EPM Approach for Erosion Modeling by Using RS and GIS

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Keywords: EPM model, GIS, sedimentation, erosion, watershed

SUMMARY

Lack of information to prepare erosion maps for quantitative and qualitative sediment evaluation is a major need in watershed management in Iran. The goal of this study was to use EPM model and apply GIS to minimize the probable errors in evaluation of soil erosion and sedimentation in Ghareh Aghach watershed in central part of Iran. To achieve this goal, in the first step a topographic map in 1:25000 scale of the study area was digitalized by ILWISE program to provide a contour map. Using the contour map, the slope and aspect maps as well as the digital evaluation model (DEM) of the site were prepared. In the second step the satellite images, aerial photos of 1:40000 scale and data obtained from the field visits were used to provide with geological, geomorphologic, vegetation cover, peddological and land use maps of the study area. By integration of geological, geomorphology facieses and slope maps and classifying them in 5 categories (0-10%, 10-20%, 20-30%, 30-40% and >40%), 21 homogenous uniform sampling units were identified to apply EPM model. Model information layers comprised of nine effective factors in erosion and sedimentation in the watershed site were obtained by digitalizing and classifying the basic information data in GIS program. In frequent field visits all the necessary data for EPM model were collected, checked and improved in 21 homogenous and uniform sampling units. Following of finalizing the information layers, all of them were integrated to create the final erosion map. The results of EPM model for homogenous and uniform sampling units indicated that 0.19% (16.69 ha) of the total watershed area was classified at class I of erosion category with very low sedimentation and 15.1% (1352.64 ha) was classified at class II of erosion category with low sedimentation and 41.3% (3698.8 ha) was classified at class III of erosion category with medium sedimentation and 13.2% (1175.3 ha) was classified at class IV of erosion category with high sedimentation and finally 30.2% (2711.41 ha) was classified at class V of erosion category with very high sedimentation, respectively. The result of comparing erosion and sediment values by EPM model with measured values showed that no significant difference between estimated and measured values ($P<0.05$).

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INTRODUCTION

The over population in the world have lead to an increased demand for food and other necessities of human beings (Lu. et. al., 2001). The gradual soil salinization along with deterioration of rangelands vegetation covers have caused accelerating soil erosion and sedimentation in water reservoirs (Meijering, A., 1995). United Nation in its development plan has reported that at present the soil erosion in Iran is about 20 ton/he , which has in creased by 10 ton/he compared to the last decade (UNDP, 1999). There is not enough sediment measurement stations in most watersheds in the country which makes it more difficult to provide with a specific models based on local watershed characteristics. One of the most important problems with empirical models of soil erosion is its lack of accuracy in processing the huge number of data which should be digitalized by GIS system and analyzed by mathematical models. EPM is an empirical model to estimate the quantity and quality of sediment. In fact quantifying and digitalizing the sediment data is an important break through in sediment assessment models development (Nearing et. al., 1999). This problem could be partially solved by estimating models (Lufafa et.al., 2003). Since soil erosion is a product of few different interacting factors, there is not a simple model to assess all the contributing elements in the same time (Daroussin and King, 2001).

The goal of this research was to apply EPM model and GIS system (to reduce the error level to the minimum) to have the most possible accurate assessment of the soil erosion and sedimentation in the study area and make the best applicable suggestions to control it.

MATERIAL AND METHODS

1. The Experimental site

The area of Ghareh Aghach watershed is about 8954. 8 hectares which is located between 51º 45' 53" and 51º 34' 54" eastern latitudes and 31º30' 28" and 31º26' 19" northern altitudes. The maximum and minimum heights of the area are 3810 and 2630m from the sea level. The mean altitude of the watershed is 2936 meters from the sea level. The watershed area is divided in five major hydrologic sections according to its topographic feature. Long term mean annual precipitation and temperature are 358 and 10.5 degrees Celsius which classifies the site in semi-arid climatic conditions according to Ambergie (Q= 40.7) and Demartin (Ia= 17.4) categories. There are about 17 different vegetation types and four major landscapes of mountainous lands, hilly lands, plateau and gravel lands consisting of nine minor land units (Isfahan Regional Water Organization, 2006).

2. EPM Model

EMP model is the other package which has been used to estimate soil erosion in Iran. However, since fewer environmental factors are considered in this model, its accuracy in sediment estimation is less them the other models (Ahmadi, 2006, Rafahi, 1994). This model was created based on erosion measurements during 40 years in previous Yugoslavia and for the first time was introduced

in River Stream International Conference (Gaverlovic, 1988). Sediment estimation in this model is based on four factors consisting:

Ψ : Erosion coefficient of watershed, X: Land use Coefficient, Y: susceptibility of rock and soil to erosion, I: mean watershed slope each one of these factors will receive a proper value according to its contribution to erosion process (Table 1).

Table1. The contributing factors in EPM model to estimate the soil erosion

Factor	necessary information	results
1	Slope map	I: mean watershed slope
2	aspect map	Ψ : value for different erosions
3	land use	Xa: value for different land uses
4	rock and soil susceptibility to erosion	Y: value for rock and soil susceptibility

3. The relationship between erosion and sedimentation in EMP model

This model is able to measure erosion, sediment carrying capacity as well as a primary as estimation of sediments behind the reservoirs.

The coefficient of erosion intensity (Z) is calculated by the following equation in this model:

$$Z = Y. Xa (\Psi + I\ 0. 5) \quad (l)$$

Were:

Y: susceptibility of rock and soil to erosion, Xa: land use coefficient, Ψ : Erosion coefficient of watershed , I: mean watershed slope

The volume of soil erosion is calculated by the following equation in this method.

$$WSP = T. H. \pi. Z^{1. 5} \quad (2)$$

Were:

H: mean annual rainfall (mm), π: 3. 14, WSP: the volume of soil erosion (m3/km2/yr)

T: coefficient of temperature which is calculated by equation No. 3 :

$$T = (t/10 + 0. 1)^{0. 5} \quad (3)$$

Were: t: mean annual temperature

The sediment production rate in this model is calculated based on the ratio of eroded materials in each section of the stream to the total erosion in the whole watershed area (Equation No. 4)

$$Ru= 4 (P. D) 0. 5 /L+10 \quad (4)$$

Were:

P: circumference of the watershed, L: watershed length (km), D: height difference in watershed area (km), After calculation of Ru value the special sediment rate is estimated by equations No. 5 and 6 (9).

$$GSP = WSP. Ru \quad (5)$$

$$GS = GSP. F \quad (6)$$

Were:

GSP: special sediment rate, WSP: volume of special erosion, Ru: coefficient of sedimentation

GS: total sediment rate (m^3/yr) , F: total watershed area (Km^2) (Ahmadi, 2006, Rafai, 2004).

RESULTS

When the proper maps are prepared in EPM model, different contributing factors in erosion and sedimentation will receive their values in GIS system.

1. EPM model

Using the EPM model to estimate the erosion, the boundary of units and subunits of the watershed were identified based on proper maps (land use, soil map and etc.) (Figure1). The maps were matched by GIS and then the mean coefficient values for each homogenous and uniform sampling units and subunit were calculated. The calculated values of four contributing factors for Ghareh Aghach watershed in EPM model is presented in Table 2 and 3. The maps of susceptibility values for each contributing factor created by ILWIS3.3 system are presented in figures 2 to 5. After the information layers were valuated to produce the erosion map, the map of erosion intensity (Z) was prepared and the susceptible sites to erosion were identified. The volume of erosion (WSP) was then calculated by equation No. 2 (Table 4) Figure No. 4 shows the erosion in the watershed area. The sedimentation yield in the Ghareh Aghach watershed was classified in four categories eroded (low, medium, high and very high) using EPM model.

Table 2. Coefficients of four contributing factors in erosion and Erosion intensity by EPM model

Uniform unit	Ψ	Y	Xa	I	Z	Erosion class
1_FS_d	0.35	0.15	0.4	2.236	0.155	Low
1_FS_Ekk	0.35	0.54	0.4	2.236	0.559	Medium
1_FS_omk2	0.35	0.66	0.38	2.236	0.649	Medium
1_FS_PL(b,c)	0.35	0.48	0.38	2.236	0.427	Medium
1_FS_Q	0.35	0.3	0.38	2.236	0.295	Low
2_FS_d	0.35	0.15	0.38	3.873	0.241	Low
2_FS_Ekk	0.35	0.54	0.39	3.873	0.889	High
2_FS_omk2	0.35	0.66	0.38	3.873	1.059	Very High
2_FS_PL(b,c)	0.35	0.48	0.27	3.873	0.547	Medium
2_FS_Q	0.35	0.3	0.38	3.873	0.481	Medium
4_FS_Ekk	0.35	0.54	0.38	5.916	1.286	Very High
4_FS_omk2	0.35	0.66	0.4	5.916	1.654	Very High
5_DM_Ekk	0.07	0.54	0.4	7.746	1.688	Very High
5_FAk_omk2	0.49	0.66	0.4	7.746	2.174	Very High
5_FAm_omk2	0.56	0.66	0.4	7.746	2.193	Very High
5_FS_d	0.35	0.15	0.4	7.746	0.486	Medium
5_FS_Ekk	0.35	0.54	0.4	7.746	1.749	Very High
5_FS_omk2	0.35	0.66	0.4	7.746	2.137	Very High
5_FS_Q	0.35	0.3	0.38	7.746	0.923	High
F	0.14	0.3	0.16	3.873	0.193	Low
Rock	0.21	0.54	0.24	6.325	0.847	High

Table 3. Coefficients of four contributing factors in erosion by EPM model

Subunits of watershed	C1	C2	C3	C4	C5
Y	0. 59	0. 53	0. 46	0. 47	0. 50
Ψ	0. 34	0. 32	0. 30	0. 33	0. 33
Xa	0. 35	0. 34	0. 33	0. 36	0. 37
I	6.87	6.22	3. 03	3.78	3. 35

2. The efficiency of EPM model to estimate erosion and sedimentation in Ghareh Aghach watershed

GIS system minimizes the personal effects in integrating the different information layers to identify the working units and detects and classifies the different erosion sites in the watershed. t student test was employed to compare the estimated erosion and sediment values by EPM model with measured values using SPSS statistical package (Isfahan Regional Water Organization. 2006.). the results in Table 5 showed that there were no significant differences (P < 0. 05) between the estimated and measured values. These results support the pervious achievements by the other researchers (Gaverlovic 1988, Shakeri,*et al*., 1996. and Shahbazi kia, *et al*., 2006).

Table 4. The calculated erosion and sediment for Gharehach watershed by EPM model

Subunits of watershed	C1	C2	C3	C4	C5
Coefficient of erosion intensity	2. 1	1. 7	0.427	0.42	0.42
Erosion class	V	V	III	III	III
Erosion intensity	Very high	Very high	Medium	Medium	Medium
WSP (m^3 /km^2/yr)	1534.1	1285.6	638.7	844.1	895.4
Area (km^2)	18. 39	16. 71	29. 08	13. 57	11. 79
Special erosion (ton/km^2/yr)	1903.9	1595.4	792.7	1047.5	1111.2
Annual erosion (ton)	14069.4	12145.7	10111.1	5565.4	11923.2
Observed erosion (ton)	31992. 5	17016. 9	124. 97	19584. 7	15901. 98
Coefficient of sedimentation (Ru)	0.1139	0.1083	0.1084	0.1332	0.1309
Special sediment (ton/km^2/yr)	281.3	233.8	114.8	151.7	162.8
Annual sedimentation (ton)	2073.4	1783.1	1465.4	809.1	1738.3
Observed sedimentation	12828. 99	7147. 1	5498. 7	7794. 7	6599. 32

Table 5. The statistical analysis and mean comparisons in EPM model

Statistical Characters	Erosion statistical Analysis					Sedimentation statistical Analysis				
	C5	C4	C3	C2	C1	C5	C4	C3	C2	C1
d_i	10574.8	-4427.3	108628	124.4	10234.2	4027.1	-1788.2	-461.5	4716.7	4114.9
$\bar{d}$			27484.736					14803.207		
S_{n-1}			45861.896					33429.46		
$S_{\bar{d}}$			20510.0637					14950.1		
Calculated **t**			1.34*					0.991*		

t: from table of P<0.05 for df=5 equal to 2.776

di: The difference between erosion and sediment (measured and estimated) (ton/ha/yr)

*: no significant difference between calculated t and t from table (P< 0.05)

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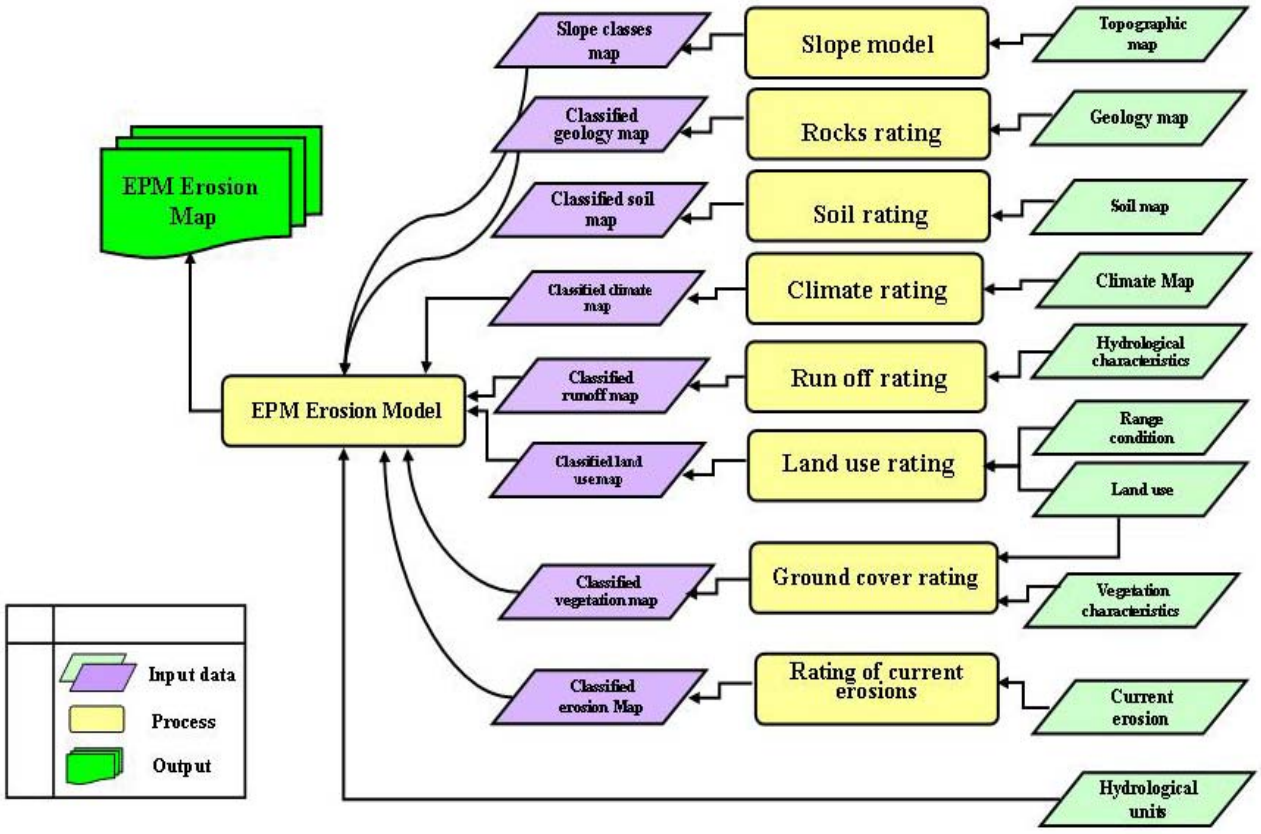

Fig. 1. EPM Model for Soil Erosion

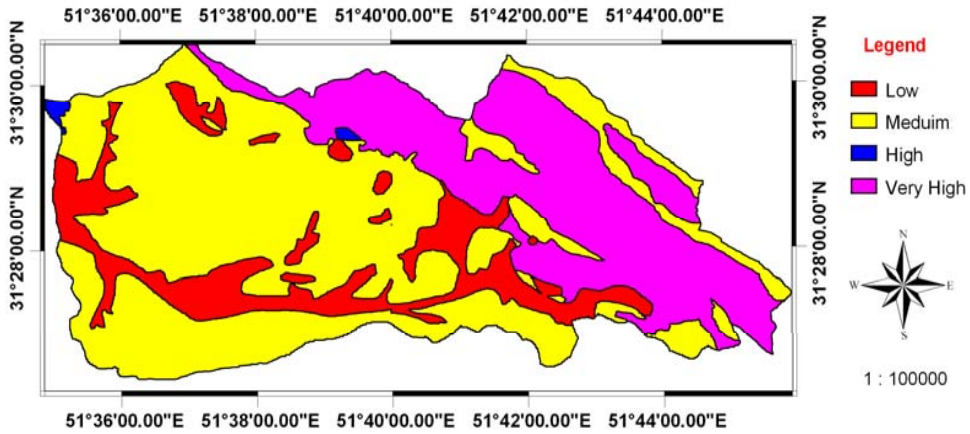

Fig. 4. The Intensity Erosion map (WSP) of Ghareh Aghach watershed

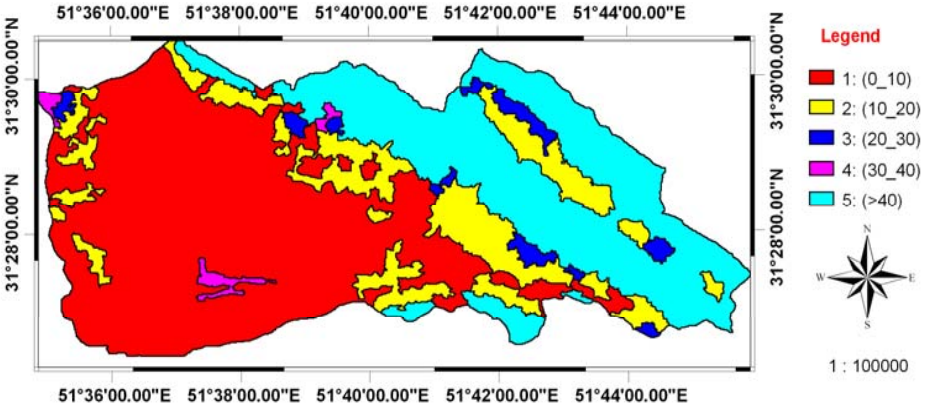

Fig 2. The Slope map of Ghareh Aghach watershed

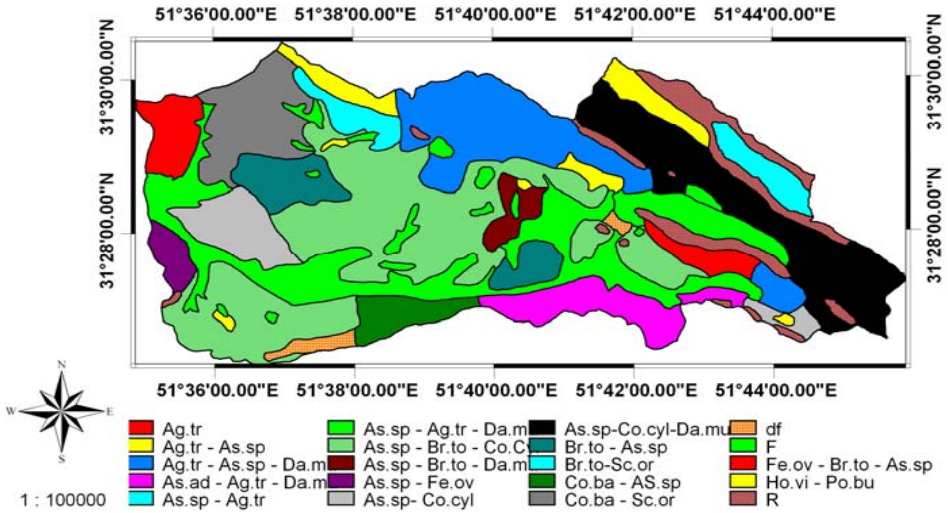

Fig. 5. The Vegetation map of Ghareh Aghach watershed

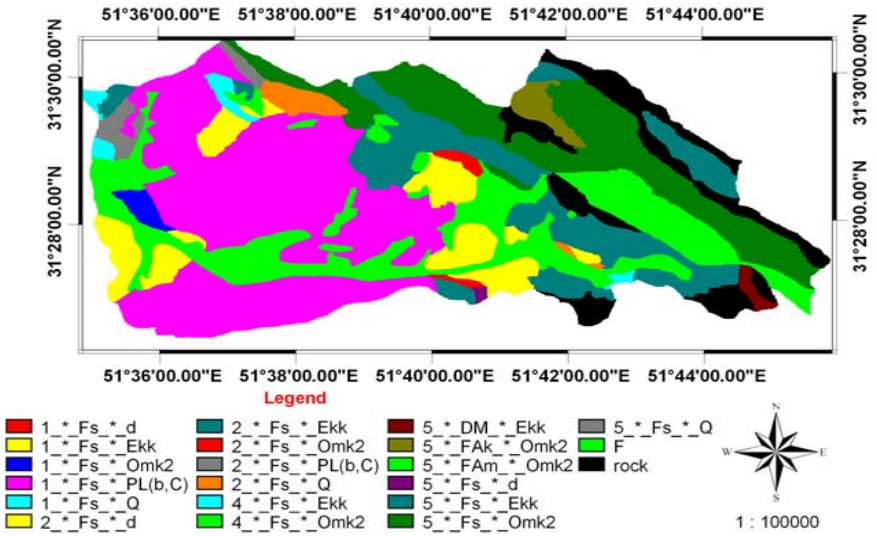

Fig. 3. Uniform Sampling Units map of Ghareh Aghach watershed