Journal of Geology and Mining Research Vol. 4(6) pp. 130-141, November 2012
Available online http://www.academicjournals.org/jgmr
DOI: 10.5897/JGMR11.029
ISSN 2006 – 9766 ©2012 Academic Journals

.Full Length Research Paper

A geographic information system (GIS)-based modified erosion potential method (EPM) model for evaluation of sediment production

Eisa Bozorgzadeh[1]* and Nemat Kamani[2]

[1]Deputy of Technical and Research, Iran Water and Power Resources Development Co., P. O. Box 19395/5897, Iran.
[2]Department of Geology, Faculty of Science, University of Bu Ali Sina, Iran.

Accepted 5 November, 2012

This research is aimed to modify erosion potential method (EPM) so that its dependency reduces to engineering judgment as well as broadly watershed visit by applying geographic information System (GIS). This study was carried out within acceptance of existing structure and framework of EPM model. In EPM model, the sediment production is evaluated in terms of four parameters including soil and rock resistance to erosion, land use, observed erosion process coefficients and average slope of the surface. The coefficient of soil and rock resistance against erosion is achieved from soil and geology maps and the mean slope is concluded directly from digital elevation method. But, the observed erosion process and land use coefficients are determined based on qualitative approach. Therefore, the parameters are strongly depended upon personal experience and how quality the watershed has been visited. The calculation methods to estimate the last two coefficients can be supported through introducing and applying of new parameters which are derived in our model entitled modified EPM (MEPM). In MEPM, the observed erosion coefficient is quantified based on climatic index, canopy percentage, drainage density and surface geology factors and the land use coefficient is quantified by using canopy percentage and slope. At first stage, the new formulations to derive the modified coefficients including the observed erosion and land use coefficients are adjusted with the same coefficients in existing EPM model and at second stage the results of MEPM model are verified with observed values at "hydrometric station" in the case study. Bakhtiari river watershed was chosen to implement MEPM model. The MEPM model was calibrated in four basins with observed data.

Key words: Erosion, Bakhtiari river watershed, canopy percentage, erosion potential method (EPM), modified EPM (MEPM), geographic information system (GIS).

INTRODUCTION

There are some empirical models to estimate the erosion and sediment production in watershed. The most common methods now being used are the universal soil loss equation (USLE) method (Wischmeier and Smith, 1965, 1978), the water erosion prediction project (WEPP) method, the Pacific southwest interagency committee (PSIAC) method, (PSIAC, 1968) and erosion potential method (EPM) (Gavrilovic, 1988). MPSIAC and EPM are the most models which are used in Iran. Based on previous studies and also climate of Iran, MPSIAC and EPM models are more correlated with observed data than other model (Ghomeshi et al., 1995; Heydarian, 1996; Development and Resources Corp, 1973; Meamarian and Tajbakhsh, 2003; Tangestani, 2006).

Recently, the geographic information system (GIS) and remote sensing (RS) techniques have been developed for evaluation of erosion and sedimentation through empirical model (Mezosi and Mucsi, 1993; Hill, 1993; Solaimani, 1997; Clark, 1999; Mohammed et al., 2001; Shrimali et al., 2001; Bissonnais et al., 2002; Yuliang and Yun, 2002; Martinez-Casasnovas, 2003; Zhou and Wu

*Corresponding author. E-mail: eisa_hp@yahoo.com. Tel/Fax: +9821 27822106.

Table 1. Land use coefficient values.

S/N	Surface condition	Coefficient amount
1	Barren lands / bad lands	1
2	Plowed field along slope	0.9
3	Orchards and vineyards without vegetation cover	0.7
4	Farms flowed by contour lines	0.63
5	Degrade forests / bushes with eroded soil	0.6
6	Mountainous pastures	0.5
7	Grasslands and similar farms	0.4
8	Grasslands, drainage meadow	0.3
9	Dense forest on slopes	0.2
10	Dense forest on flat area	0.05

2008; Terranova et al., 2009; Tomczyk, 2011; Navas et al., 2012). Each scored input parameter could be considered as a layer severally and the required calculation could be formulated in GIS package.

This investigation was conducted to present new method for quantifying two coefficients involving in EPM model more than ever. In this regards, the new parameters have been applied to calculate the observed erosion and land use coefficients. The canopy percentage, climatic index, drainage density and surface geology factors are used for former calculation and canopy percentage and slope surface are applied for later estimation. At first stage, the two new coefficients deriving in MEPM model are adjusted with the corresponded amounts in existing EPM model. At second stage, the annual yield of sedimentation compare with recorded data at hydrometric station in a case study. A GIS-based model also have been used to simplify and accurate calculation.

MATERIALS AND METHODS

EPM model

The EPM was applied after 40 years of research in former Yugoslavi with the aim of evaluation of soil erosion. In EPM model, sediment production is evaluated in terms of four parameters including, soil and rock resistance to erosion (Y), land use coefficient (X_a), coefficient of the observed erosion process (φ) and mean slope (I). The coefficient of erosion (Z) is calculated by the following equation:

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

The erosion production is estimated as follows:

$$V_{sp} = T.H.\pi\sqrt{Z^3} \quad (2)$$

Where, V_{sp} is the average annual especial erosion rate ($m^3/km^2 \;\; in\ year$), T is the temperature of area and H is the mean annual amount of precipitation ($mm/year$).

In the EPM model, the amount of annual sediment has been calculated as follows:

$$G_{sp} = V_{sp}.SDR \quad (3)$$

Where, G_{sp} is the average annual special sedimentation rate ($m^3/km^2 \;\; in\ year$) and SDR is the sediment delivery ratio.

MEPM model

MEPM has four parameters like EPM. In MEPM, two parameters containing coefficient of the observed erosion process and land use coefficient are calculated by new formulation.

Coefficient of soil and rock resistance to erosion

In EPM model, this parameter is scored according to geological classification and soil maps. It seems that, there is no alternative method to quantify this parameter more than ever. However, the calculating process is easily performed by using the GIS software. The calculation method for coefficient of soil and rock resistance to erosion is the same in MEPM and EPM.

Mean slope

This coefficient is calculated from digital elevation model (DEM) and therefore, the current method is quantitative enough.

Land use coefficient

In EPM model, the land use coefficient is obtained according to Table 1. The land use coefficient was calculated based on visual assessment of watershed as well as desk study. The current method for calculation of land use is strongly depended on expert experience and judgment and how quality the watershed is visited.

In this research, authors suggest applying other factors such as canopy percentage and slope to calculate land use coefficient instead of current coefficient.

Formulation is developed and calibrated with Table 1 as ensuing general form:

Land use coefficient = F (canopy percentage, slope)

Table 2. Observed erosion coefficient values.

S/N	Surface condition	Coefficient
1	Gully erosion area and intense erosion	1
2	Areas with 80% gully and rill erosion	0.9
3	Areas with 50% gully and rill erosion	0.8
4	Areas with surface erosion, sediments and alluvium, low gully and rill erosion and immense karstic erosion	0.7
5	Areas with surface erosion without deep erosion (gully, rill, alluvium and …)	0.6
6	Areas with 50% surface erosion	0.5
7	Areas with 20% surface erosion	0.3
8	Areas with landslides and river bank erosion	0.2
9	Farming areas with erosion	0.15
10	Areas mostly covered with permanent vegetation and forest	0.1

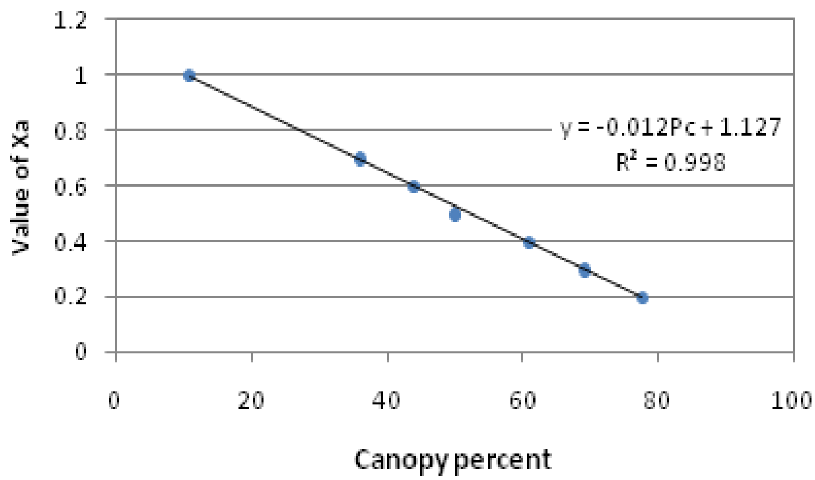

Figure 1. Linear regression between canopy percentage and land use values for related point in Table 1.

The slope was already calculated by using GIS package and canopy percentage can be achieved by using RS technique and GIS software.

Coefficient of the observed erosion process

In EPM, the coefficient of observed erosion process is achieved based on Table 2. Similar to land use coefficient, the abundant field investigation is necessary to estimate this coefficient. It is also depended upon expert experience and judgment. In this research, the new parameters are introduced to measure this coefficient. The exact review of Table 2 made the authors to know that this coefficient can be calculated in terms of canopy percentage, climatic index, geology index (Coefficient of soil and rock resistance to erosion) and drainage network. The drainage network could be calculated in GIS package and the rest were already achieved. So, the authors propose the new formulation as follows:

Coefficient of the observed erosion process = F (canopy percentage, climatic index, geology index, drainage network).

This formulation must be calibrated and adjusted with Table 2.

Model development

At first stage, which could be named either partial calibration or model development process, the aforementioned formulas are adjusted with Tables 1 and 2 to develop pertinent formula. The basic concept of partial calibration is that the results achieving from new formulas must be as much as possible assimilated with the amounts getting from Table 1 and 2 for the land use and observed erosion process coefficients, respectively (Figure 2). It means that the framework of EPM and MEPM models is the same and MEPM is supported by all investigations that have been done in the field of EPM model.

All terms which are entered in MEPM/EPM are roughly estimated and have uncertainties. These terms that are already described are slope, soil and rock resistance to erosion and SDR and so on. At

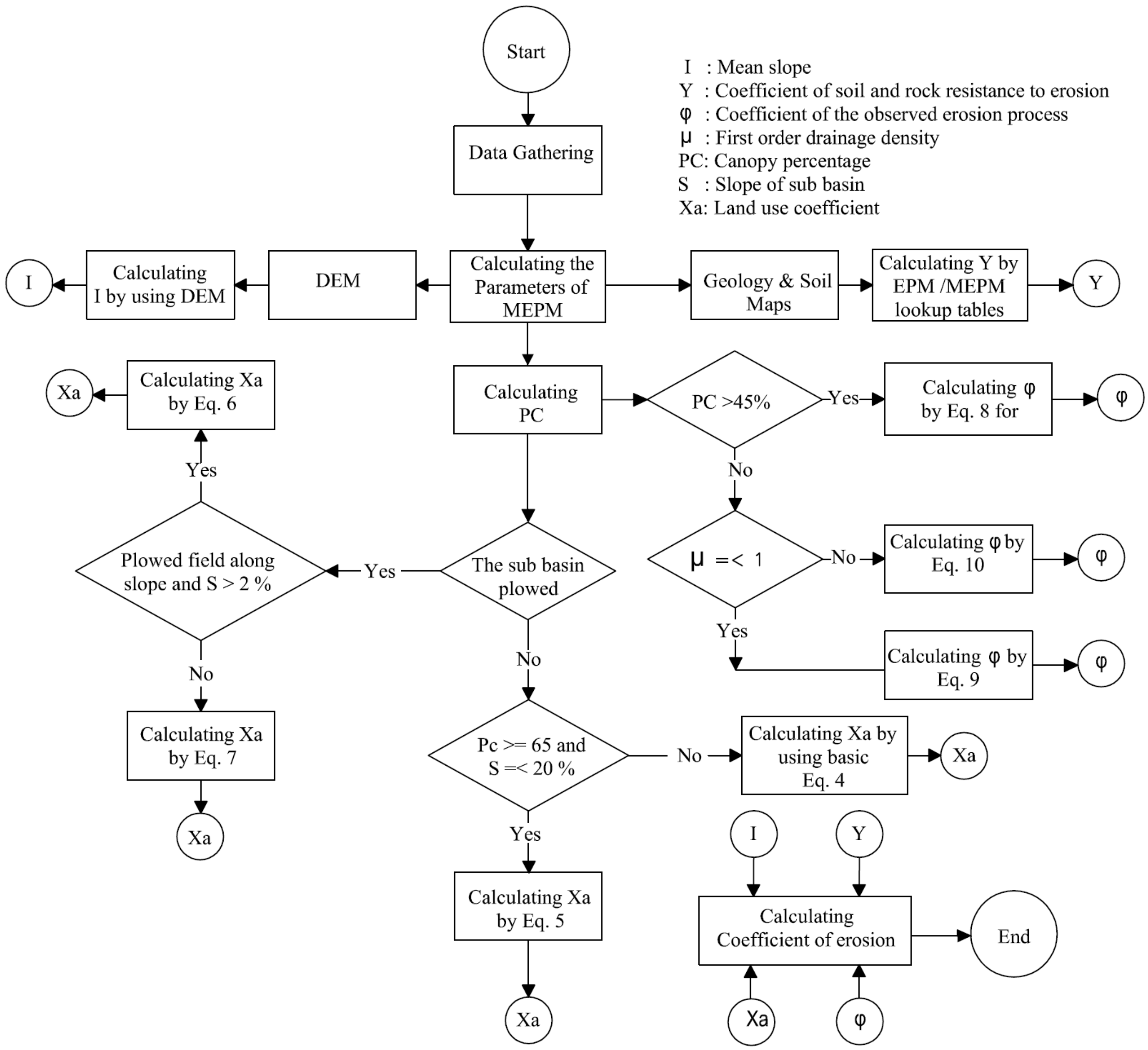

Figure 2. The algorithm for calculating MEPM parameters.

second stage which is evaluated of MEPM model, the annual yield of sedimentation in pilot watershed is calibrated with hydrometric station results (Figure 2).

Land use coefficient

Accurate inspection and verification of Table 1 demonstrates that in EPM model, to determine values of the land use coefficient, watershed circumstance have been categorized in 10 states which are mostly related to cover crop. Therefore, the parameters such as canopy percentage or normalized difference vegetation index (NDVI) which are achieved from processing of satellite image can be used for estimation of land use coefficient. Although the canopy percentage cannot be perfect agent of the rows 2, 4 and 10 in Table 1, however, the rest rows are completely delegated by canopy percentage or NDVI. So in this research, it was tried to achieve land use coefficient from canopy percentage that is based on NDVI. So a linear equation is fitted between the land use coefficients for rows 1, 3 till 9 of Table 1 and mean canopy percentages (P_c) thereof (Figure 1). The basic equation for estimating the land use coefficient (X_a) is as follows:

$$X_a = Min(-0.012Pc + 1.127 \ ,1) \quad (4)$$

This equation which is named basic equation properly covers all classes of Table 1 except rows 2, 4 and 10. Now, we are trying to modify this basic formula for aforesaid rows.

Generalizing of basic equation for row 10: The terms and definitions of rows 9 and 10 are nearly the same (Dense forest) except that the slope at class 10 is different. Therefore, the land use equation for class 10 can be derived from the equation of class 9 (basic equation) if the role of slope is determined. Regarding to the rows 9 and 10 of Table 1, for dense forest (Pc > 65), the land use coefficient can be varied from 0.2 in non-flat region (S > 20%) to 0.05 in flat area. Therefore, the equation that is governed at class 10 of Table 1 is:

$$IF\ P_c \geq 65\ \&\ S \leq 20\% \qquad \Rightarrow X_a = Min\left(\frac{-0.012Pc + 1.127}{k_1}, 1\right) \tag{5}$$

Where $k_1 = Min(-15s + 4.75 \quad , 4)$ and S is the slope.

Generalizing of basic equation for row 2: Class 2 of Table 1 belongs to agricultural area and which direction the field is plowed. So either satellite image or aerial photo must be verified in this case. The authors believe that the higher the slope, the bigger the land use coefficient. In this regard, a multiplier coefficient (K_2) is calculated. K_2 varies from 1.06 till 1.4 for the slope between 2 and 40% or more. Anyway, the land use coefficient for class 2 is limited up to 0.9 in compliance with Table 1. Therefore, in plowed field along slope and S ≥ 2%, we have:

$$X_a = k_2 * Min(-0.012Pc + 1.127 \quad , 0.9) \tag{6}$$

$$k_2 = Min(0.917s + 1.043 \quad , 1.4)$$

Generalizing of basic equation for row 4: If the investigation concludes that there is contour farming in agricultural area, the land use coefficient must be limited up to 0.63 according to class 4 of Table 1. So in case of contour farming we have:

$$X_a = Min(-0.012Pc + 1.127 \quad , 0.63) \tag{7}$$

Coefficient of observed erosion process

To formulate the observed erosion process coefficient, all parameters that affect the amount of this coefficient were identified and their relationships were verified. According to Table 2, this coefficient is categorized to 10 classes too. At classes 5 to 10, the surface erosion was only described and scored and its amount varies from 0.1 to 0.6. At classes 1 to 4 that the other kinds of erosions including gully and rill erosions are mentioned, the amount of this coefficient was increased up to 0.4 and its maximum amount was equated to 1. So it seems that, Table 2 can be divided into two parts. Part 1 belongs to surface erosion and part 2 pertain to gully and rill erosion.

The canopy percentage was assigned as indicator to distinguish these parts so that if the canopy percentage is more than 45% in an area then the surface erosion would mostly be existed. Otherwise the other kinds of erosion such as gully and rill erosion might be created.

Totally, the canopy percentage, climatic index (6 h rainfall with 2 years return period (p_z)), geology indicator (Coefficient of soil and rock resistance to erosion) and drainage density are considered to estimate the observed erosion process coefficient. However, as mentioned earlier, the formulation commences based on canopy percentage.

If the canopy percentage is more than 60%, the area can be categorized as jungle with permanent vegetation. So, the observed erosion process coefficient can be selected as 0.1 which is minimum amount according to row 10 of Table 2. If Pc > 45%, then there is no significant erosion in the area, therefore, the coefficient is low. In other words, in this case, the area circumstance is similar to rows 8 to 10 of Table 2. So we have:

$$IF\ P_c \geq 45 \quad \varphi = Max(-0.00666p_c + 0.5 \ , 0.1) \tag{8}$$

In the case that the canopy percentage is less than 45%, the other indexes participate to develop new formulation such as geology, climatic indicators and drainage density. The two first indexes are used to formulate rows 5 to 7 that there are no significant gully and rill erosions (the density of drainage is less than 1) and the last one is applied for the rows 1 to 4 for better modeling of gully and rill erosions. Therefore, for the rows 5 to 7 we have:

$$IF\ P_c < 45\ \&\ \mu < 1 \quad \varphi = Min\left(Y/_4 + 0.01p_z, 0.6\right) \tag{9}$$

Y (geology index) is the coefficient of soil and rock resistance to erosion.

In this research, the drainage density μ was considered as indicator to evaluate medium to high intensity of erosion. If the density of waterways order 1 is more than 1, then the term of gully-rill erosion (Y/4) must be considered as follows:

$$IF\ P_c < 45\ \&\ \mu \geq 1 \quad \Rightarrow \quad \varphi = Min\left(Y/_4 + 0.01p_z + \frac{\mu}{4}, 1\right) \tag{10}$$

As mentioned earlier, the Equation 11 is adjusted for rows 1 to 4 of Table 2.

Case study

Bakhtiari river watershed is located in southwest of Iran from longitudes 48°47′ - 50°18′ E latitudes 32°34′ - 33°18′N (Figure 3). It covers an area of about 6285 km^2 and most parts of its area are in Lorestan province. This basin is located in Zagros mountainous area and most of its parts are inaccessible due to topographic condition. Its altitudes vary from 520 m.a.s.l. in outlet point of basin to more than 4000 m.a.s.l. in mountainous part at east of basin. The watershed comprised 3 geological zones including Sanandaj-Sirjan, High Zagros and simply folded Zagros. The oldest rock unit is Precambrian metamorphic rock and the youngest formation is recent alluvial (NIOC, 1998). The average annual precipitation and temperature varies from 575 to 1125 mm and 0 to 40℃, respectively. The watershed has been divided into 14 sub-basins according to hydrological network and hydrometric stations (IWPC, 2005). There are four hydrometric stations in the basin that their data have been used to verify MEPM results. These stations are Tang e pange, Ghalyan, Zardfahre and Kazemabad (Table 3 and Figure 3). Based on previous investigation, Tang e pange station, have more reliable data with 45 years duration (IWPC, 2005).

RESULTS

Implementation of MEPM model in Bakhtiari river watershed

All data and information which are needed to implement MEPM model were gathered such as geological maps in 1/100000, topographic maps in 1/50000 and 1/25000 scale, soils maps, satellite image with spatial resolution of 24 m, aerial photo as well as data that gathered from hydrometric and climatology stations.

All data in different scales were prepared and

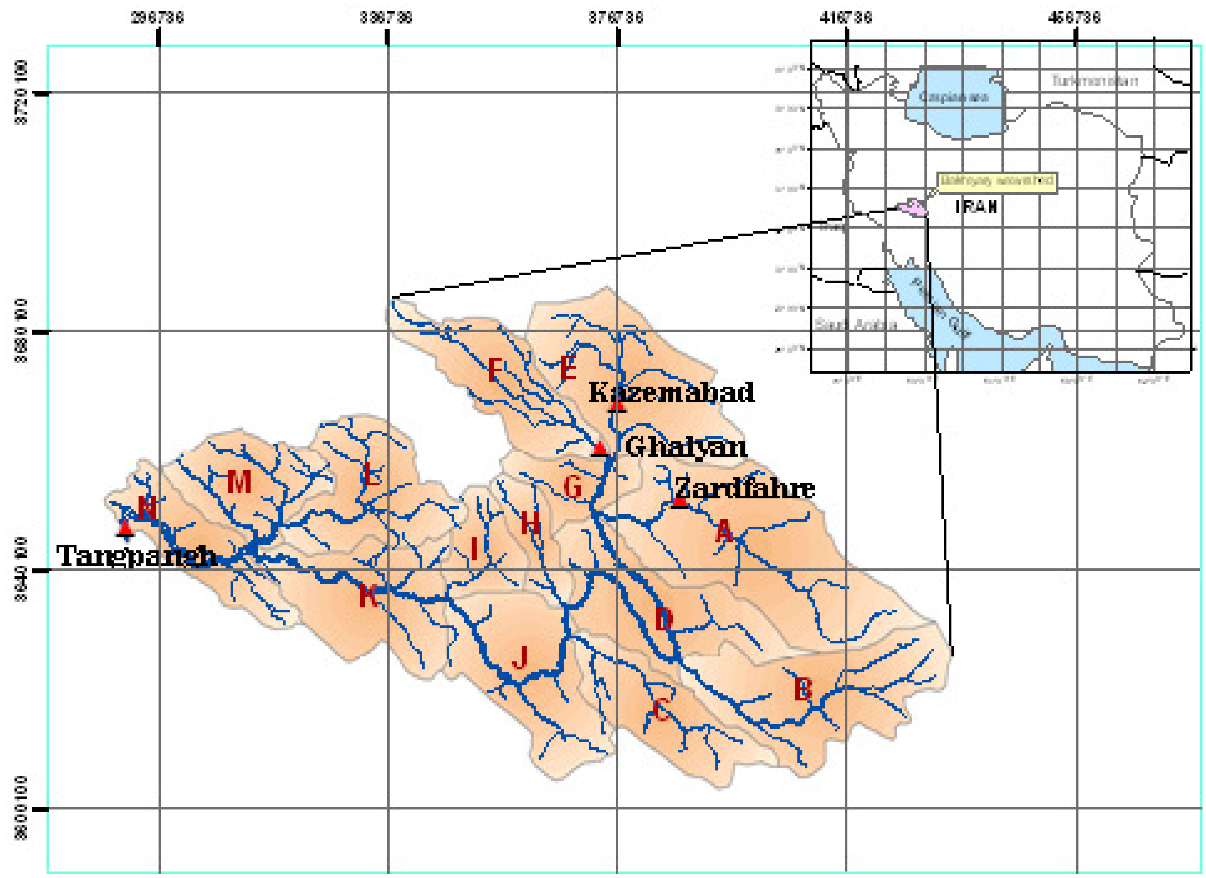

Figure 3. Study area and location of four hydrometric stations. Letters A-N, name of 14 sub-basin.

Table 3. Characteristics of 4 hydrometric stations in studied area.

S/N	Station	River	Elevation of station (m)	Area (km^2)	Period (year)
1	Tang e pange	Bakhtiary	600	6432	1955 - 2000
2	Zardfahre	Vahargan	1361	778	1982 - 2000
3	Ghalyan	Ghalyan	1873	414	1982 - 2000
4	Kazemabad	Kakolestan	1920	438	1982 - 2000

manipulated in vector format. A medium scale was selected for data preparation and registration. Next, all data layers converted into raster format. A spatial resolution of 24 m was selected based on Indian Remote-Sensing (IRS) satellite imagery. Digital elevation of the interest area was created based on 1:25000 topographic maps. The vertical and horizontal accuracy of generated DEM was 7.5 and 5 m, respectively.

In this study, to estimate the coefficient of soil-rock resistance to erosion, soil and geological maps were digitized and prepared, classified and scored according to EPM/MEPM look up tables. These vector data were converted to raster with 24 m pixel size (Figure 4). In creation of slope map, topographic maps at different scale assembled in single vector map. The slope map was derived from DEM (Figure 5). The observed erosion and land use coefficients were calculated based on new methods mentioned earlier. The methods applied to drive these coefficients in Bakhtiari watershed are also described.

Land use coefficient in Bakhtiari river watershed

To estimate the land use coefficient, the canopy percentage must be calculated. In this regard, NDVI was used as a common indicator to assess vegetation canopy and density (Gamon et al., 1995; Jordan, 1969;

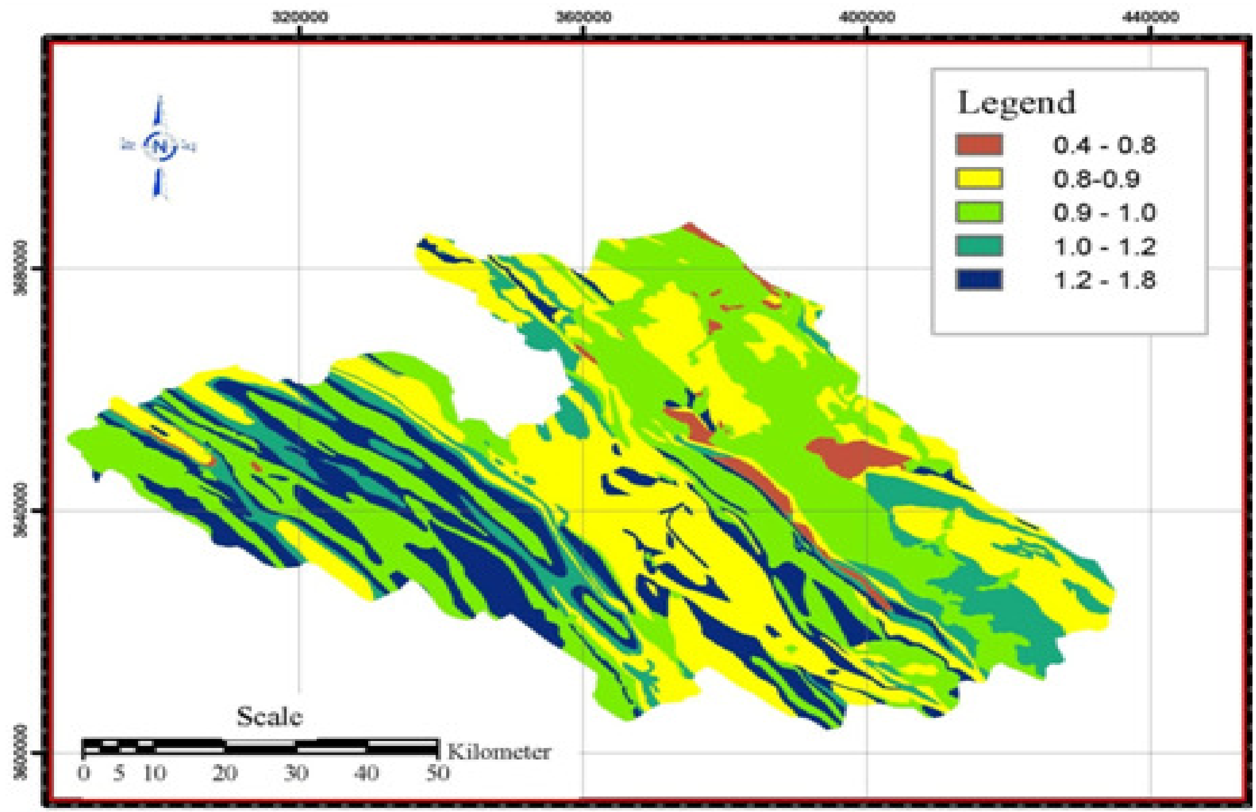

Figure 4. Distribution of soil and rock resistance to erosion.

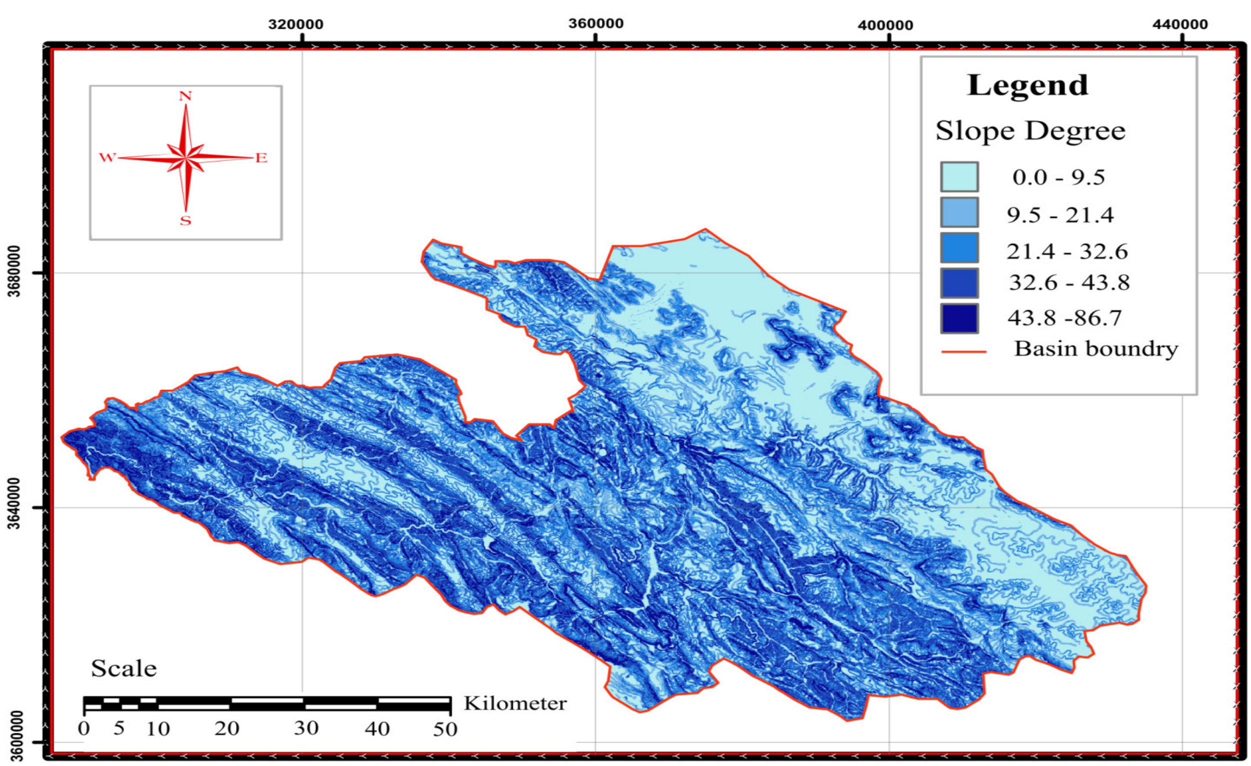

Figure 5. Slope degree map in Bakhtiari basin.

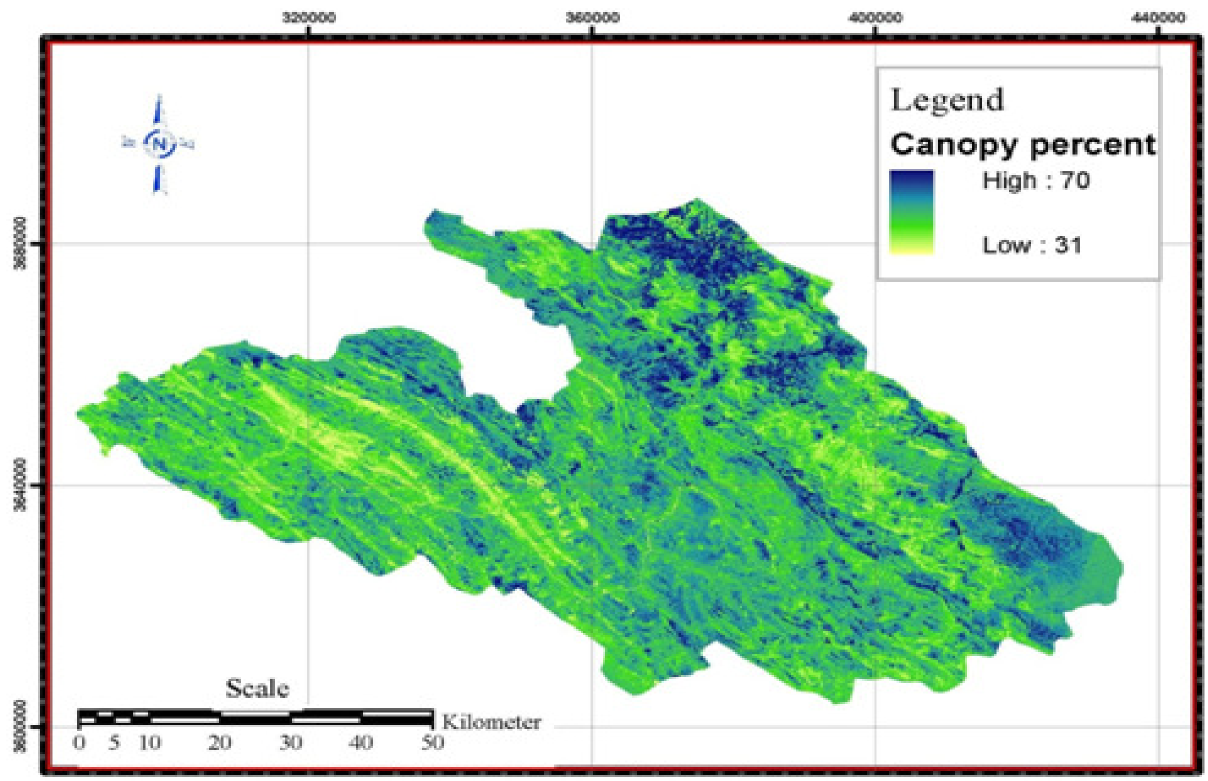

Figure 6. Canopy percentages that concluded from 2 and 3 bands of IRS-LISS III satellite image.

Mather, 1999; Turner et al., 1999; Broge and Lablance, 2000). This index was concluded from bands 2 and 3 of IRS-LISS III satellite image and the canopy percentage was achieved through supervised classification (Mather, 2001) (Figure 6). Then the Equations 4 and 5 were run by using ARCVIEW software. In area that there are plowed lands and counter farming, additional verifications are necessary. So these kind of areas located in northeast of basin were rechecked by using aerial photo and PAN satellite image with spatial resolution of 5 m. The land use map for Bakhtiari river watershed is shown in Figure 7.

Coefficient of observed erosion in Bakhtiari river watershed

According to MEPM model, the Bakhtiari watershed was classified into two parts based on canopy percentage (less and more than 45%) to estimate the coefficient of observed erosion. Then the Equations 8 and 9 were calculated in ARCVIEW software for the area that has canopy percentage of more or less than 45%, respectively.

In case that the canopy percentage is less than 45%, for calculating the observed erosion coefficient, the drainage density was assessed. The observed erosion map for Bakhtiari river watershed is shown in Figure 8.

DISSUSSION

Evaluation of MEPM model

All calculated parameters which were in raster format were applied in Equation 1 to estimate coefficient of erosion maps (Figure 9). The especial erosion rate was achieved by using coefficient of erosion, annual precipitation and temperature (Figure 10). Finally, especial erosion rate was multiplied in SDR to calculate especial sedimentation rate (Table 4). The MEPM results were compared with the historical and observed data at four hydrometric station including Ghalyan, Zardfahre, Tang e Pange and Kazemabad as well as EPM results. To describe the accuracy of MEPM model quantitatively, the relative error (RE) of the model for each station and the mean relative error (MRE) were calculated by using the following equations:

$$RE_{(di)} = \frac{\left|G^{(di)}_{sp\,(o)} - G^{(di)}_{sp\,(m)}\right|}{G^{(di)}_{sp\,(o)}} \qquad (11)$$

$$MRE = \frac{1}{n}\sum_{i=1}^{n} RE_{(di)}$$

Where RE(di) is the relative error for station of di, $G^{(di)}_{sp\,(o)}$ is the measured G_{sp} of station of di, $G^{(di)}_{sp\,(m)}$ the predicted

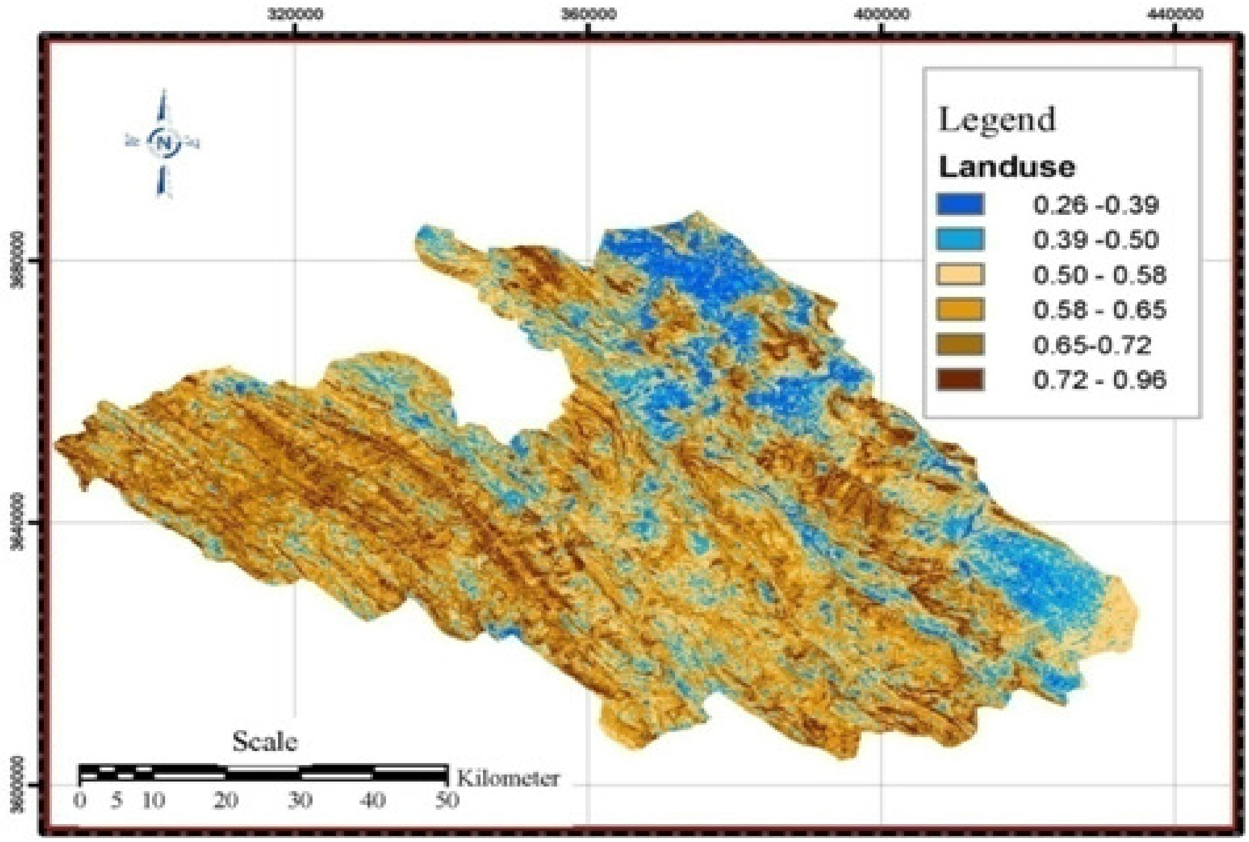

Figure 7. Land use map in Bakhtiari basin.

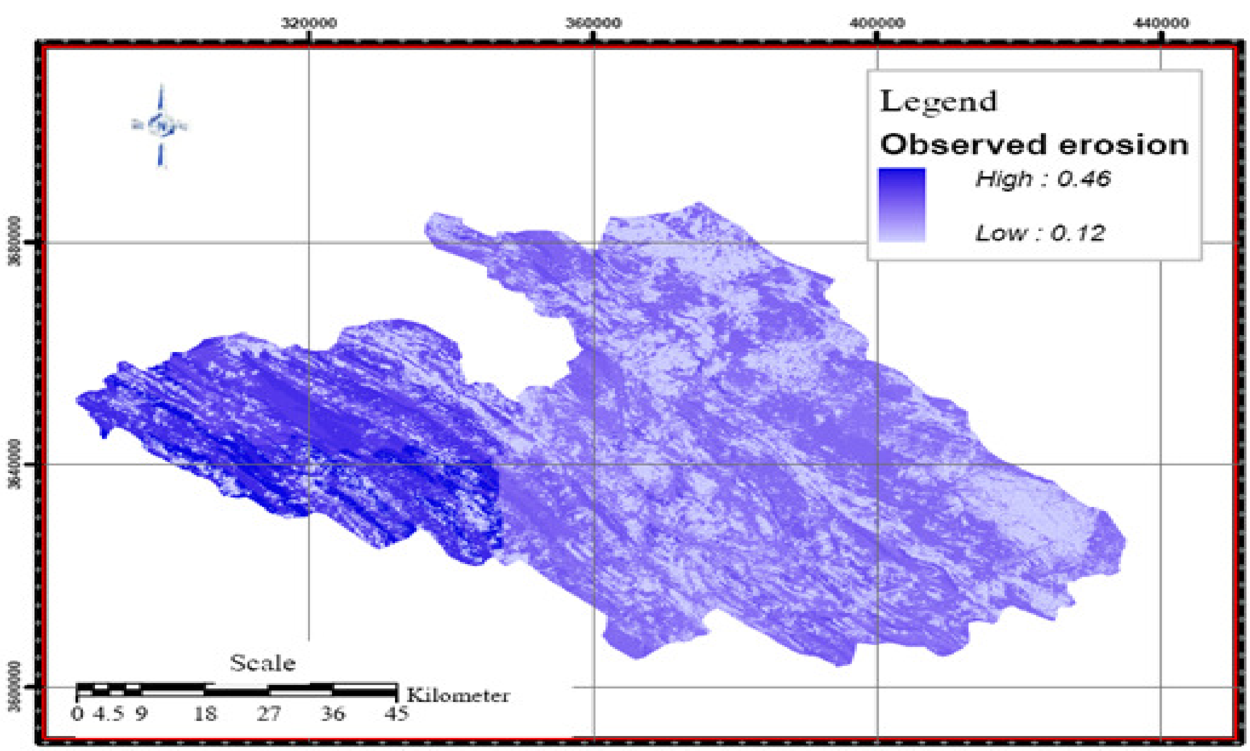

Figure 8. Observed erosion map in the basin.

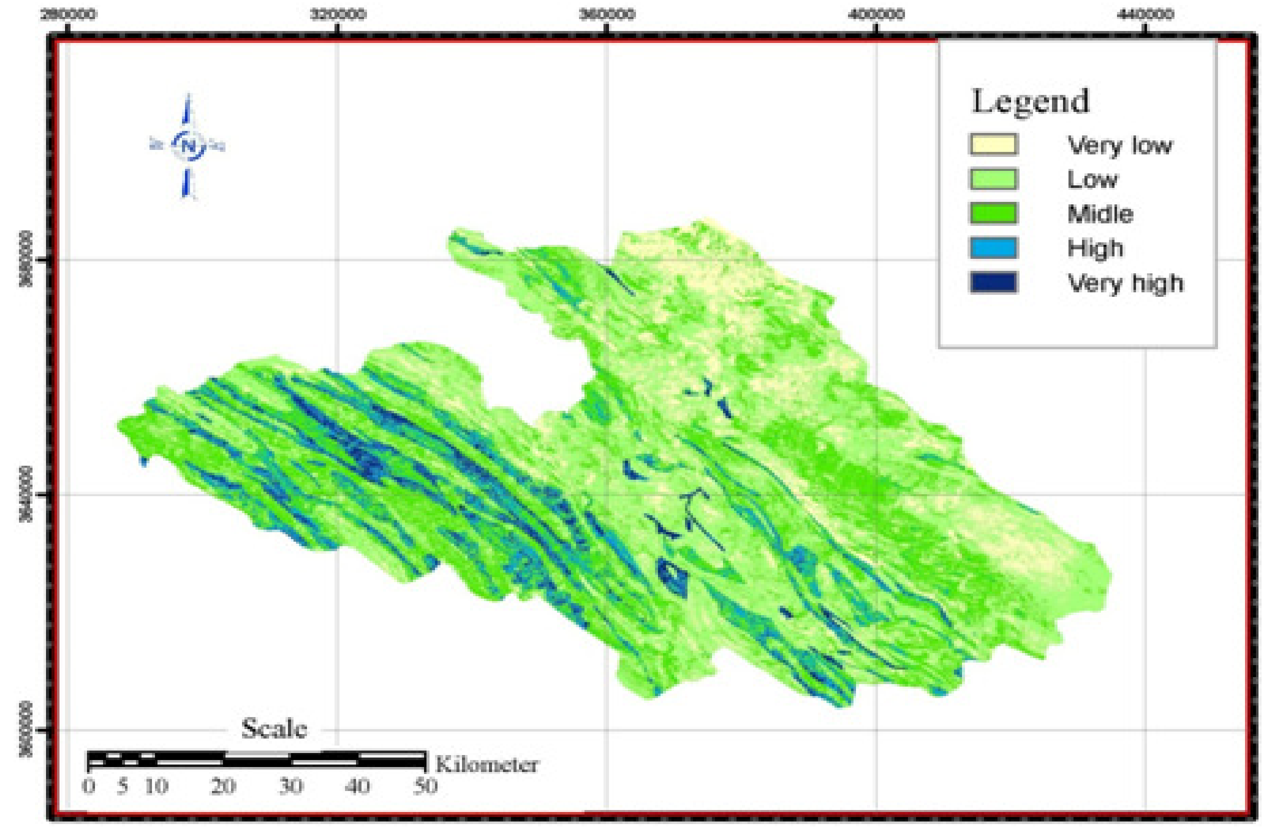

Figure 9. Coefficient of erosion in basin of Tang e pange station.

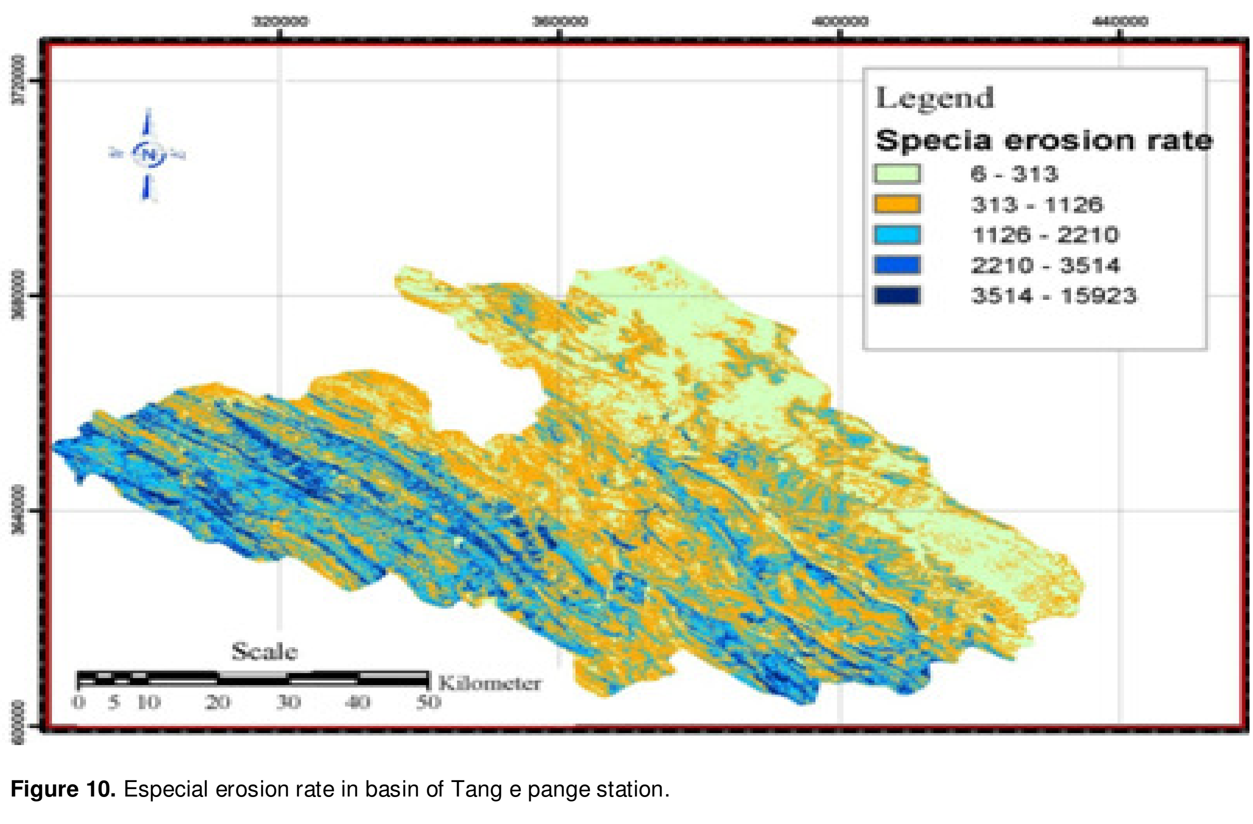

Figure 10. Especial erosion rate in basin of Tang e pange station.

Table 4. Evaluation of MEPM and EPM model.

Row	Station	Measured (ton)	Predicted (Model)		Predicted/Measured		RE		MRE	
			EPM (ton)	MEPM (ton)	EPM (%)	MEPM (%)	EPM (%)	MEPM (%)	EPM (%)	MEPM (%)
1	Galyan	180392	161176	197865	89.35	109.69	10.65	9.69	11.57	4.38
2	Zardfahre	337186	282744	350755	83.85	104.02	16.15	4.02		
3	Kazemabad	77200	70903	79471	91.84	102.94	8.16	2.94		
4	Tang e pange	5684214	5040558	5634380	88.68	99.12	11.32	0.88		

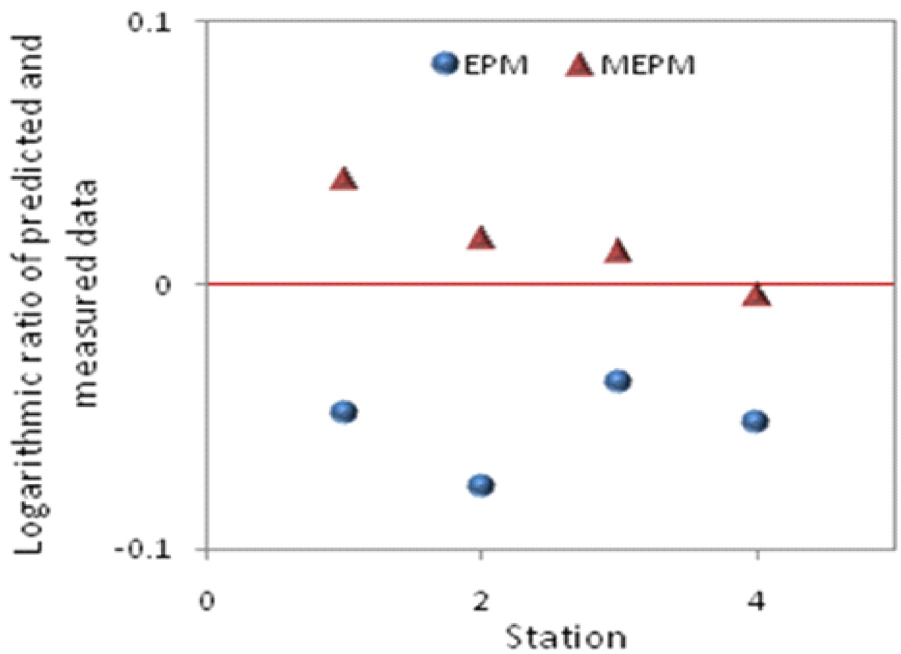

Figure 11. Logarithmic ratio of predicted/measured average of annual special sedimentation rate.

G_{sp} of station of di, and MRE is the mean relative error. Table 4 shows that, RE of MEPM is less than EPM, especially for the Tang e pange that is, main station with 45 years period (1955 - 2000) and located at the downstream of Bakhtiari river watershed. Moreover, MRE is found as 4.38, demonstrating the good accuracy of the MEPM model.

In the base of comparing measured data and predicted model (RE and MRE), MEPM result is acceptable and seems that it does not need adjustment of annual special sedimentation (G_{sp}).

The comparison of two models is also shown in Figure 11. It illustrates how inherent inaccuracy of models distributed graphically. Figure 11 shows that MEPM results are closer than EPM to zero line. So, it the ability of MEPM on estimating more accurate values for the amount of average annual special sedimentation rate rather than EPM model.

Conclusions

The EPM is suitable for estimating soil erosion risk in different arid to semi-arid land uses, primary evaluation of sedimentations that will be stored behind dams as well as estimation of the annual sediment in rivers with no hydrometric data. Numbers of coefficients used in this model are limited and easily estimated. However, the scoring of input parameters strongly depends on expert judgment and how accuracy watershed is visited.

The new approaches were elaborated to calculate the land use and observed erosion coefficients through partial calibration. The canopy percentage and slope were used to estimate land use coefficient; also the canopy percentage, drainage density, climatic index, geology indicator were applied to calculate the observed erosion coefficient. The GIS and RS techniques have properly been used extensively in this research.

The present study was conducted in the Bakhtiari

Watershed, Steeply Mountain Zagros, Iran, to test the applicability of the modified EPM in estimation of sediment yield. The comparison of two models by observed data at four hydrometric station showed that accuracy of MEPM is more than EPM. Also, the results demonstrated very high correlation between EPM and MEPM. So, modified EPM is a suitable model to estimate sediment yield in large watersheds like Bakhtiari, especially using GIS and RS.

It should be mentioned, although, the MEPM was presented to reduce EPM dependency to field visit and engineering judgment by using new parameters; however, watershed visit strongly is recommended to better estimating.

ACKNOWLEDGEMENTS

The authors would like to appreciate Iran Water and Power Resources Company (IWPCO) who supported this research. We have used the reports of Dez/Bakhtiari basin sediment evaluation provided by Dez Ab consultancy engineer. The authors also acknowledged Dez Ab Company.

REFERENCES

Bissonnais YL, Montier C, Jamagne M, Daroussin J, King D (2002). Mapping erosion risk for cultivated soil in France. Catena 46:207-220.

Broge NH, Lablance E (2000). Comparing prediction power and stability of broadband and hyperspectral vegetation indices for estimation of green leaf area index and canopy chlorophyll density. Remote Sens. Environ. 76:156-172.

Clark KB (1999). An estimate of sediment yield for tow small watershed in a geographic information system. M. Sc. Thesis, Geography, University of New Mexico.

Development and Resources Corp (1973). Dez Watershed Resource Management Plan. Gov. Iran Report, Ministry of Agric. Tehran, Iran.

Gamon JA, Field CB, Goulden ML, Griffin KL, Hartley AE, Joel G, Penuelas J, Valentini R (1995). Relationships between NDVI, canopy structure, and photosynthesis in three Californian vegetation types. Ecol. Appl. 5(1):28-41.

Gavrilovic Z (1988). The use of an empirical method (erosion potential method) for calculating sediment production and transportation in unstudied or torrential streams. International Conference of River Regime., Wallingford, England. pp. 411-422.

Ghomeshi M, Bina M, Sedghi H (1995). Sediment Distribution and Evaluation of the Useful Life-Time of Dez Reservoir in Iran. 6th Inter Symposium on River Sedimentation, New Delhi, India.

Heydarian SA (1996). Assessment of erosion in mountain regions Proceedings. 17th Asian Conference on Remote Sensing, Sri Lanka.

Hill J (1993). Land degradation and soil erosion hazard mapping in Mediterranean environment with operational earth observation satellites. Proc. Int. Symp. Operationalization Remote Sens. 9:41-52.

Iran Water and Power resource development Co (IWPC) (2005). Updating erosion map of Dezz watershed, Report No. 5004312.

Jordan CF (1969). Derivation of leaf area index from quality of light on the forest floor. Ecology 50:663-666.

Martinez-Casasnovas JA (2003). A spatial information technology approach for the mapping and quantification of gully erosion. Catena 50:293-308.

Mather PM (1999). Computer processing of remote sensed images. 2nd Edition, John Wiley & Sons.

Mather PM (2001). Classification method for remotely sensed data. First Edition, Taylor & Fransis.

Meamarian H, Tajbakhsh M (2003). The Sediment Yield Potential Estimation of Kashmar Urban Watershed Using MPSIAC Model in The GIS Framework. Map India Conference., GIS Dev.

Mezosi G, Mucsi L (1993). Soil erosion assessment with the help of remote sensing methods Proc. Int. Symp. Operationalization Remote Sens. 9:29-40.

Mohammed Rinos MH, Aggarwal SP, Ranjith Premalal DS (2001). GIS-based soil erosion modelling and application of remote sensing on soil erosion assessment Proceedings of the ninth Annual Conference of GISRUK, 18–20 April, University of Glamorgan. pp. 592-594.

National Iranian Oil Company (NIOC) (1998). Hafttanan and Kohkino Geological maps in 1/100000 scale.

Navas A, López-Vicente M, Gaspar L, Machín J (2012). Assessing soil redistribution in a complex karst catchment using fallout 137Cs and GIS. Geomorphology., In Press, Corrected Proof.

PSIAC (1968). Report of the Water Management Subcommittee on Factors Affecting Sediment Yield in the Pacific Southwest Area and Selection and Evaluation of Measures for Reduction of Erosion and Sediment Yield. ASCE., 98, Report No. HY12.

Shrimali SS, Aggarwal SP, Samra JS (2001). Prioritizing erosionprone areas in hills using remote sensing and GIS—a case study of the Sukhna Lake sub-catchment, Northern India. Intl J. Appl. Earth Obs. Geoinformation 3:54-60.

Solaimani K (1997). Estimating Changes in Morphology and Sediment Supply using Remote sensing and field Techniques in River Basin. University of Glasgow, U.K.

Tangestani MH (2006). Comparison of EPM and PSIAC models in GIS for erosion and sediment yield assessment in a semi-arid environment: Afzar Catchment, Fars Province, Iran. J. Asian Earth Sci. 27:585-597.

Terranova O, Antronico L, Coscarelli R, Iaquinta P (2009). Soil erosion risk scenarios in the Mediterranean environment using RUSLE and GIS: An application model for Calabria (Southern Italy). Geomorphol. 112(3-4):228-245.

Tomczyk AM (2011). A GIS assessment and modelling of environmental sensitivity of recreational trails: The case of Gorce National Park, Poland. Appl. Geogr. 31(1):339-351.

Turner D, Cohen W, Kennedy R, Fassnacht K, Briggs J (1999). Relationships between leaf area index and Landsat TM spectral vegetation indices across three temperate zone sites. Remote Sens. Environ. 70:52-68.

Wischmeier WH, Smith SS (1965). Predicting rainfall-erosion losses from cropland east of the Rocky Mountains Agriculture Handbook No. 282. US Department of Agriculture, Washington, DC.

Wischmeier WH, Smith SS, (1978). Predicting rainfall-erosion losses: a guide to conservation planning Agriculture Handbook No. 537. US Department of Agriculture, Washington, DC.

Yuliang Q, Yun Q (2002). Fast soil erosion investigation and dynamic analysis in the loess plateau of China by using information composite technique. Adv. Space Res. 29:85-88.

Zhou W, Wu B (2008). Assessment of soil erosion and sediment delivery ratio using remote sensing and GIS: a case study of upstream Chaobaihe River catchment, north China. Int. J. Sediment Res. 23(2):167-173.