to erosion and the results presents for the prediction of qualitative amount of erosion and sedimentation by applying Geomorphology method we due to the calculation of intensity coefficient of erosion (Z) in homogeneous units. The calculations have showed that only two units have low sensitivity to erosion and four units have average erosion and five units of the total units have high sensitivity to erosion.

For better comparison of the erosion intensity by mentioned methods, we can coincide intensity map of the erosion of two Geomorphology and EPM methods and by their coincidence; we can determine the relative difference of each erosion classes. The results showed that four units out of the total homogeneous units are in equal in both methods and five units have one level of difference in erosion intensity and also two units have two levels of difference with each other (Figure 19).

Science the Geomorphology method is a qualitative method, numerical comparison of the amount of erosion and sedimentation with the results obtained by EPM method and also observed amount is not possible. In order to suitably compare the results of this method with that of EPM method and observed amount, intensity classes of erosion in Geomorphology method become

Table 3. Calculated values from EPM in primary and secondary sub basins in study basin

Name of sub basin	C_1	C_2	C_3	C_4	C_5	CP
Mean rainfall (mm)	194.8	248.81	248.81	227.21	221.4	216.71
Mean temperature (˚C)	1.0044	9.3	9.3	10.13	10.7	10.97
Erosion coefficient (Z)	11.38	1.3232	1.1775	0.9253	1.096	0.6457
Specific erosion (WSP) ($M^3Km^{-2}Y^{-1}$)	659.669	1152.95	967.842	642.265	828.954	371.489
Mean elevation (M)	2760	3320	3320	3040	3040	2900
Output elevation (M)	2340	2580	2600	2548	2480	2180
Elevation difference (M)	0.42	0.74	0.72	0.49	0.56	0.72
Perimeter of basin (Km)	16.47	17.15	8.85	11.8	37.52	83.32
Length of basin (Km)	3.04	5.2	3.78	6.11	5.74	12.46
Sedimentation coefficient (RU)	0.81	0.94	0.73	0.6	1.16	1.38
Specific sedimentation (GSP) ($M^3Km^{-2}Y^{-1}$)	532.206	1080.87	709.175	383.458	965.631	512.433
Area (Km^2)	3.33	4.64	4.85	16.11	14.12	24.99
Discharge of total sedimentation (G_S) (M^3Y^{-1})	1772.25	5015.25	3439.5	6177.51	13634.7	12805.7

qualitatively and a special number is assigned to them for each erosion type, so according to the estimated amount of sedimentation by two empirical methods of EPM and Geomorphology and by comparison of them with the calculated amount from the statistics of the measurement station of sedimentation as an example, it was concluded that estimated amount of sedimentation by using EPM method has 77.22% difference with observed statistics of sedimentation and also estimated amount of sedimentation obtained by applying

Geomorphology method has 48.96% difference with the observed statistics of sedimentation. These results are shown in Figure 19 and Figure 20.

CONCLUSION

There are different methods for estimation of the suspension sedimentation and large difference between these estimations are obtained; and the common method (sedimentation measurement – current curve) predicts the amount of suspension current less than the actual amount due to average out in this method; and according to the structure of lithology, stones of the study area are hard and without fine particles in the level of silt and clay, therefore it seems that the bottom current percentage is more than suggested amount of 25% in resources, and also the amount of 45% is suggested as bottom current, therefore it`s not suitable to use sedimentation measurement curve for the estimation of actual amount of sedimentation in this area because this curve only calculates the amount of suspension current of the river. Furthermore, most of the facies in the area are stony bulk and stone protrusion with high slop. EPM model is poor in this case and it calculates the amount of erosion and sedimentation more than actual one, so we conclude that if the stony bulk is omitted in this model, the estimated amount of sedimentation will be balanced.

This research when compared with similar studies in Mazandaran Province of Iran, similar results were found. Abadi and Ahmadi (2011) with evaluation and comparison of EPM and geomorphology methods for erosion and sediment yield assessment in Kasilian Watershed, Mazandaran Province, Iran, was found that the amount of sediment yield in Geomorphology method was 3.6% less (1197 ton/year) and EPM model was 4.8 times more (5322 ton/year) than field observation (1243 ton/year). The results are consistent with previous researches under similar conditions and it appeared that analytical output results are compatible with field observations of, Khaleghi (2005), as well as Maleki (2003).

Therefore, we can modify the formula of sedimentation coefficient according to the watershed conditions till the amount of this coefficient becomes near to the actual amount. Sedimentation coefficient in mountainous area is less than 0.8 while this amount is 0.9 and in some cases more than 1.0 in the study area.

SUGGESTIONS

According to the sedimentation kinds which are usually granite destruction and can be fixed in mountain slope, fixation and reduction of sedimentation in mountain slope are done by the help of fence of stones.
The precision of EPM model will increase in less area and the application of it in units present more accurate results, it is suggested that Geomorphology model be used with EPM model and this model should become quantitatively in order to be used in sedimentation-erosion study with more confidence.

Because of the short period of working with statistics and lack of certainty in the suitability of sampling conditions in hydrometry station and lack of confidence in real amount and insufficient statistics, it`s suggested that the authorities do the necessary procedures.

Large area of the watershed consists of hard construction like granite and lime therefore the high percentage of produced sedimentation is bottom load so other methods should be used instead of sedimentation measurement curve to estimate sedimentation directly.

In the case of using other methods except sedimentation measurement curve, because of the lack of enough information about bed load in different watersheds and existence of the modifying dams, suspension load and bed load should be defined and dissociated by installing sediment traps in the bed and measuring precise discharge of suspended and bed load of sedimentation in cross section of constructions.

Geographical Information System (GIS) is suggested to be used to provide necessary parameters and maps in EPM and Geomorphology model, because GIS increases not only the speed but also the precision of the work.

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