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Estimating of erosion and sediment yield of Gorganrud basin using erosin potential method

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Abstract
Soil erosion can be considered as one of the most important obstacles in the way of sustainable development of agriculture and natural resources. The aim of this study is to estimate erosion and sediment yield of basin using Erosion Potential Method, in Gorganrud basin, north of Iran. The main factors in the EPM (slope average percent, erosion, rock and soil resistance, and land-use) were evaluated using a GIS software. Then, each of the parameters has been classified in different categories based on the importance. Finally, the prepared layers integrated and overlaid in EPM model, and soil erosion map are calculated. The spatial distribution of erosion intensify classes showed that 7.4% of the total basin area had tolerate erosion, 25.9% slight erosion, 27.96% moderate erosion, 10.46% strong erosion, 9.91% very strong erosion, and 18.34% destructive erosion. The highest amount of erosion occurred in the northwest to northeast regions with lithological units including loess, and alluvial deposits and agricultural use despite the fact that slope factors in these areas were less than 10%. In the central, western, and eastern parts of the basin, in spite of 15%-55% of slope, the areas depicted a slight to moderate potential of erosion. This is supposed to be due to the dense forest coverage in the region that decreases the energy of rain droplets. Results showed that about 66.7% of the study area is classified in moderate to destructive erosion intensify (Wsp >15 t ha^{-1} $year^{-1}$). For avoiding soil erosion in this basin, soil conservation operation should be performed.

Keywords
erosion potential method, sediment yield, soil erosion.

1. Introduction
Soil erosion is one of the most significant environmental degradation processes that affect all landforms. Soil erosion refers to soil detachment, movement, and deposition by water, wind or farming activities such as deforestation, intensive plowing, and etc. Soil erosion rate depends on factors such as intensify of rainfall, topography, vegetative cover, type of soil, and land-use

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practices (Ritter & Eng, 2015; Renschler et al., 1999; Blanco & Lal, 2010). The intensification of Soil erosion may influence many natural phenomena and ecological processes (Yimer et al., 2007) such as a remarkable change in soil properties (Kertész & Huszár-Gergely, 2004; Wang et al., 2009), decreases the productivity of natural and agricultural ecosystem (Blanco & Lal, 2010; Toy et al., 2002), increase of runoff depth by the loss of soil (Feng et al., 2015; Kavian et al., 2014), reduces the water holding capacity and nutrient storage (Lal & Stewart, 1990; Pimentel & Burgess, 2013), and pollution and reducing their lifetime of reservoirs (Kumar et al., 2015; Ritter & Eng, 2015).

United nation in its developmental plan has reported that the soil erosion in Iran is about 20 ton/ha at the present, which has increased by 10 ton/ha compared to the last decade (UNDP, 1999). Changes in land use due to overgrazing, deforestation, cultivation, road construction, and industrial development are possible causes that tend to accelerate the removal of soil material in excess of that which is removed by geological erosion (Safamanesh et al., 2006). Thus, estimation of soil loss, and identification of critical area for implementation of best management practice are central to success of a soil conservation program (Saha, 2003). It is necessary to get help from quantitative and qualitative models for programming and making priority in soil conservation due to lack of sediment gauging station in some catchment for anticipating and evaluating of catchment erodibility and many limitations in cost of erosion plots possess, and constraint of limited samples in complex environments for quantifying soil (Zia Abadi & Ahmadi, 2011; Chen et al., 2011).

Many soil erosion models were developed to quantify priority watersheds based on the sediment production rate (Chen et al., 2011; Pandey et al., 2007). These models range from empirical Revised Universal Soil Loss Equation (RUSLE) (Ganasri & Ramesh, 2016; Wischmeier & Smith, 1978), Pacific Southwest Interagency Committee (PSIAC) (Heydarian, 1996; Clark, 2001), and Erosion Potential Method (EPM) (Gavrilovic, 1988; Da Silva et al., 2014) to physical process-based models such as Erosion Productivity Impact Calculator (EPIC) (Williams et al., 1983), Kinematic Erosion Simulation Model (KINEROS) (Woolhiser et al., 1990), and so on. Since all these factors are varied in both space and time, the use of remote sensing and Geographical Information System (GIS) techniques helps to study patterns of spatial change in soil erosion and their driving forces over different periods of time with reasonable costs, and better accuracy in larger areas (Wang et al., 2003; Bartsch et al., 2002; Arekhi et al., 2012).

In this study, EPM model was used to estimate the quantity and quality of sediment. EPM model was created based on erosion measurement during 40 years in previous Yugoslavia, and for the first time introduced in River Stream International Conference by Gavrilovic in 1988. An significant evolution of the Gavrilovic EPM model is its application based on spatially distributed input data of four basic factors which influence erosion rate: (a) climate (precipitation and temperature), (b) vegetation (type and distribution), (c) relief (difference in elevation; slope angle) and, (d) soil and rocks properties (erodibility and resistance) (Emmanouloudis et al., 2003; Fanetti & Vezzoli; 2007; Globevnik et al., 2003; Solaimani et al., 2009).

Although EPM model is an semi-quantitative, it not only predicts erosion rates of ungauged watersheds using knowledge of the watershed characteristics and local hydro climatic conditions, but also presents the spatial heterogeneity of soil erosion that is too feasible with reasonable costs and better accuracy for environmental monitoring and water resources management in larger areas (Angima et al., 2003). This method has been implemented in some catchments area in Iran, and it is appeared that output results are appropriate for rapid assessment of the effects of environmental change and watershed management interventions (Maleki, 2003; Khaleghi, 2005; Modallaldoust, 2007; Rostamizad & Khanbabaei, 2012). This paper shows the application of EPM model in qualifying the erosion severity and estimating the total annual sediment yield in a part of Gorganrud basin, north of Iran. Since erosion and sediment measurement in some cases are costly, we have to estimate these important parameters through the proposed models. By using erosion models, we are able to locate erodible areas, then put them on priority to soil conservation programs, and bring them under control.

2. Study area

The study area is situated in the Golestan Province, south of Caspian Sea in Iran. The area of Gorganrud drainage basin is 1480 Km^2, which is located between latitude of 36° 30′ - 38° 8′ N and longitude of 53° 57′ - 56° 22′ E. The geomorphology is characterized by flat area in the north section and mountains in the south with elevations ranging from -23 to 3708 m above the sea level and slopes varying among 1 to 80%. The mean annual precipitation and temperature are 549 mm and 16 °C respectively, which classified the site in Mediterranean climatic conditions according to Koppen (Csa) and De Martonne (I=21.6) categories. The main lithological units are Shale, Marl, Limestone, Dolomite, Sandstone, and Fluvial deposits in the study basin. Moreover, to survey the land degradation at the study area, the basin subdivided into homogeneous terrain units based on the Digital Elevation Model (DEM) and river layer in ArcHydro Extension of ArcGIS software. Sub-basin characteristics such as morphological and properties are shown in Figure 1 and Table 1.

Table 1. Characteristics of sub-basins at the study area.

Sub basin	Length (Km)	Area (Km^2)	Average slope (%)	Annual temperature (°C)	Annual precipitation (mm)
1	24	151.74	16.07	15.1	605.76
2	18	128.90	13.88	17.2	542.08
3	16	90.55	36.78	16.3	640.41
4	18	65.79	16.25	15.7	652.29
5	17	151.98	9.61	14.7	640.39
6	24	144.71	18.40	14.8	642.06
7	16	250.55	45.35	8.9	524.71
8	11	141.84	27.21	6.5	370.22
9	13	153.80	34.09	5.3	399.85
10	14	90.51	32.20	9.2	564.05
11	33	139.22	34.32	10.2	464.51

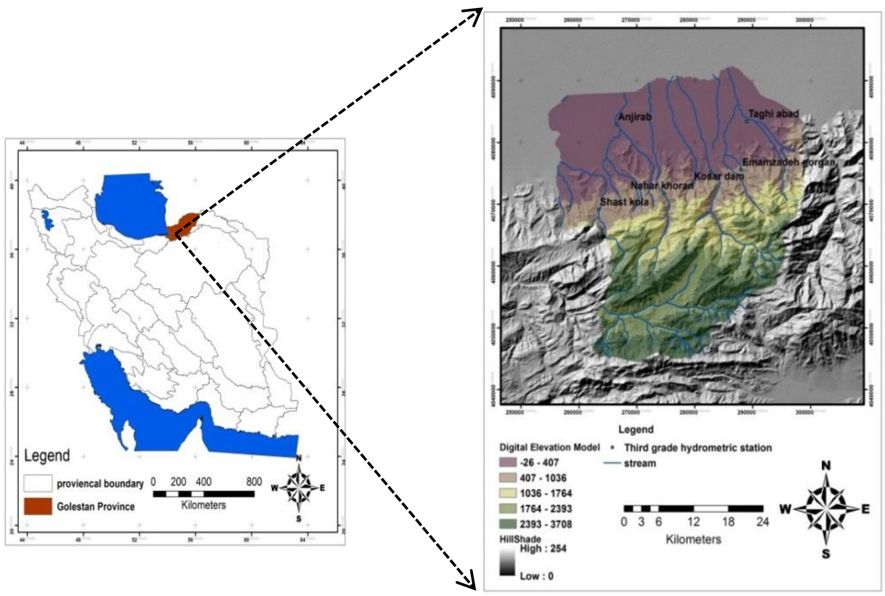

Fig. 1. Geographical location of the Gorganrud basin in Golestan province, Iran

3. Materials and Methods

3.1. Model description

Lack of information to prepare erosion maps for quantitative and qualitative sediment evaluation is a major problem for watershed management in Iran. There are not enough sediment measurement stations in most watersheds of the country, which makes it more difficult to provide specific models based on local watershed characteristic. One of the most important problems with empirical models of soil erosion is their lack of accuracy in processing large number of data, which must be digitalized by the Geographic Information System (GIS) and analyzed by mathematical models (Amiri & Tabatabaie, 2009). EPM is an empirical model to estimate the quantity and quality of sediment. According to the EPM model, the coefficient of erosion intensity (Z) is calculated by Equation (1) in this model.

$$Z = Y.X_a\left(\Psi + I^{0.5}\right) \quad (1)$$

where, Y is Susceptibility of rock and soil erosion, rating from 0.25 – 2, Xa is the land use coefficient, ranging from 0.05 – 1, Ψ is erosion coefficient of watershed, ranging from 0.1 – 1 and I is the average land slope in terms of percentage. The basic EPM value of the quantitative erosion intensity is the Erosion Coefficient (Z). The quantitative value of the erosion coefficient (Z) has been used to separate erosion intensity into classes or categories according to Table 2 (Gavrilovic, 1988).

Table 2. Classification of Z coefficient value (Gavrilovic, 1988)

Erosion and torrent category	Qualitative name of erosion category	Range of values of coefficient (Z)	Mean value of coefficient (Z)
I	Excessive erosion	Z > 1	Z = 1.25
II	Heavy erosion	0.71 < Z <1	Z = 0.85
III	Medium erosion	0.41 < Z <0.71	Z = 0.55
IV	Slight erosion	0.2< Z <0.4	Z = 0.30
V	Very slight erosion	Z < 0.19	Z = 0.10

The mean value of the EPM erosion coefficient (Z) for the basin area is the basic value for all EPM calculations. The volume of soil erosion is calculated by Equation (2) in this method.

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

where, Wsp is the volume of soil erosion ($m^3/km^2/yr$); H is mean annual rainfall (mm); π = 3.14; Z is erosion intensity, and T is coefficient of temperature calculated by Equation (3).

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

where, t is mean annual temperature in centigrade. The sediment production rate in this model is calculated based on the ratio of eroded material in each section of the stream to the total erosion in the whole watershed area by Equation (4).

$$Ru = 4\left(P.D\right)^{0.5} / \left(L + 10\right) \quad (4)$$

where, P is the circumference of the watershed; L is watershed length (Km); D is height difference in watershed area (Km). After calculation of Ru value the special sediment rate is estimated by Equation (5) (Refahi, 2004).

$$G_{SP} = W_{SP}.Ru \quad (5)$$

Where, Gsp is special sediment rate; Wsp is volume of special erosion; and Ru is coefficient of sedimentation (Ahmadi, 2006; Refahi, 2004).

3.2. Data collection

The EPM model was developed based on spatially distributed input data such as surface geology (rock and soil), topography (elevation and slope), climatic factors (mean annual precipitation and temperature), and the land use in a Geographic Information System environment (Solaimani et al., 2009). After establishing the set of criteria, each criterion should represent as a map layer in the GIS data base. In the presented study, the Digital Elevation Model (DEM) with a resolution of 30 m was used to generate slope parameter through Raster Surface tools in ArcGIS. The DEM layer was provided by National Cartographic Center of Iran

(NCC). Lithological map of Gorganrud area was prepared by scanning, geo-referencing and digitizing the 1:100,000 geology map produced by the Geological Survey and Mines Bureau of Iran. Also, Landsat-ETM$^+$ satellite image with spatial resolution of around 15 and 30 m was downloaded from https://earthexplorer.usgs.gov/ and was used for producing of land use parameter in the area. Moreover, meteorological data for calculation of mean annual temperature and rainfall was obtained from the Meteorological Organization, and imported into the ArcGIS environment. In next stage, The Inverse Distance Weighted (IDW) interpolation method was used to generate a raster maps for this parameters. Also, the available 1:1,000,000 erosion map prepared by the Geological Survey and Mines Bureau of Iran represents only the major erosion in the area. Therefore, image processing techniques were employed to delineate other erosion of the study area. The erosion map was modified using digital and thematic maps for identifying and classification of area with a similar pattern of erosion. This would be required to DEM layer and identifying the area with a similar conditions such as geological and vegetation characteristics. Finally, an erosion map was produced by merging the erosion map prepared by the Geological Survey and Mines Bureau of Iran and modified layer using GIS techniques. Then, all parameter maps were converted to grid layers with 30m × 30m cell size. In next stage, the layers were overlaid and multiplied pixel by pixel, using Equation 1 to 5, to determine the soil erosion intensify and the spatial distribution of soil erosion. Figure 2 shows the schematic representation of the methodology and the following sections describe the techniques used to generate the data and to evaluate the erosion factors.

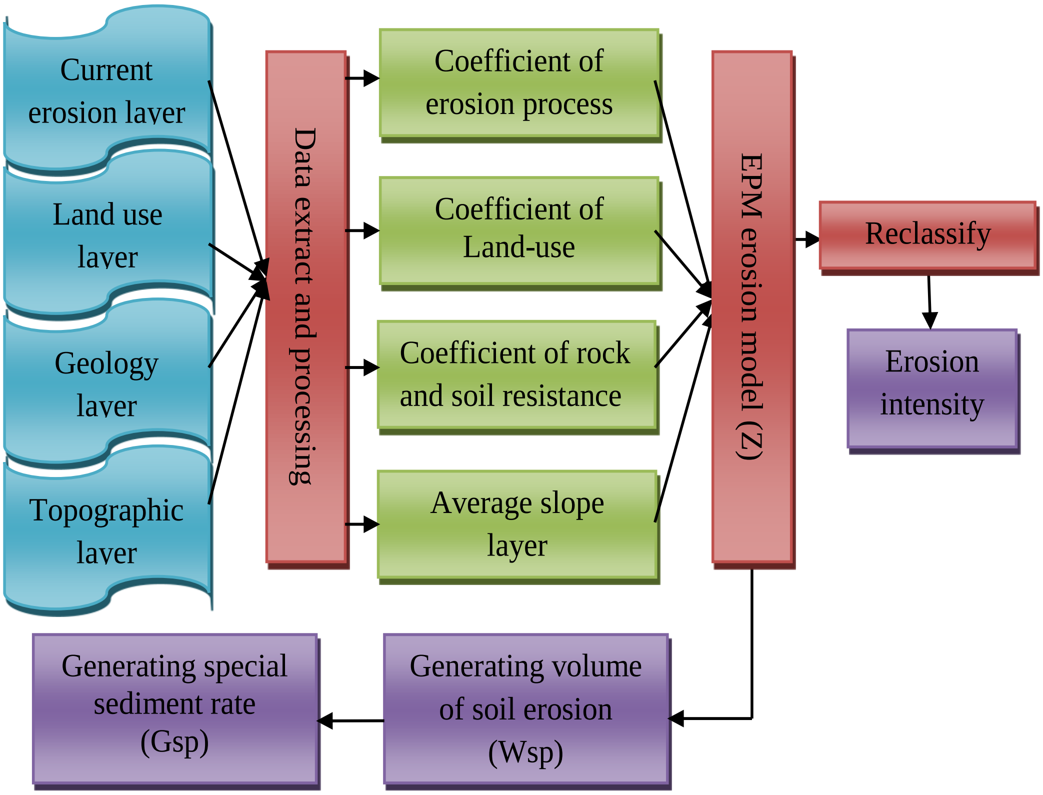

Fig. 2. Schematic representation of the methodology

3.3. Implementation of erosion potential modelling in GIS

3.3.1. The coefficient of rock and soil resistance to erosion (Y-factor)

Different rocks can have very different resistance attributes not only due to their different material strengths, but also because of the different geologic structures associated with the different rock types (Tan, 2005). In this study, the lithological layer was obtained through scanning, geo-referencing, and digitizing the 1:100,000 geology map produced by the Geological Survey and Mines Bureau of Iran. Rock exposures in the study area mostly consist of Upper Red, Doroud, Lar, Mobarak, Shemshak formation, and Quaternary deposits with different resistance to erosion. Lithological units were reclassified into 17 categories based on their resistance to erosion according to Feyznia's Method (1995), and the Y coefficient were assigned from 2 (high sensitivity to erosion) to 0.25 (low sensitivity to erosion) based on EPM Guide Table. The evaluated Y-coefficient is shown in Table 3 and Figure 3(a). Result showed the lowest coefficient was given to the Limestone dolomite, Limestone, Sandstone, Conglomerate, Slate shale and Limestone thick bedded units due to highest resistance to erosion and the highest value of coefficient was given to Fluvial deposits and Loess units due to lowest resistance to erosion.

Table 3. The evaluated coefficient of rock and soil resistance to the erosion (Y-coefficient)

Main litology	Symbol	Y- coefficient
Limestone dolomite, limestone	Cm1	0.5
Alternation of limestone and marl	Pr	1.2
Alternation of tuff, marl with bedding of conglomerate	E1mt	0.9
Loess	Qc	1.8
Dark shale, marl, limestone, dolomite and sandstone	Dkh	1.2
Green schist, Quartzite sandstone, Slate stone and marble	Osch	0.9
Limestone thick bedded, marl and lime shale stone	Cmlm	0.9
calcareous sandstone with bedding of shale	E3ts	1.2
White marl limestone	Ku1	1.4
Limestone thick bedded	Jl1	0.5
Gray shale with bedding of sandstone	Js2	1.8
Limestone, sandstone, conglomerate, slate shale	Pd1	0.7
Fluvial deposits	Qal	2
Alternation of conglomerate and sandstone and clay	Plc	0.9
Sandstone, conglomerate, shale	Clgh	0.7
Mainly sandstone and silt clay	Qsc	1.4
Marl shale with bedding of calcareous sandstone and onglomerate	Js3	1.2

3.3.2. Land use coefficient (Xa-factor)

Human–induced changes to natural landscape have been identified as one the greatest threats to fresh water resources (Dale et al., 2000). Soil erosion, salinization, desertification, and other soil degradations associated with intensive agriculture and deforestation reduce the quality of land resources and future agricultural productivity (Lubowski et al., 2006). In order to determine the Xa factor value, Landsat-ETM satellite images were applied to generate land use map. Multi-spectral and panchromatic ETM^+ images with spatial resolution 30 m and 15 m, respectively, can be combined in a variety of ways to accommodate a wide range of high resolution imagery applications using for land use mapping. We were able to distinguish plantation forest from the natural one. Then, The Digital Elevation model (DEM) and Ground Control Points (GCPs) were used for geometric correction. In next stage, training samples must carefully be determined. Training samples were obtained from a visit of field works, Google earth, digital topographic maps and interpretation of false color composite. Finally, Image classification was done using supervised classification maximum likelihood. Based on this method, eight land use categories were defined that the achieved overall accuracy and the kappa coefficient were 92.33% and 0.9%, respectively (Table 4). According to Stehman (2004), accuracy assessment reporting requires the overall classification accuracy above 70% and kappa coefficient above 0.7 which were successfully achieved in the present research.

Then, relative sensitivity of each category could be rescaled into the range 1 (for high sensitivity area to erosion) to 0.05 (for low sensitivity area to erosion) according to EPM Guide Table (Gavrilovic, 1988). The evaluated of Xa-coefficient is shown in Table 5 and Figure 3(b).

Table 4. The accuracy of classification of satellite image processing

Land use classes	Producer's accuracy	User's accuracy
Residential area	90.1	100
Dense forest	100	91.66
Semi-dense forest	100	100
Semi-woodland-pasture	90.9	93.02
Thin woodland-pasture	86.11	88.57
Pasture-bare land	97.5	90.69
Agriculture- plantation	86.2	83.33
Industrial	92.1	97.22
Kappa coefficient	0.91	
Overall accuracy	92.33	

Table 5. The evaluated coefficient of land-use (Xa- coefficient)

Land-us/Cover	Xa coefficient
Dense forest	0.1
Semi-dense forest	0.3
Pasture-bare land	0.7
Semi-woodland-pasture	0.5
Thin woodland-pasture	0.6
Agriculture- plantation	1
Industrial	0.8
Residential area	0.8

3.3.3. The coefficient of erosion processes (Ψ-coefficient)

Soil erosion has been considered as one of the most influential causes of land degradation due to loss of surface soil and plant nutrients (Wijitkosum, 2012). The primary map of erosion processes, produced by Geological Survey and Mines Bureau of Iran, was overlaid and modified based on rock type, slope-classes, and canopy percentage. Then, the generated erosion map was reclassified into 5 categories, ranging from 0.3 to 1.0 to determine the Ψ factor. The coefficient values for each category were presented in Table 6 and Figure 3(c).

Table 6. The coefficient values for observed erosion processes (Ψ-coefficient)

Erosion category	Ψ Coefficient
Slight erosion	0.3
Medium erosion	0.5
50-80 %of basin area affected by surface erosion	0.7
Whole area affected by erosion	1

3.3.4. The coefficient of slope classes (I-factor)

Slope gradient is a factor affecting raindrop detachment, infiltration and energy of runoff. Thus, not only the magnitude of soil loss, models of runoff and soil erosion are also affected by slope gradient (Zhang & Hosoyamada, 1996). Land slopes were generated using a Digital Elevation Model (DEM). The coefficient of slope classes is shown in Figure 3(d).

Once the criteria maps are preprocessed and the associated coefficient assigned to each input layer, these output data are transformed to produce erosion intensity and specific sediment yield maps. The quantitative output of the erosion severity (Z) (Fig. 4) in the EPM model was evaluated by Equation (1) and then the mean value of the erosion coefficient (Z) were categorized into slight to extreme erosion zones according to Table 2.

Besides, the volume of soil erosion (Wsp) after EPM model was predicted using H and T parameters according to Equations (2) and (3) (Figs. 5a and 5b). The classification of temperature parameter is shown in Table 7.

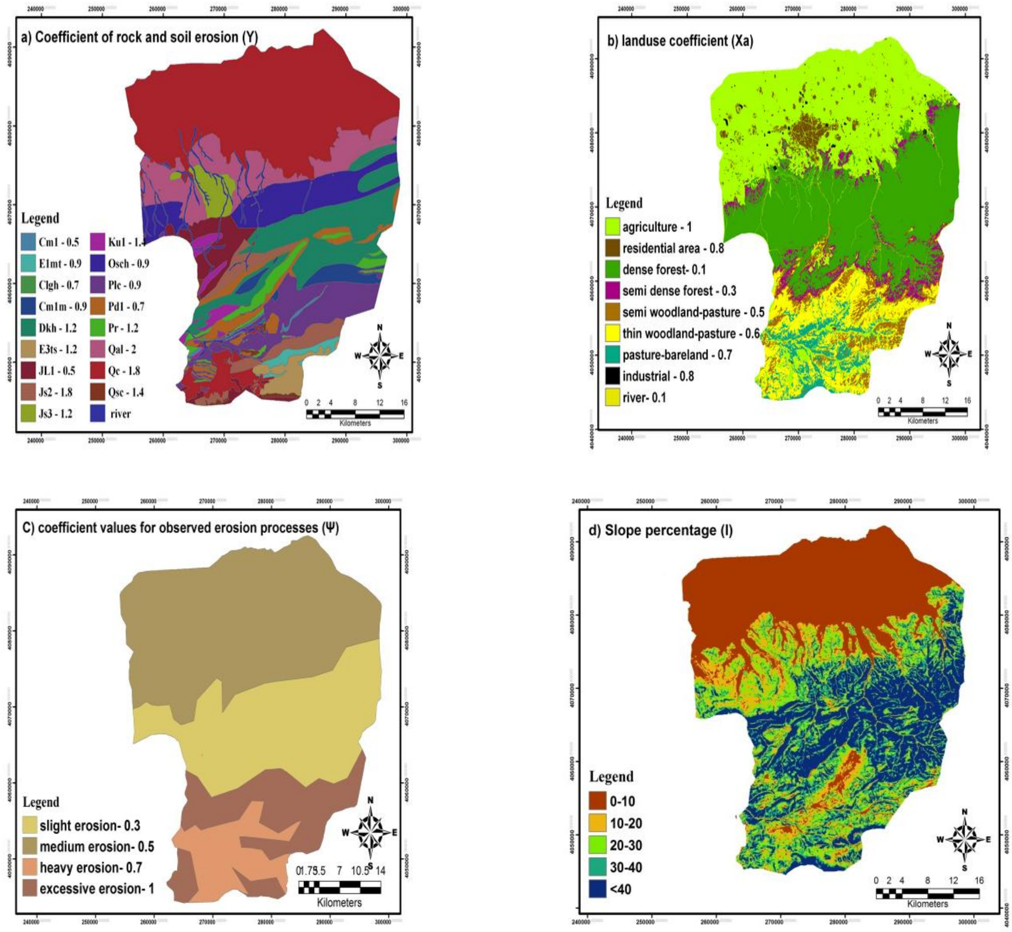

Fig. 3. The category of factors for implementing the Erosion Potential Model

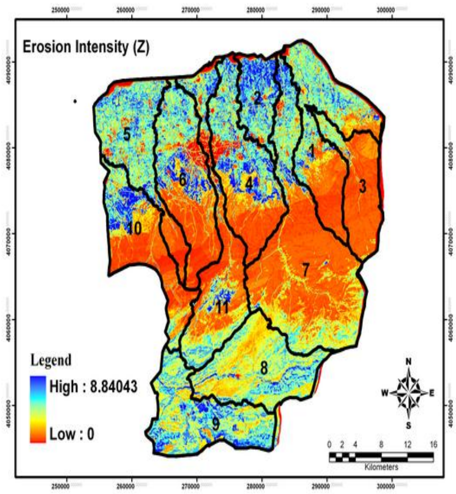

Fig. 4. The quantitative output of the erosion severity (Z) in the EPM model

Table 7. Mean annual temperature intervals and the calculated T parameter used in EPM

Temperature (°C)	Coefficient temperature (T)
0 - 5	0.59
5 - 10	0.92
10 - 15	1.16
15 - 20	1.36

When all factors required for the EPM model were prepared, these data layers were overlaid and soil loss per year was calculated. The steps for producing the volume of soil erosion (Wsp) and special sediment rate (Gsp) are shown in Figure 5. Moreover, in order to determine the amount of soil loss from each sub-basin, the sub-basin boundaries were overlaid with annual soil erosion map (Table 8).

Table 8. Coefficient of erosion and sedimentation yield for all sub basins of Gorganrud basin

Sub-basin units	Z coefficient	Erosion class	Erosion intensity	Average of Wsp ($m^3/Km^2.yr$)	Average of Gsp ($m^3/Km^2.yr$)	Area (%)
1	1.5	I	Excessive	4744	3032	2.3
2	2.6	I	Excessive	6140	5760	4.4
3	0.3	IV	Slight	1860	944	6.6
4	2.2	I	Excessive	6068	5788	11
5	2.1	I	Excessive	7285	5736	9.4
6	1.5	I	Excessive	5800	5632	11.2
7	0.7	III	Medium	3987	3787	21.30
8	0.45	III	Medium	2854	2364	10.77
9	2.5	I	Excessive	4757	2879	10.16
10	0.34	IV	Slight	1311	1245	2.4
11	0.7	III	Medium	3977	3730	10.54

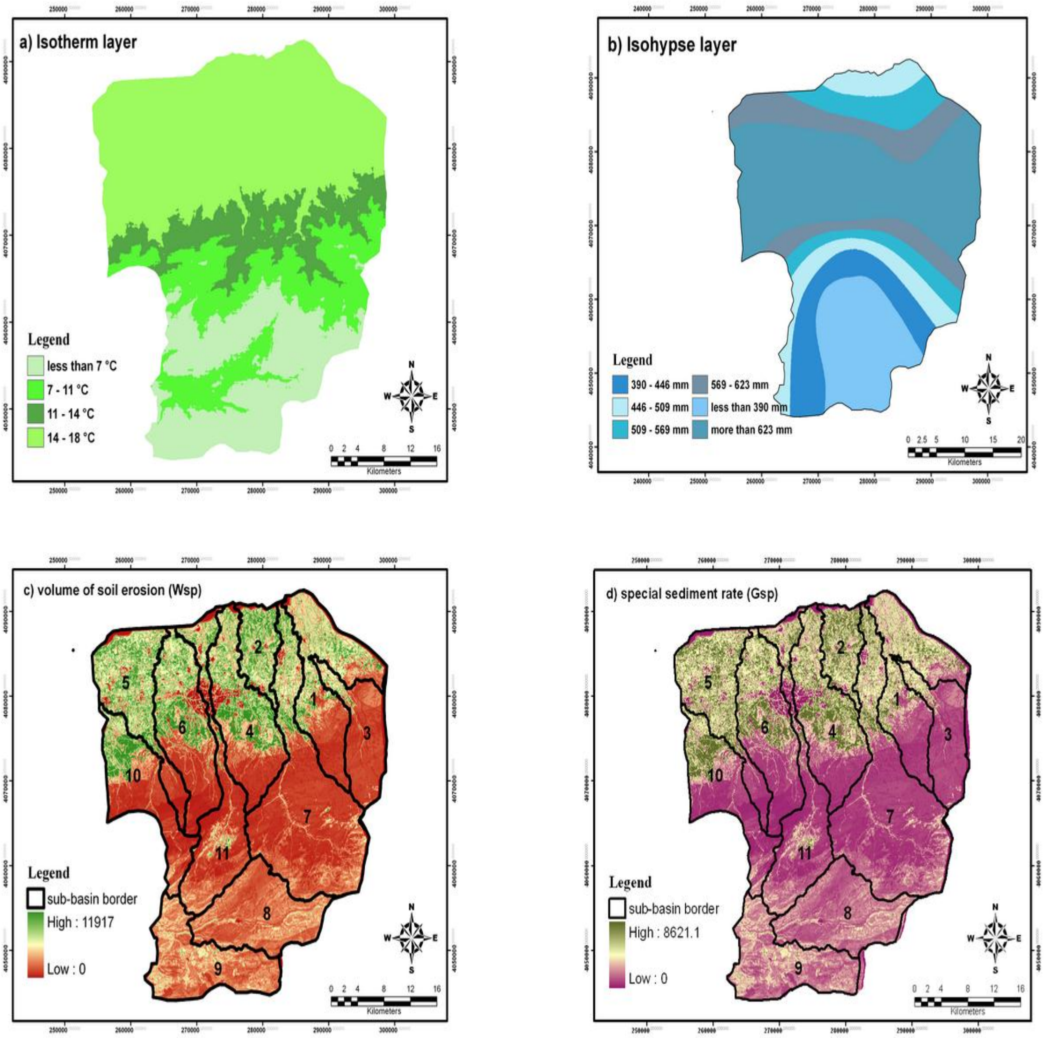

Fig. 5. The steps for producing of the volume of soil erosion and special sediment rate

4. Results and Discussion

4.1. General characteristics of soil erosion

The results presented in Table 8 showed that the average volume of soil erosion (Wsp), and the average of spatial sediment rate (Gsp) in the drainage basin was 4434 m^3/Km^2.yr and 3717 m^3/Km^2.yr, respectively. In addition, in order to assess the roles of land use and slope in soil loss, land use and slope maps of the area were intersected with volume of soil erosion map. In this stage, The volume of soil erosion map is converted to ton in hectare and is classified into six classes based on "Technical standards for comprehensive control of water and soil erosion" (SL657-2014), such as, (a) tolerate (<5 $t{\cdot}ha^{-1}{\cdot}year^{-1}$); (b) slight (5 to 15 $t{\cdot}ha^{-1}{\cdot}year^{-1}$); (c) moderate (15 to 40 $t{\cdot}ha^{-1}{\cdot}year^{-1}$); (d) strong (40 to 60 $t{\cdot}ha^{-1}{\cdot}year^{-1}$); (e) very strong (60 to 80 $t{\cdot}ha^{-1}{\cdot}year^{-1}$); and (f) destructive (>80 $t{\cdot}ha^{-1}{\cdot}year^{-1}$) (Zhang et al., 2015). The reclassified soil loss is shown in Figure 6.

The results showed that about 33.3% of the study area is classified as tolerate erosion to slight erosion intensify (Wsp <15 t ha^{-1} $year^{-1}$), while rest of the area is under moderate to destructive erosion risk. In terms of actual soil erosion risk, the spatial distribution of erosion intensify classes was 7.4% of the total basin area had tolerate erosion, 25.9% slight erosion, 27.96% moderate erosion, 10.46 strong erosion, 9.91% very strong erosion, and 18.34% destructive erosion. The spatial pattern of classified soil erosion risk zones indicates that the areas with strong to destructive erosion risk (units number: 1, 2, 4, 5, 6, 9) are located in the north west to north east and southern regions of the study area while the areas with tolerate erosion to moderate risk (unit numbers: 3, 7, 8, 10, 11) are in central, western, and eastern parts of the study area.

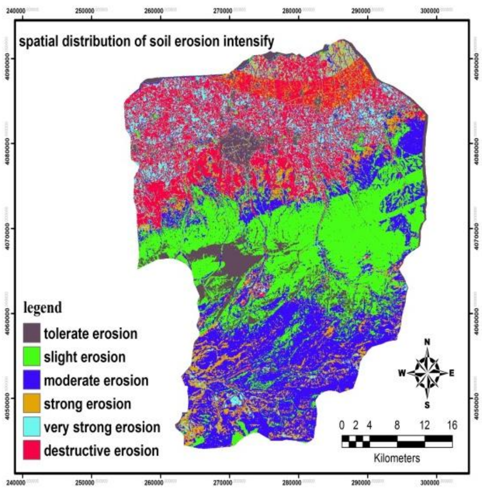

Fig. 6. The spatial distribution of soil erosion intensify map

4.2. Relationship between soil erosion and land use

Tabulate intersect analysis of land use and soil erosion intensify maps in Table 9 showed that about 92.77% of erosion area in dense forest land is classified as tolerate to moderate erosion intensify. Also, the highest area percentage values of erosion in semi dense forest land are slight to strong erosion (85.7%), as similar as performance showed in semi woodland- pasture (95.1%), thin woodland- pasture (96.7%), and pasture- bare land (96.1%). This issue pointed that vegetation cover type and density have significant roles in decrease of soil erosion intensify. Van Dijk et al. (1996) pointed out the interest in the relationships between plant and the effects on soil erosion, showed that vegetation density and a complete canopy are key features for sediment trapping. Also, result showed that about 83.5%, and 61.1% of erosion area in agriculture and industrial lands are classified as strong to destructive erosion intensify. This area is mainly located in the northwest to northeast regions and it is much serious problem in study area. Zhang et al. (2015) pointed out the forest and orchard land show positive effects on reducing runoff and sediment yield while the farmland and fallow land have opposite effects.

Table 9. Related feature tables between soil erosion and land use in the study area

Intensify level	Agriculture land		Residential area		Dense forest		Semi dense forest		Thin woodland-pasture		Semi woodland-pasture		Pasture - bare land		Industrial area	
	Area (km^2)	Ratio (%)	Area (km^2)	Ratio (%)	Area (km^2)	Ratio (%)	Area (km^2)	Ratio (%)	Area (km^2)	Ratio (%)	Area (km^2)	Ratio (%)	Area (km^2)	Ratio (%)	Area (km^2)	Ratio (%)
Tolerate	23.2	4.7	12.8	34.5	67.1	12.5	3.8	5.3	0.6	0.3	1.6	2.0	0.15	0.2	2.0	5.3
Slight	11.5	2.3	0.4	1.1	325.7	61.0	18.4	25.3	14.6	8.3	7.4	9.1	9.4	13.2	2.9	7.6
Moderate	47.2	9.5	3.1	8.2	102.6	19.2	32.6	45.2	124.4	70.7	58.6	72.4	46.9	66.1	5.5	14.8
Strong	63.6	12.8	4.2	11.3	19.9	3.7	10.4	14.5	31.3	17.8	10.9	13.6	11.9	16.8	5.1	13.6
Very strong	119.0	24.0	6.1	16.3	6.2	1.2	1.9	2.7	4.2	2.4	1.9	2.4	2.0	2.9	7.9	21.1
Destructive	231.5	46.7	10.3	28.0	13.1	2.4	5.1	7.1	0.8	0.4	0.4	0.5	0.7	0.9	14.2	37.9

4.3. Relationship between soil erosion and slope

Tabulate Intersection analysis of slope and soil erosion intensity maps in Table 10 showed the slope related to the amount of erosion is not linear and other factors affect the rate of erosion. Result showed that 64.1% of total erosion area in 0-10% slope class is classified as strong to destructive erosion intensify. overlaying the slope map with the land use and litologhical map showed that lithological units in this class is including loess and fluvial deposits and vegetation cover consist mainly of farmland and orchards. Also, the highest area percentage values of erosion 10-20% slope class is located in slight to strong erosion (85.7%), as similar as performance showed in 20-30%, and 30-40% of slope class. overlaying the slope map with the land use and litologhical map showed that the erosion rate is increased due to the high slope, poor land cover, and litoloigcal units of loess, calcareous sandstone with bedding of shale, tuff, and marl. Also, soil erosion in slope lands above 40% accounts for 60.7% of total erosion area in this class. The areas are located from tolerate to slight erosion potential. The main reasons are that these lands have been conserved with high forest coverage and few human activities. Other researchers found that the soil erosion increased exponentially with increasing slope gradient (Jordan et al., 2005), but the relationships are distinct for different slope degrees, landforms, soil types and other factors (Solaimani et al., 2009; Zhang et al., 2015).

Table 10. Related feature tables between soil erosion and slope in the study area

Intensify level	0-10		10-20		20-30		30-40		<40	
	Area (km^2)	Ratio (%)	Area (km^2)	Ratio (%)	Area (km^2)	Ratio (%)	Area (km^2)	Ratio (%)	Area (km^2)	Ratio (%)
Tolerate	30.4	5.8	11.0	6.1	15.3	7.0	12.9	6.8	33.5	9.4
Slight	27.9	5.3	47.6	26.6	63.0	28.6	64.7	33.9	182.3	51.3
Medium	65.3	12.4	65.4	36.5	86.4	39.3	79.5	41.6	109.9	30.9
Strong	65.2	12.4	19.6	11.0	25.5	11.6	20.8	10.9	22.2	6.2
Very strong	122.2	23.2	8.9	4.9	7.5	3.4	4.9	2.5	4.6	1.3
Destructive	215.1	40.9	26.8	15.0	22.3	10.1	8.2	4.3	3.1	0.9

5. Conclusion

Soil erosion is a major environmental threat to the sustainability and productivity in Iran. The average soil loss in Iran is estimated to be 20 to 30 ton/ha per year, which totals to about 5 billion tons per year. Thus, quantification of the actual rate and pattern of soil erosion and sedimentation is necessary for designing degradation control strategies. The EPM model is normally applied to estimate the soil erosion and the sediment rate in rehabilitation plans of watersheds. Based on the amount of parameter Z, most of Gorganrud basin has excessive erosion. By reviewing the amount of Wsp parameter and criteria map of the study area, we noted that the slope related to the amount of erosion is not linear and other factors affect the rate of erosion. In this study, land use and geology factors were very impressive compared to slope factor. The highest erosion has occurred in the northwest to northeast basin with lithological units including loess and fluvial deposits and agriculture use although the slope classes were 0% to 10%. In the central, western, and eastern parts of basin, in spite of 15-55 percent slope, the areas are located from slight to moderate erosion potential. This is due to the dense forest coverage in the region that decreases the energy of rain droplets. In south of basin, the erosion rate is increased due to the high slope and poor land cover. The study provided useful data on sediment yield for basin area, which could be used in natural resources and soil conservation projects. Although the EPM is a method for rapid and easy access to the erosion severity and sediment yield, it is completely knowledge based, and the accuracy of analyzed data primarily depends on the experience and knowledge of the experts who determine the values of erosion coefficients. However, because the EPM model considers only six factors for erosion potential assessment, it could readily be used for fast estimation of erosion potential in a sub-basin area, for which the database layers are limited.

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