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ORIGINAL ARTICLE

Evaluation of WEPP and EPM for improved predictions of soil erosion in mountainous watersheds: A case study of Kangir River basin, Iran

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Abstract

In the current study, WEPP and EPM models were used to estimate the amount of soil erosion and sediment in the basin of Kangir. The required data for implementation of the WEPP model were prepared in six categories including soil, climate, management, slope, drainage and reservoir based on which we took the information needed to build soil and management files. Some information such as texture, cation exchange capacity, organic matter, sand content, effective hydraulic flow and critical shear stress was used. After production of all the layers, the WEPP model was implemented using the GEOWEPP software. In this software, erosion and sediment amounts were estimated by three methods: domain, watershed and flow path methods. In the Kangir River watershed, the sediment content was 7.64 t/ha/year, 6.13 t/ha/year and 11.87 t/ha/year. Thus, the two methods of domain 7.64 t/ha/year and flow path 11.83 t/ha/year were closer to the observed sediment 10.5. Based on the EPM model, the sedimentation coefficient of the Kangir basin was 0.81. The results of the research indicate the high erodibility rate of the watershed basin. The erosion-sensitive units were located in the western and southwestern regions of the basin. In the EPM model, the erosion rate (*Z*) was 0.6 indicating moderate to high erodibility rate in the watershed. Furthermore, the highest erosion rate was in the western and southwestern parts of the watershed. Finally, the results of estimating soil erosion and sediment production in the watershed of Kangir illustrated that the WEPP model has a more accurate estimation of soil erosion and sediment production, and in this model, the flow path method used to estimate the amount of soil erosion and sediment production was close to the observed sediment at the hydrometric station.

Keywords Soil erosion · Mountainous watersheds · Sediment yield · WEPP · EPM · Kangir River basin

Introduction

Soil erosion and sediment production have a great impact on reducing soil fertility and waste and also lead to the filling of the reservoirs of dams. This destruction of the environment is as a result of human pressure on land use which has now become a major global problem (Alam 2018; Erlich 1988; Wilson 1992). Due to the high rate of population growth and the rapid degradation of natural resources, the effects of this destruction are felt in developing countries more than in developed countries (Feoli et al. 2000; Porro et al. 2020). Soil erosion, or so-called soil cancer, is a complex process with environmental impacts that pose a potential threat to human life (Owengh 2003). Understanding the type of erosion, the cause and mechanism of its creation help to control erosion and its management (Grauso et al. 2007). Therefore, investigating the behavior and nature of the river and watersheds, and accordingly, studying the drainage basin from many aspects such as flood control, erosion and

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sedimentation are of important significance (Brierley and Fryirs 2006).

Erosion models can be used to study and evaluate soil erosion in relation to land changes and the identification of sedimentary resources (Feng et al. 2010). They can be used to study soil erosion processes in relation to the way land is used in many parts of the world; they can also be used to produce hazard maps for soil erosion in basins where water conservation programs are proposed (Fox et al. 2006; Khan et al. 2001; Jain and Goel 2002). Nevertheless, several empirical, numerical and experimental methods have been developed to estimate the sediment yield of a watershed (Noori et al. 2016). Despite the wealth of erosion models and applications, though, selection of an appropriate model for operational mapping remains a difficult undertaking (Karydas and Panagos 2018; Zheng et al. 2020).

Comparison of different models in watersheds is available in the literature. Amore et al. (2005) analyzed scale effects in WEPP and USLE to compute soil erosion in three watersheds in Sicily. Verma et al. (2009) applied WEPP and HEC-HMS models to simulated erosion and watershed runoff in Upper Baitarani River basin of Eastern India. Defersha et al. (2012) evaluated erosion 3D and WEPP in Mara River basin in Kenya. Chandramohan et al. (2015) evaluated Unit Sediment Graph (USG), Water Erosion Prediction Project (WEPP) and Modified Universal Soil Loss Equation (MUSLE) in small watershed in Kerala, India. Fernández and Vega (2018) evaluated performance of WEPP and RUSLE for soil erosion modeling after wildfire in northwest of Spain. Abdelwahab et al. (2018) compared AnnAGNPS and SWAT models in Apulia, Southern Italy.

All these literatures suggest local scale erosion modeling and testing the models in watershed regarding their special conditions (Jazouli et al. 2019). The WEPP and EPM models were selected to evaluate the erosion in the Kangir watershed. The EPM model is an effective model that can be used for initial estimations of the rate of sedimentation in water paths in plans related to dams' under-construction and other structures that require such data. In this model, the factors affecting soil erosion including topography, lithology, soil and land use as well as climatic factors of the basins are applied. The WEPP erosion estimation model is basically a physical model that calculates soil erosion and loss using spatial development approaches (Foster et al. 1995), and in contrast to the USLE/RUSLE and RUSLE2 models that have been used recently, the WEPP represents a new approach in calculating and estimating soil erosion and loss in a watershed (Kinnell 2017; Kinnell et al. 2018; Yu et al. 2000). The WEPP not only possesses all the capabilities of the USLE model and other models of estimation of soil erosion and sediment but also considers runoff as a factor in predicting soil loss and calculates erosion with considerably more fundamental tools (Flanagan et al. 2007; Jiang et al. 2019; Kinnell 2017). Furthermore, the WEPP model is also able to assess the effects of management and interventions as well as environmental changes occurring in the basin on spatial scales (Yu et al. 2000). Moreover, freely availability of model and applicability at various scales and working with little data (Defersha et al. 2012) plus results of many papers which approve WEPP model abilities in events (Acharya et al. 2011; Fernández and Vega 2018; Mirzaee et al. 2017; Srivastava et al. 2020; Yu and Rosewell 2001) and in comparison with SWAT (Shen et al. 2009), other models lead us to use it.

In the Kangir watershed, this is the first erosion research. The purpose of this study was to evaluate the erosion amount and sediment production in the Kangir watershed using WEPP and EPM models and find the best model for this watershed and similar basins. This has not been carried out thus far, and the aim is to fill this gap in the research literature and achieve precise and applied results in soil erosion and sediment production in areas with high vulnerability and low number of conservation programs. The specific research objectives of the study are to (1) identify potential sediment source areas and estimate the rate of sediment yield and (2) to evaluate WEPP and EPM's performance in predicting soil erosion. Results from this study will help quantify the current rate of erosion, identify erosion hot spot areas and also evaluate the effect of different factors on the erosive processes.

Study area

The Kangir watershed covers an area of 71.553 square kilometers in the southeast Ivan basin in the west and north of Ilam Province. The basin is at longitude of 46° 17′ 11″ to 46° 27′ 35″ East and latitude 33° 41′ 14″ to 33° 50′ 57″ North. Kangir River is the only permanent river of the basin which originates from Sarab Ivan located 9 km southwest of the Kangir basin. The river flows from the southeast to the northwest and receives temporary flow from the northeast and southwest directions. Kangir watershed is one of the subbasins of Ivan which is located between the Ilam, Sirrwan, Mehran and Gadar basins. In fact, the main river in this basin is the Kangir River created as a result of the connection between the two rivers of Chavar and Kangir. Kangir Dam was also constructed at the site of the river (Fig. 1).

Materials and methods

WEPP model

In 1980 the first steps were taken to develop Water Erosion Prediction Project (WEPP) model (Laflen and Flanagan

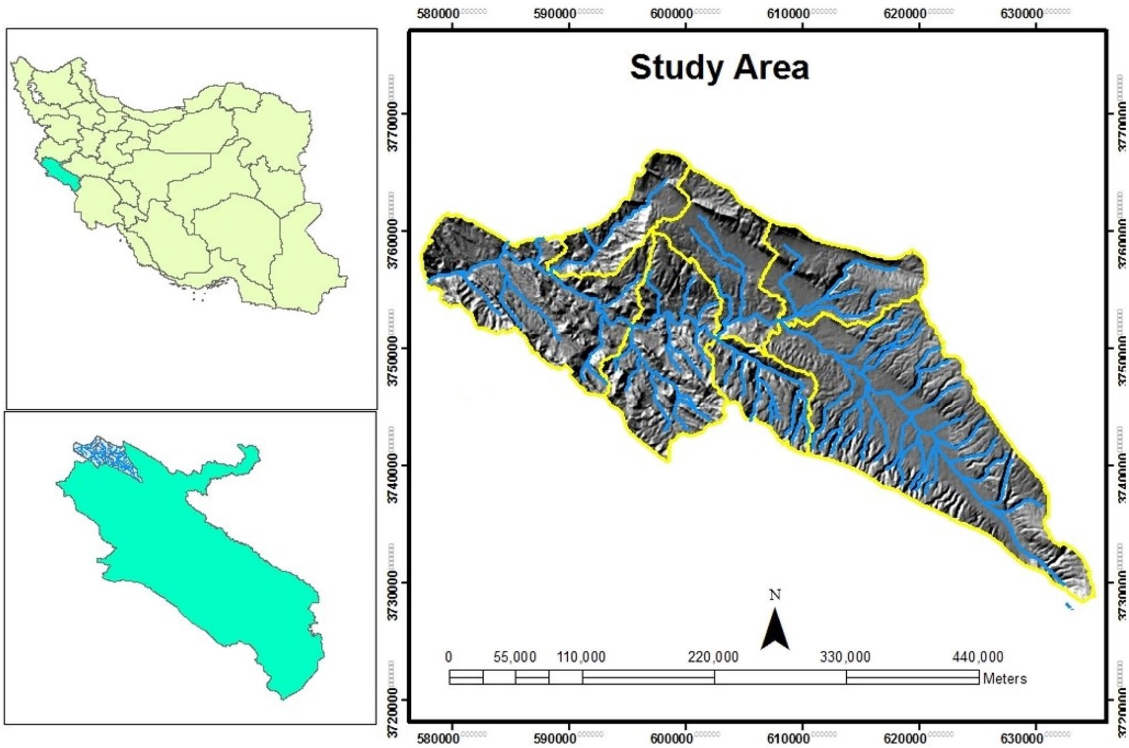

Fig. 1 Map of the geographical location of the watershed of Kangir River and the subbasins of the Kangir River basin in Ilam Province

2013). Finally, it is developed in 1995 to provide new generation prediction technology to use by people and organizations who are active in soil and water conservation and environmental planning and assessment (Flanagan and Nearing 1995). WEPP is a continuous simulation computer-based model that is able to predict spatial and temporal distributions of net soil loss and deposition in small channels and in impoundments for a wide range of time periods and spatial scales (Amore et al. 2005). According to Laflen and Flanagan (2013) "The WEPP components included plant growth, residue decomposition and management, water balance, weather generation, soil disturbance by tillage, rill and interrill soil detachment, sediment transport and deposition, and sediment particle size distributions" (Fig. 2).

The WEPP model is able to simulate the area in two ways: the domain and the watershed. In order to study the area by domain method, information is required in the form of four separate files of soil, climate, topography and management (Ahmadi et al. 2018). In the WEPP model, the topographic factors are introduced through a slope file. Among the topographic factors, the slope and direction factors should be entered in the relevant windows. For slopes more and less than 21%, calculation of slope length and calculation method are different. In case of soil data, the soil characteristics are maximally measured up to a depth of 1.8 m. Soil-related parameters important for the model are depth of each horizon, clay and sand, organic

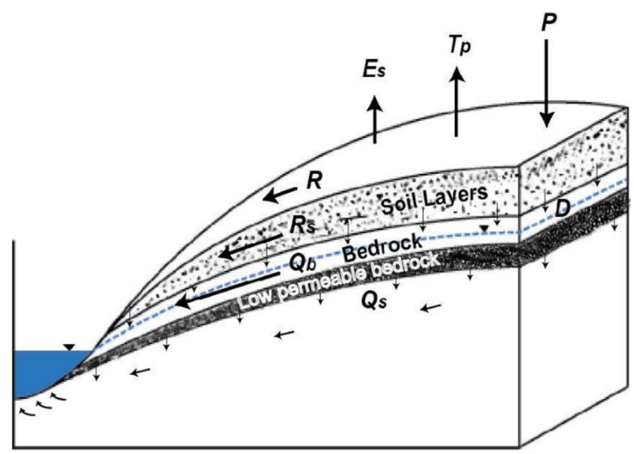

Fig. 2 Schematic of hillslope hydrologic processes. P, precipitation; Es, soil evaporation; Tp, plant transpiration; R, surface runoff; Rs, subsurface lateral flow; D, deep percolation; Qb, baseflow and Qs, deep seepage. The dotted blue line represents the groundwater level (Srivastava et al. 2015)

matter, cation exchange capacity, rocky mass, albedo, initial level of soil saturation, interlayer erodibility, critical shear stress and hydraulic flow. The percentage of the sun's radiation reflected in the atmosphere (Albedo) is used to estimate the pure radiation that reaches the surface of the Earth, and its acceptable range is from 0 to 588% (Ahmadi et al. 2007).

Regarding climate factor, the most important information needed to perform the collision is the amount of temperature and daily rainfall and the parameters that must be calculated for the rainfall factor are: the average monthly precipitation, standard deviation, rainfall skewness coefficient and the probability of a wet day after a rainy day or a wet day after a dry day. The factors to be calculated for the temperature factor are the average monthly maximum temperature, the average monthly minimum temperature, the standard deviation of monthly maximum temperature and the standard deviation of monthly minimum temperature (Ahmadi et al. 2007). Chanel-related information including channel soil, channel slope, channel management and type of channel is used in this model too (Ahmadi et al. 2007). In order to determine the type of the channel, information including the shape of the channel, the friction slope, the type of control section in the outlet of the channel and the edge slope must be considered. Finally, in the WEPP model, any structure that causes the accumulation of water and sedimentation as a result is called reservoir (Ahmadi et al. 2007).

These reservoirs include agricultural basins, sediment reservoirs and reservoirs that are created in the area of the flow of water under the roads. Detailed information about the WEPP model can be found in (Srivastava et al. 2015) and WEPP user summary. (https://www.ars.usda.gov/ARSUserFiles/50201000/WEPP/usersum.pdf).

EPM model

The EPM model, in fact, is the advanced classification method using the (M.Q.C.E) method. In this method, four characteristics including erosion coefficient of the watershed (ψ), land use coefficient (Xa), rock and soil sensitivity to erosion (Y) and mean slope of basin (I) in different land units or in created networks are investigated on the map. For each of the components of the land unit or networks, based on these four factors, the (Z) value or erosion intensity coefficient is calculated from the following equation (Eq. 1):

$$Z = Y \times X_a(\Psi + I^{0.5}) \tag{1}$$

The EPM method is performed in two steps: first, determining the severity of erosion and, second, calculating the transported sediment. After calculating Z value, using Table 1, the qualitative classification of erosion is carried out (Refahi 2003). In this regard, the specific erosion or amount of erosion per unit area during a year in the watershed basin is obtained from the following equation (Refahi 2003):

$$W_{SP} = T \cdot H \cdot \pi \cdot Z^{1.5} \tag{2}$$

where W_{SP} is erosion rate in cubic meters per square kilometer per year. H is average annual rainfall in the basin in millimeters, and T is the coefficient of temperature obtained from this equation $T = (t/10 + 0.1)^{0.5}$ where t is the mean annual temperature of the basin in C, while Z is the erosion intensity and π = the *Pai* number.

Table 1 Quantitative and qualitative classification of erosion in the EPM model

Erosion classification	Erosion intensity	Limit values Z	Average values Z
I	Very intense	$Z > 1$	1.25
II	Intense	$1 > Z > 0.71$	0.85
III	Average	$0.7 > Z > 0.41$	0.55
IV	Little	$0.4 > Z > 0.2$	0.30
V	Very little	$0.19 > Z$	0.10

In the EPM model, the following mathematical functions are used to estimate the rate of sediment; thus, the amount of sediment produced in the basins is calculated in this way. Usually, the amount of sediment that is measured at the outlet of the river is less than the eroded soil at the watershed area. Because a large amount of eroded soil might have sediment at another point in the basin, it is necessary to determine the sedimentation coefficient of the basin which is obtained from Eq. 3 (Refahi 2003):

$$\mathrm{RU} = \frac{4(P * D)^{0.5}}{L + 10} \tag{3}$$

where RU = sedimentation coefficient of the watershed; P = the perimeter of the watershed with km scale; L = watershed length in km (i.e., the longest length or the length of the main drainage); D = the height difference in meters, the value of which is obtained through Eq. 4 which Dav is average height of the watershed and DO = height of the outlet point in the river (Refahi 2003):

$$D = (\mathrm{Dav} - \mathrm{DO}) \tag{4}$$

At the end, to calculate the specific sediment rate, the amount of erosion in the sedimentation coefficient is multiplied which is obtained from Eq. 5 and the total sediment discharge and the special sediment discharge in the total area of the watershed are multiplied which is obtained from Eq. 6 (Refahi 2003):

$$G_{SP} = W_{SP} \cdot \mathrm{RU} \tag{5}$$

$$G_S = G_{SP} \cdot \mathrm{F} \tag{6}$$

where G_{SP} is the specific sediment rate in cubic meter per square kilometer per year; W_{sp} = the amount of specific erosion in cubic meter per square kilometer per year; RU = sedimentation coefficient of the watershed (which is the same as the SDR of the PSIAC method) G_S = total sediment discharge in cubic meter per year; G_{SP} = specific sediment discharge in cubic meter per square kilometer in a year, and *F* is the area of the watershed in square kilometers.

Finally, to implement the models information regarding the climate was collected from Ilam station which is the nearest station to the area of study in terms of topography and geographical location (Table 2). For soil file, factors such as clay percentage, percentage of gravel, organic matter percentage, cation exchange capacity, soil texture, effective hydrological flow, critical shear stress, rill erodibility, inter-rill erosion, initial saturation level and albedo percentage were investigated in the samples (Table 3). After sampling, the total watershed area of Kangir was divided into 21 units in terms of soil type.

There are five types utilization of the Kangir watershed area: rangeland, garden, forest, agricultural and residential uses. Most of the area consists of forests and rangelands which are further divided into two categories of rangelands of the village and upstream rangelands of the basin. Grazing is the only action carried out in the rangelands. In gardens, actions such as harvesting the garden plans at the surface (twice a year), irrigation and shoveling around the trees are performed. After sampling the area and according to the type of utilization, 23 types of management were identified in the region.

In this research, the factor of slope was entered into two files: one in the slope file (hillslope size) and the other file of the drain (the value of the drainage slope). The slope information was entered into the software Geo WEPP using a digital elevation map and in the form of longitudinal profile. Therefore, for this purpose, the drainage path was first identified and then the appropriate section for each hillslope was selected on topographic map. In the next step, ArcGIS 10.4 software was used to draw up the relevant profile. Finally, the achieved numbers were written in the table relevant to slope file. Information regarding this file was prepared using the GeoWEPP software. In addition to drawing the networks of drainage and the slopes leading to each drainage, this software draws the longitudinal profile of each slope. Slopes cause an increase in water speed (both surface and river flows) and in the kinetic force of water and consequently its power of destruction and removal. Thus, it can be said that the volume of flood and surface currents directly depend on the slope of the basin. Channels in the area can be divided into three main categories. (1) Channels with a floor covered with stone and sides of the same material as of surrounding formations. (2) Channels with floors and sides of soil as of surrounding slopes. (3) Channels with floors and sides covered with gravel with a diameter of up to two centimeters. With regard to the above, it seems that the three types of drain paths are sufficient. However, for greater accuracy, the information of the drain path in each management unit was considered and 21 channels of water were created for the area and stored under the same management unit name.

Table 2 The results of the calculated factors for the climate file in the watershed during the statistical period (2001–2014)

Parameters	January	February	March	April	May	June	July	August	September	October	November	December
The average monthly rainfall	3/89	1/108	2/94	7/80	3/68	8/9	5/1	4/0	1/0	2/1	4/36	2/80
Rainfall standard deviation	0.3	0.23	0.33	0.44	0.54	0.22	0.17	0.55	0.2	0.65	0.33	0.34
Rainfall skewness coefficient	0.2	0.43	0.24	0.39	0.27	0.16	0.53	0.44	0.22	0.15	0.52	0.32
The probability of a wet day after another wet day	0.44	0.36	0.22	0.11	0.1	0. 9	0.8	0. 12	0.1	0.13	0.29	0.41
The probability of a wet day after a dry day	0.29	0.22	0.17	0.25	0.11	0. 6	0.07	0.15	0.9	0.13	0.24	0.27
The average of the minimum temperature (F)	55.58	48.56	49.46	55.22	66.02	81.14	91.22	97.52	95.54	88.34	75.56	64.22
The standard deviation from maximum temperature	5.42	6.77	4.33	2.71	1.78	1.67	1.24	2.13	2.61	3.33	3.98	4.57
The average of the minimum temperature (F)	37.58	32.9	33.26	37.94	47.3	58.82	66.92	73.04	70.88	64.58	54.86	45.32
The standard deviation from minimum temperature	4.92	5.37	5.43	3.61	2.98	2.6	2.4	1.9	3.11	4.08	5.31	6.35

Table 3 Results of calculated factors for the soil file in the Kangir watershed basin during the statistical period (2003–2014)

The name of the subbasin	Longitude	Latitude	Depth of soil horizons (mm)	Sand (%)	Clay (%)	Minerals (%)	Caption exchange capacity (NFR/100HS)	Gravel (%)
A1	46/29/39	33/29/46	290	7.34	23.53	0.53	33.43	1
	46/38/10	33/38/54						
A2	46/27/39	33/26/28	300	36.8	27.41	1	17.87	1.2
	46/38/32	33/31/08						
A3	46/23/59	33/25/14	400	49.5	22.02	0.88	19.02	1.3
	46/35/16	33/30/23						
A4	43/23/28	33/23/55	200	22.9	29.37	0.17	49.87	2.1
	43/31/22	33/28/59						
A5	46/24/50	33/29/46	500	50.4	43.96	0.45	33.76	1
	46/31/11	33/36/56						
A6	46/20/33	33/29/07	450	56.7	48.55	0.37	44.65	1.6
	46/28/02	33/37/10						
A7	46/16/36	33/23/27	200	19.5	54.72	0.21	64.32	2.7
	46/24/49	33/29/58						
Total basin	46/16/36	33/23/27						
	46/38/32	33/38/54						

Results and discussion

WEPP model

Watershed, flow paths and slope simulations methods were carried out into the WEPP model. By laying the subbasin's boundary layer on the map after preparing the sediment yield of the basin, the intensity of sedimentation area, sediment load and the sediment amount emitted from the basin can be calculated in a time period (e.g., a year). In other words, soils that are separated from their bedrock are not all carried away with the flow of water, and some parts of the sediment are deposited elsewhere. The materials which move along with water and reach the reservoir of the dam or any other control point are called the sediment load or the sediment production value. The specific sediment (the amount of sediment that is removed from the basin at a time per unit area) and the amount of sediment of each class in each of the subbasins can be obtained in terms of tons per hectare per year. The WEPP model does not estimate erosion quantitatively, but calculates the sediment delivery ratio (SDR) coefficient according to soil characteristics and hydrological basin sedimentation. Therefore, specific and total sediments are calculated from the (SDR) coefficient which for the methods of watershed, the flow path and domain were 7.64, 6.01 and 11.87 t/ha per year, respectively. Subsequently, specific erosion was obtained by dividing these values by specific sediments. Total erosion was also achieved with regard to specific erosion and area of the studied region (Table 4). Comparison of the correlation coefficient with the sedimentation in the hydrometric station and the achieved results indicated that the WEPP model had acceptable results in estimating the erosion and sediment values of the studied basin (Fig. 3). The inadequacy of statistical information from the study area created some limitations in the implementation of the research. Therefore, in conducting research projects and even studies, especially those that are in line with operational activities, the utilized methods and techniques for collection of the required statistics and data are important issues that play a significant role in achieving the goals and must be well considered. Given the nature of such projects, the use of specific methods and

Table 4 Erosion and sediment values derived from the three methods in the WEPP model

Type of parameter	Methods			Type of parameter
	Watershed	Flow path	Domain	
Specific erosion (t/ha/year)	5.3	12.47	8.93	–
Total erosion (t/year)	52,631	123,830	88,681	–
Specific sediment (t/ha/year)	6.01	11.87	7.64	10.5
Total sediment (t/year)	59,685	117,870	75,871	104,271.3

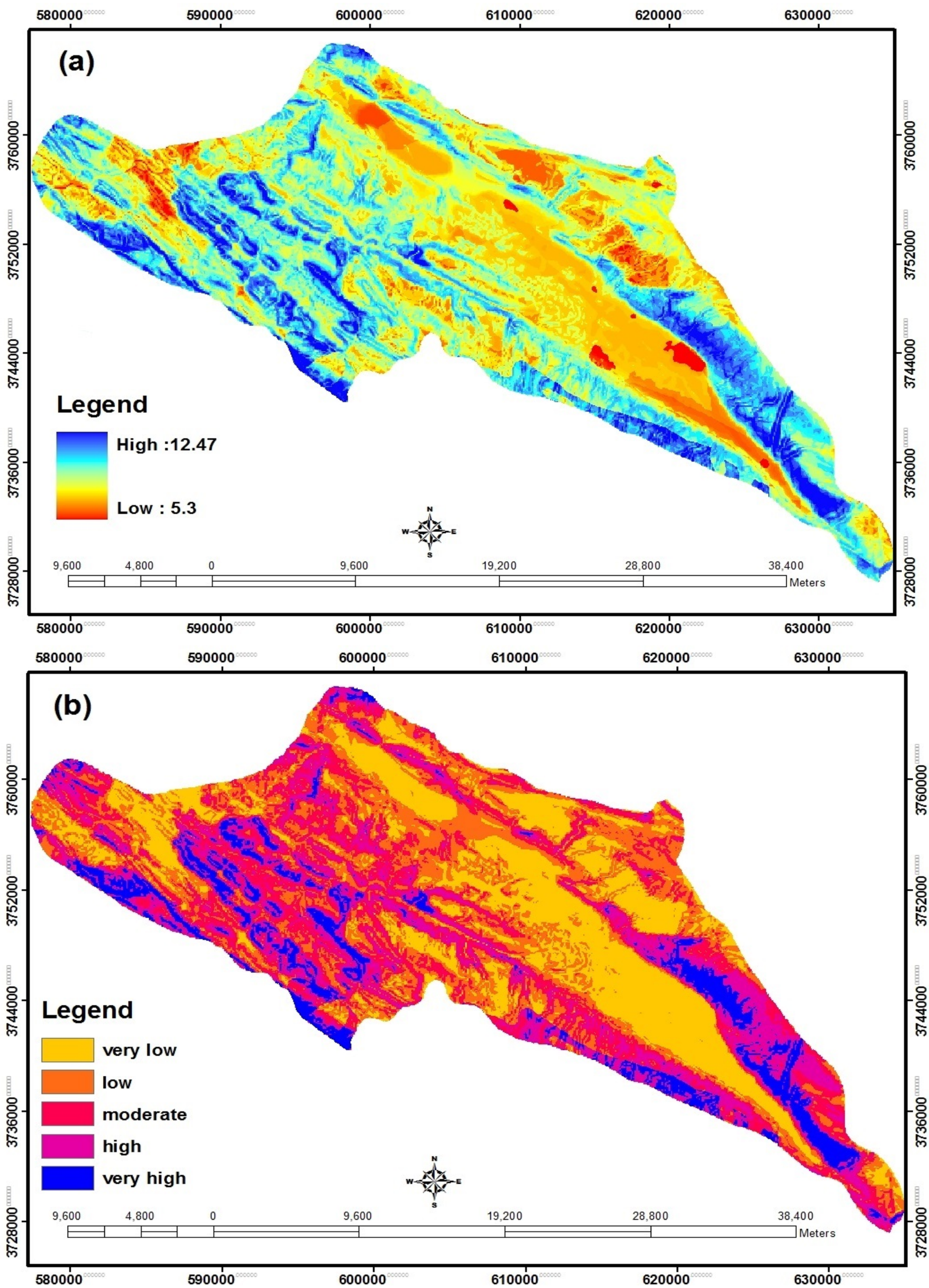

Fig. 3 Map of erosion and sediment intensity in WEPP model show **a** erosion intensity, **b** erosion classification in Kangir watershed

techniques has undeniable effects on increasing the speed and accuracy of the results.

EPM model

The assessment of the current erosion condition depends on some other factors. For example, if 80% of the area is affected by a variety of rill and gully erosion, it has the highest score, and if reversely the area has good vegetation, it has a low score. Here, to investigate the current state of erosion in the area, the researcher undertook a field study on the rate of rill and gully erosion and other factors that can affect the erosion of the region. ETM satellite 2016 was also used to investigate the four types of erosions: gullies, rills, sheet and stream bank erosion. In the layer of land use coefficient, a coefficient of 1 is considered for erodible areas and a coefficient of 0.1 is considered for areas that are forested and the soil is protected. In this section, the average of four coefficients is examined and analyzed. The results of the average of four coefficients for soil erosion are shown in Table 5. Four layers were overlaid in the ArcGIS 10.4 software, and the potential erosion map of the area was produced. Thus, according to Eq. (1) and with the overlapping of the information layers, the erodibility map of the basin was prepared. It should be noted that the coefficient of erosion intensity (*Z*) for each subbasin was calculated separately (Table 5), and its average was considered for the whole basin. The results of this map illustrate that the highest erosion was in the southwest and west of the basin because this area is composed of unstable formations which are susceptible to erosion. The steep slopes in addition to heavy precipitation and land use changes in this area have caused many of its supplies to encounter erosion crisis. The value of *Z* for these areas is greater than 1 which indicates the intense erodibility of this area.

The maps of the coefficients of erosion intensity of the watershed in Kangir River are shown in Fig. 4. The erosion map of the Kangir basin is shown which indicates that the least amount of erosion is related to the central and flat parts of the area where the plain of Ivan exists and most of the aquatic and dry farming as well as gardening are carried out at low slope. The highest rate of erosion belongs to the southwest and west of the basin (Fig. 4).

According to Eq. (2), the temperature layer, precipitation and layers of erosion intensity were multiplied by the Pai number using the above-mentioned analytical function and the annual map of specific erosion of the basin was obtained as a result. The map was then classified into five classes; by using this method, erosion can be obtained both quantitatively and qualitatively (Fig. 5). The amount of WSP for the basins and erosive units was calculated in terms of (Ton/hayear) and (m^3/km^2 year). Finally, with regard to the apparent weight of soil, the annual erosion was obtained in terms of Ton/h for the basin. The calculated value of the specific erosion for the basin of the study was 9.61 Ton/ha year (Fig. 6).

It is clear that in order to calculate the total sediment discharge in Ton per year for the area of study, the G_s must be multiplied by the apparent weight of the basin soil, and as a result, the mean of the computed parameter values was calculated for each subbasin (Tables 6, 7).

Comparing EMP and WEPP models

Table 8 shows the result of the comparison of EMP and WEPP models using sediment load value in Kangir study station graph. As indicated in Table 8, the obtained sediment values using WEPP and EMP models in the area of study were 11.87 and 8.01 Ton/ha year, respectively. By comparing the specific sediment values obtained from the two models of WEPP and EMP, it can be said that the two methods of domain with 7.64 Ton/ha year, and flow path with 11.87 Ton/ha year, have closer values to the observed number 10.5 and are suitable for assessing the amount of sediment and erosion in the region (Fig. 7). In the EMP model, the sediment production value is 8 Ton/ha. Finally, the results obtained from measuring the sediment and erosion amount in Kangir watershed showed that the WEPP

Table 5 Determination of the coefficient of erosion intensity *Z* and erosion class in the subbasins Kangir basin

Sedimentation and erosion class	Subbasin	Area km	Land use	Erosion coefficient	Geology coefficient	Slope	*Z*
Average III	A1	7.89	0.57	0.53	0.71	0.53	0.63
IV	A2	8.69	0.48	0.51	0.53	0.46	0.27
Little IV	A3	5.159	0.54	0.63	0.66	0.49	0.34
Average III	A4	9.162	0.63	0.71	0.83	0.63	0.43
Average III	A5	4.152	0.5	0.44	0.76	0.69	0.54
Intense II	A6	8.113	0.59	0.55	0.81	0.71	0.78
Very intense I	A7	5.109	0.51	0.78	0.93	0.77	1.2
Total basin average III		857.5	0.54	0.59	0.74	0.61	0.6

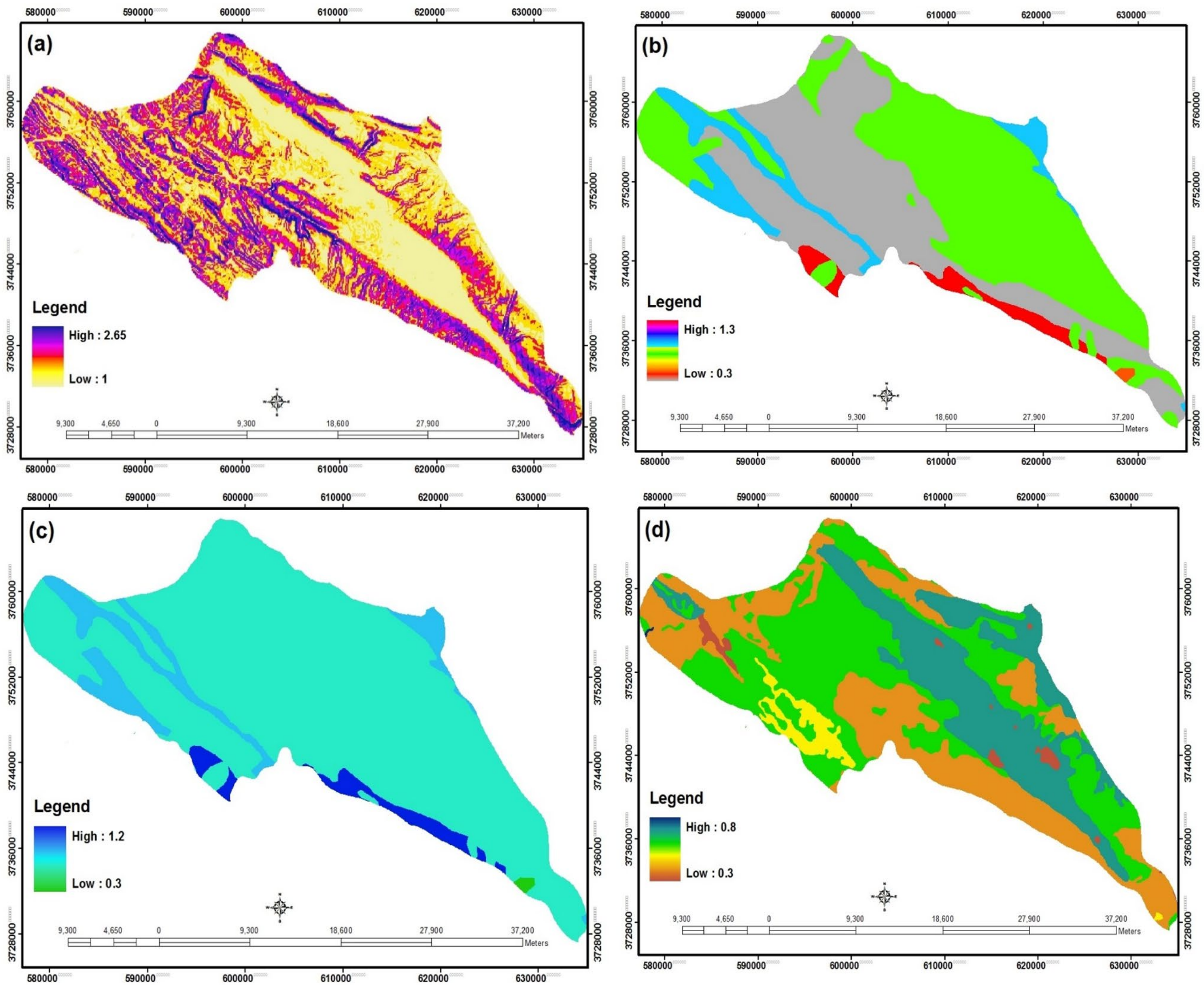

Fig. 4 Map of erosion intensity coefficient of Kangir watershed shows **a** slope weight, **b** weight of the geological agent, **c** weight of the erosion factor, **d** weight of the utilization

model has more accuracy in estimating erosion and sediment production. Furthermore, in this model the method of flow path has a closer value to the observed sediment of the hydrometric station and thus can be used for assessing soil erosion and sediment production. Finally, the results of this study have a good relationship with the results of other researchers regarding the efficiency of the WEPP model in simulating soil erosion and sediment (Ahmadi et al. 2018: Ahmadi et al. 2007: Amore et al. 2005: Defersha et al. 2012: Grønsten and Lundekvam 2006: Mahmoodabadi and Artemi 2013: Mahmoodabadi et al. 2014: Pandey et al. 2009: Singh et al. 2011). The findings of this study could be utilized in promoting the quantitative methods of assessing soil erosion and sediment yield computation in mountainous watersheds in Iran and elsewhere. The findings will provide information for scholars and those who intend to research soil erosion and sediment yield computation in mountainous watersheds, and such research has been less developed in the protection of soil and water resources in study area and Iran, because in recent decades the vulnerability of sensitive areas has been less considered.

Conclusion

Basically the application of a single method for prediction of the erosion phenomena in watersheds is not effective and a set of actions and preparations which lead to optimal results must be taken. According to the obtained results, the Kangir basin is in the intense class in terms of erosion and sedimentation. Therefore, in order to prevent and control erosion, remedial and improved measures of rangelands

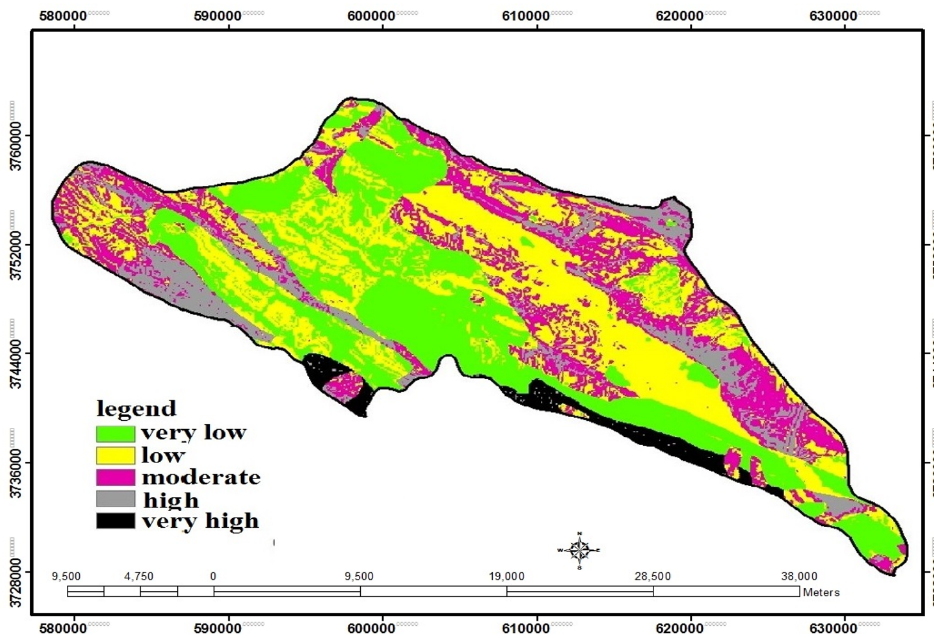

Fig. 5 Map of erosion intensity in Kangir watershed

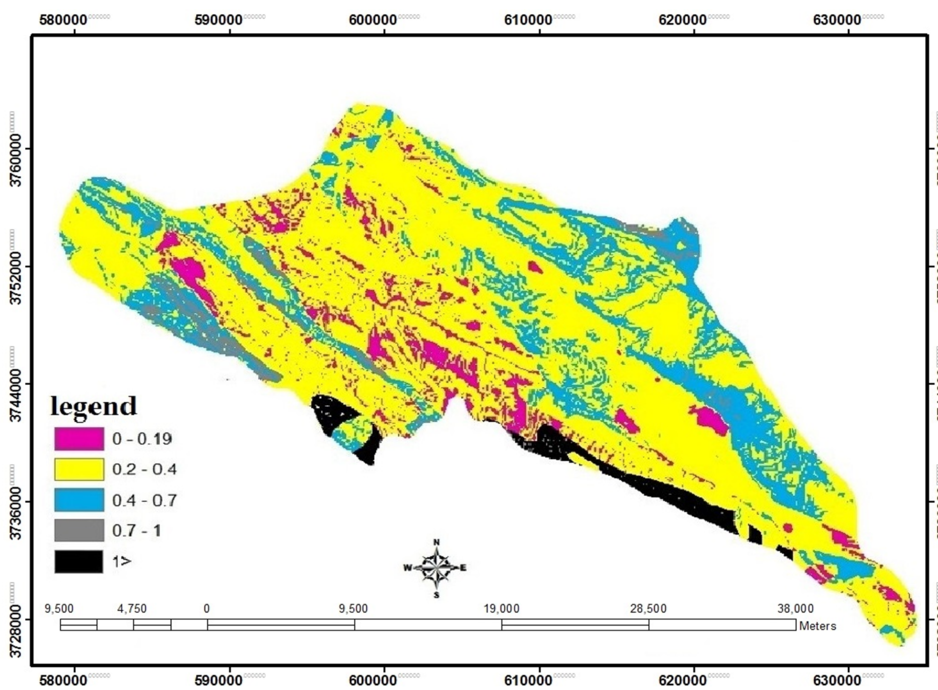

Fig. 6 Map of erosion intensity coefficient of the study area

Table 6 The mean of the computed parameters values in EPM model

Total sediment m^3/year	Specific sediment m^3/km^2/year	Sedimentation coefficient	Specific erosion m^3/km^2/year
150,970	4617.4	0.8	15,564

must be carried out for areas with low erosion, and the use of land platforms and biological methods for areas of average rate of erosion and biological operations for areas with high erosion must be undertaken. In addition to biological operations, other effective measures such as controlling over grazing and forest pests and management of the area must be organized to prevent human destruction. With regard to the development of natural resources, appropriate models are essential for proper estimation of erosion and sediment production. Considering the results of this research, soil erosion

Table 7 The mean of the computed parameters value for each subbasin in EPM model

Sedimentation and erosion class	Sedimentation intensity	Subbasin	Area hec	Specific load m^3/km^2 year	Sediment load m^3 year	Specific sediment ton/ha year	Specific sediment (ton/km^2 year)	Sediment load (Ton year)	Area (km^2)
III	Average	A1	7.89	7.372	59.14754	6.5	05.542	34.19423	5/38
II	Little	A2	8.113	4.235	28.879	4.3	9.347	87.1363	9/3
II	Little	A3	5.159	3.211	27.643	4.3	55.330	978.78	7/2
IV	Intense	A4	9.162	9.523	68.14577	8.8	4.783	8.22755	1/27
III	Average	A5	4.152	2.361	5.15953	3.5	56.545	5.27344	5/47
III	Average	A6	7.69	9.390	4.21330	5.7	53.581	8.3164	9/53
IV	Intense	A7	5.109	7.574	7.1224	8.74	344.817	76.1589	9/1

Table 8 Comparing the observed statistics of sediment with the achieved values in WEPP and EMP models

Type of parameter	WEPP model			EMP model	The observed number
Specific sediment (t/ha/year)	Domain	Flow path	Watershed		
	7.64	11.87	6.01	8	10.5

and sediment production studies can be undertaken in areas with the same conditions using the method and materials of this research. In this study, erosion and sediment rates were measured by three different ways in the WEPP model: domain, watershed and flow path for which the sediment values were 7.64, 6.08 and 11.87 t/ha/year, respectively, in the Kangir watershed. Based on this, the two methods of domain with 7.64 Ton/ha year and flow path with 11.87 Ton/ha year have closer values to the observed sediment value of 10.5 and are suitable for assessing the amount of sediment and erosion in the region. In this research, using EPM erosion model and field analysis, the map of potential erosion in the study area was determined and the erosion rate in this basin was estimated to be 13.5 Ton/ha year and 961 m^3/km^2 year, and the coefficient of sedimentation of the Kangir basin was calculated to be 0.81. Overall, the results of the research indicate an average to high erodibility rate of the region. The erosion-sensitive units are located in the west and southwest of the basin. And the sedimentation rate is high in the whole area of study. In this study, the rate of mean erosion (Z) in the whole basin was 0.6 which indicated a moderate to high rate of erodibility for the area. Moreover, the highest rate of erosion was found in the western and southwestern parts of the watershed which had very high rainfall, steep slopes and sensitive formations against erosion. The least erosion rate was in the center and northwest of the watershed. In fact, functional changes and human intervention have affected the

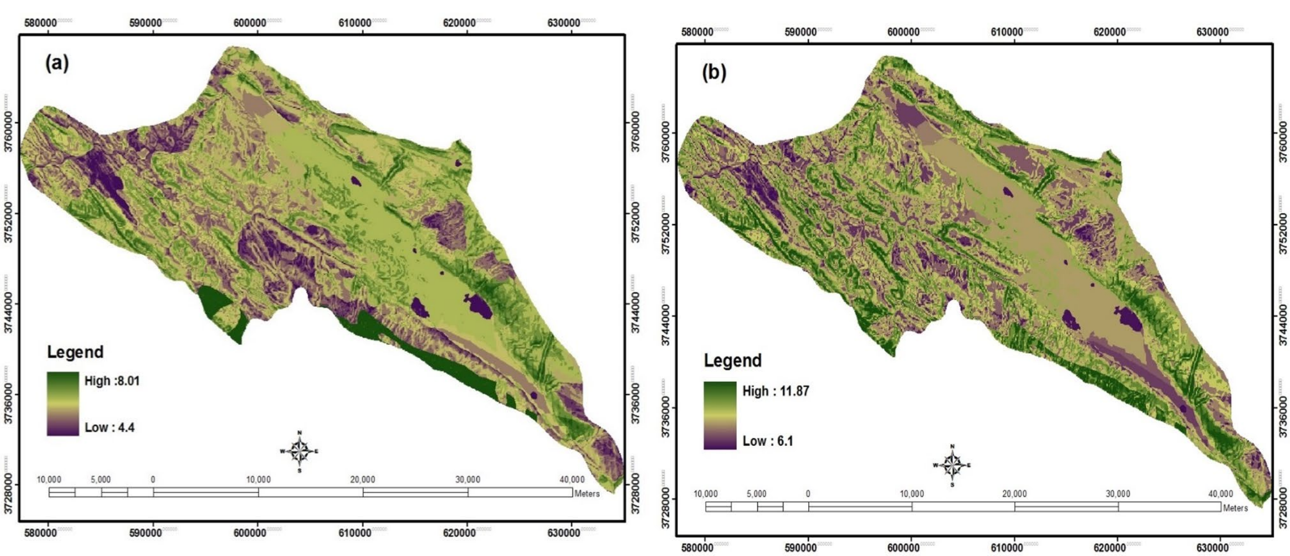

Fig. 7 Map of sediment intensity shows **a** sediment intensity in EMP model, **b** sediment intensity in WEPP model

erodibility of the area in recent years which through proper measures and correct management of the watershed the damage caused by erosion and sediment can be reduced to a great extent. The analysis of the data and research findings of the EMP model in estimating potential sedimentation and erosion of the watershed showed that the sediment value is 8 tons per hectare. Finally, the results of the estimation of soil erosion and sediment production in the Kangir watershed showed that the WEPP model has a more accurate estimation of soil erosion and sediment production than that of the EPM model. In this model, the flow path method used for estimating the amount of soil erosion and sediment production had a closer rate to the observation sediment in the hydrometric station. In addition, it was determined that in the WEPP model, the watershed method is not a suitable method for estimating erosion and sediment, but the flow path and domain methods are appropriate methods.

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