The zoning of the erosion intensity and sediment yield using the geographic information systems and remote sensing, with the application of the MPSIAC model (Case study: Syazakh dam basin, Kurdistan)

Marouf Emamgholi[1], Kaka Shahedi[2], Valeed Khaledian[3,*], Khaled Babaee[3]

[1]University of Agricultural Sciences and Natural Resources, Sari, Iran

[2]Department of Agricultural Sciences and Natural Resources, School of Natural Resources, Sari, Iran

[3]Kurdistan's Regional Water Resources, Kurdistan, Iran

*E-mail address: Hamid_fila@yahoo.com

ABSTRACT

The aim of the present research was to estimate erosion and sediment and to formulate a map of the basin's erosion intensity using the satellite data, GIS technique and to compare the hydrometric stations' statistics. Using the Land sat satellite images among the results obtained from these data through (TM, ETM$^+$), coverage index (NDVI) as well as a combination of bands 2, 3 and 4 for determining the type of land use and for assessing the soil texture in terms of regional aerial images tone and in accordance with the physiographic of the basin through sampling the soil texture , the map of the basin's texture was obtained. Assessing the surface and river erosion was also conducted using the aerial images and field visits. Given the data obtained and the model being applied, the special sediment rate in the basin was 5/19 tons per hectare, while the overall sediment rate obtained for the entire basin was estimated 5496533 tons in a year. Meantime, the observed and estimated value in the hydrometric station of Nesare Olya for as much as 553230 tons in a year shows a less than 1 % difference in the entire estimation of the sediments accumulated in the back of the dam while its sediment load rate estimation as much as 5/16 tons per hectare shows a 0/03 difference rate for the station.

Keywords: Erosion and sediment; Remote sensing; Geographic information systems; Syazakh basin; MPSIAC

1. INTRODUCTION

Since it is located in an arid and semi-arid region, Iran is in a more unfavorable water situation than the average countries of the world. The occurrence of subsequent and prolonged droughts, high water and weather fluctuations, have exacerbated the water level

resources (Bashiri et al, 2013). To continue with his life, man needs food stuff that are obtained because of earth and water.

A factor threatening water and earth is erosion. It is because of this that fighting erosion is an inevitable phenomenon that cans not be eliminated entirely. However, man's activities could escalate or reduce that. Soil is regarded one of the most important natural sources. Today, soil erosion is considered a danger of the human's well fare and his life (Tajgardan et al, 2008). In region where erosion is not controlled, soil starts to erode gradually losing its fertility.

Not only does erosion results in poor soil and farms being deserted, thereby leaving huge and irrecoverable danger, but it also, through deposited material in streams, reservoirs, a dams, ports and a reduction in their intake capacity causes various losses (Safamanesh et al, 2006).

Thus, the issue of soil protection should not be taken for granted. Today, protecting soil and fighting erosion are necessary measures by each government, because replacing the soil lost requires hundreds of years. The major soil erosion factor is human intervention that occurs through non observance of farming rules, over grazing and forest destruction (Refahi, 2006).

Little research have been done with regards to the erosion and sediment rate for upstream dams of the country and in order to reduce deposited material and erosion as well as for raising the useful life of dams and their volumes.

Hence to study the basin control field visits, the MPSIAC method was utilized. The aim of the research was to estimate the output sediment in the dam catchment of Syazakh using properties such as soil properties, slope, rainfall, area, exploiting the land, and other parameters needed as well as comparing this estimation with the observed value of the regional hydrometric station in order to giving priority to the sub watersheds for watershed measures so that their life length is increased and their volume is preserved.

2. METHODOLOGY

Region under study: Dam catchment of Syazakh in situated in the Zagros foothills, west of Iran. The extent of this basin is around 1058 square kilometers and its maximum height is 3053 while the minimum eight of it is 1755 meters.

Its location is 682300 to 647334 northern, and 3992199 to 3992199 eastern (UTM). The basin's average slope is 16/92 % while the average annual rainfall is 530 millimeters.

The location of the region under study is in Iran and in Kurdistan as shown in Figure 1.

To assess erosion and sediment in these sub basins and assess the 9 fold factors of the MPSIAC model, using the equations of this model (Figure 2), one can summarize the research procedures in the following stages:

1. Library studies (examining the existing sources in the technical archives of the Kurdistan's regional water, natural resources of the province and the research center of Kurdistan),
2. Field visits (to determine the land control points and sampling),
3. Laboratory studies (extracting data from satellite images and maps),
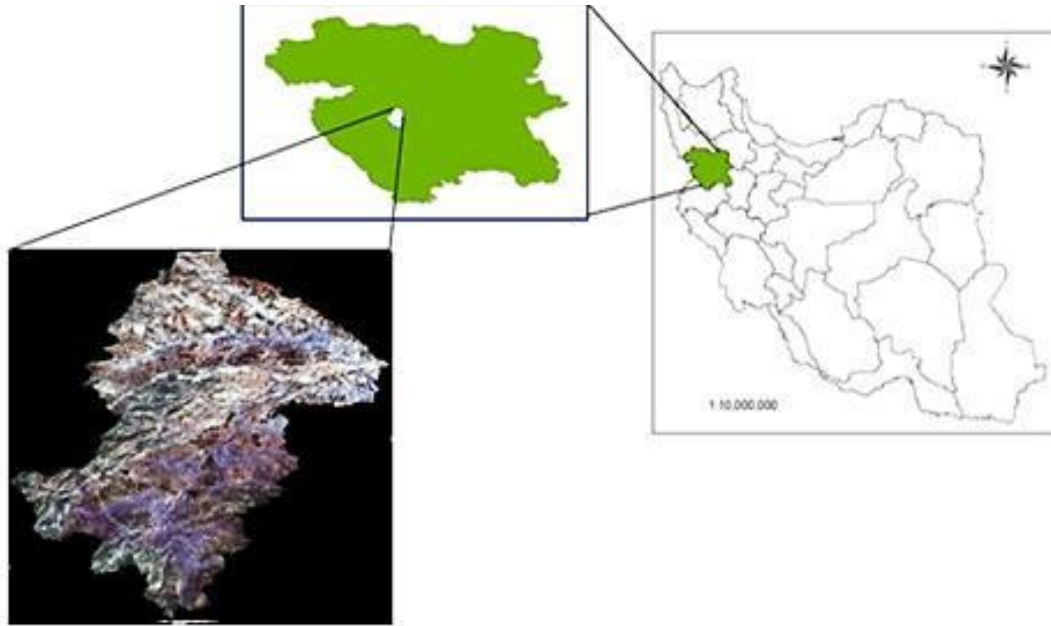4. Analyzing satellite images and maps by ENVI and Arc Map software.
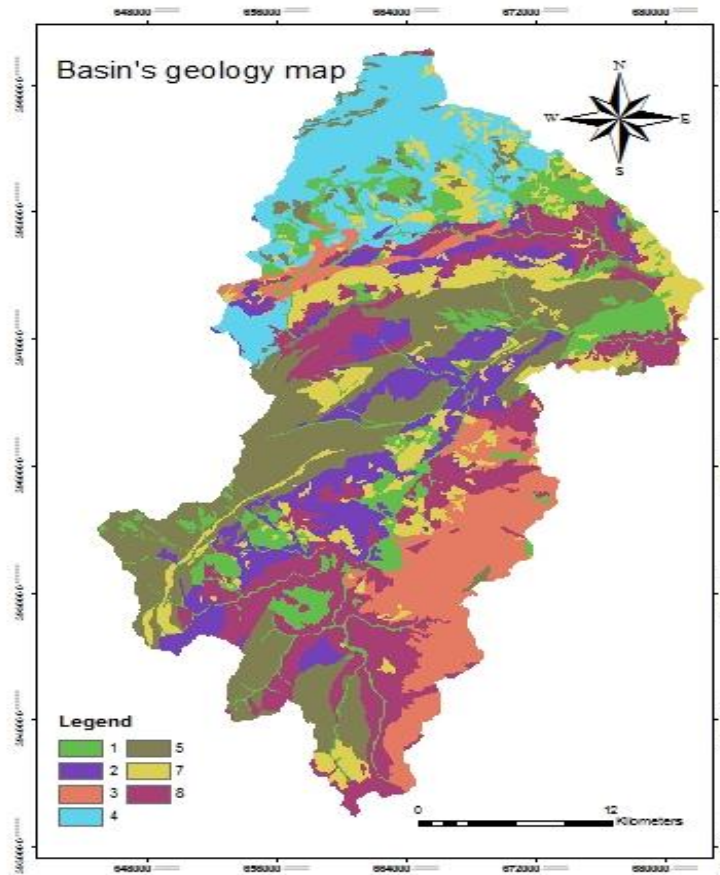
Figure 1. Region under study.

Figure 2. Basin's geology map.

2. MPSIAC MODEL

This model was presented by the American earth and water management committee in order to estimate the intensity of the soil's erosion and sediment yield in arid and semi arid region of the United states of America in 1968 (Refahi, 2007). In this method, estimating erosion and sediment was considered as the most important effective factor on erosion (9 fold) compared to the other methods. Factors under study in this method are surface geology, soil, climate, runoff, topography, land coverage , land exploitation, high land erosion, gully erosion, and river erosion. The final score related to the above mentioned 9 factors in each of these units is indicative of the intensity of soil's erosion and sedimentation degree in that unit. To estimate erosion and sediment in the basin under study, the 9 factors should be examined separately through the MPSIAC method and then after the 9 factors being summed up the sediment rate and accordingly the sediment class are determined. After determining the sediment rate, using the relationship 1 the specific sediment is estimated.

Relationship 1 $$Q_S = 0/186 \, e^{\,0/036 \, R} \qquad (1)$$

Q_S = Specific sediment in terms of cubic meters per hectare in a year, R: sediment rate and e: Nepryn number

3. EXAMINING THE 9 FOLD FACTORS OF THE MPSIAC MODEL - FINDINGS

3. 1. Surface geology

In MPSIAC, depending on the stones' sensitivity, the score 0 to 10 has been considered for the geology factor. The geology map of Divandare - Bijar became shape file in the GIS space after being dereference. Then, in this report the y_1 layer in accordance with the structure status and geology report, the sensitivity score in terms of stone units was determined and considered as the first factor for each sub basin (Figure 2). Score related to the geology factor in the MPSIAC method is estimated from the relationship 2:

$$y_1 = x_1 \qquad (2)$$

x_1 : is the average sensitivity score towards erosion for each structure.

3. 2. Soil factor

To assess the soil texture from the regional aerial photos tone and according to the physiographic of the basin through each tone, the related polygon was provided in the GIS space, and then, based on the related coordinates , sampling of the soil texture was done . In the end, the soil texture having been determined, through Table 1, the score related to the K factor was determined and the soil factor was determined from the basin (Figure 3).

Table 1. Morgan's way to determine K through the soil's texture (Ahmasdi, 2007).

Soil status	K	Soil status	K
Surface soil with gravel coverage	0.5	Resisting land against erosion	0.1

Sand soil	0.16	Fine sand soil	0.42
Sand loamy soil	0.12	Loamy sand with very fine sand	0.42
Loamy silt soil	0.48	Loamy soil	0.37
Clay silt soil	0.25	Clay loamy soil	0.37

$$y_2 = 16/67 \ x_2 \quad (3)$$

y_2 : is the average soil factor score of each basin after weight average
x_2 : is the average score related to the soil erodibility in each sub basin.
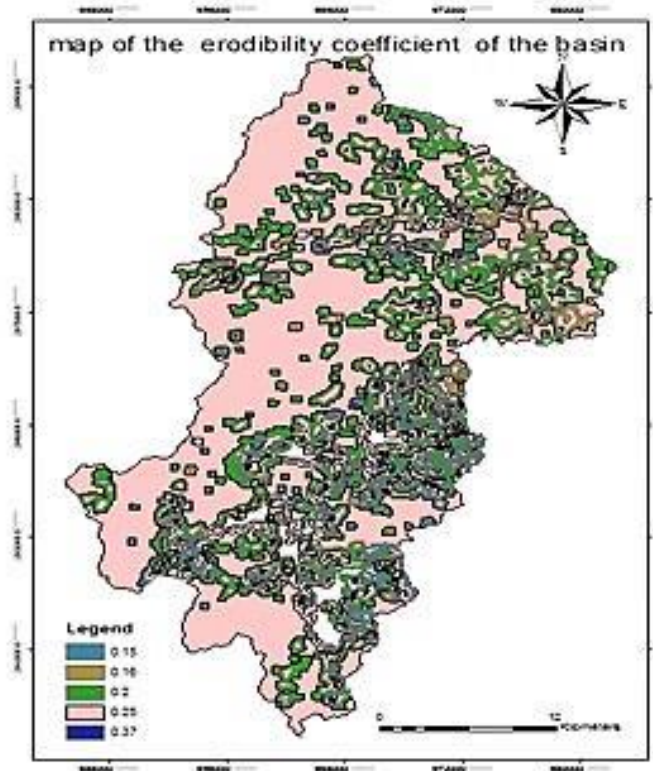

Figure 3. Map of the coefficient erodibility of the basin.

3. 3. Climate factor

To score this factor, the 6 year rainfall with the return period of 2 years that has the highest correlation with the soil's credibility, was used. First, by assessing the rainfall volume of a maximum of 24 hours, the 1 hour rainfall degree with the return period of 10 years (Alizade, 1988), using the following equation is estimated (relationship 4).

$$P_{(60,10)} = \{(1.3352 - 0.1964 \, LnX_i)X_i\} \qquad (4)$$

where X_i is the average maximum rainfall in 24 hours in a 15 year old statistical period (Equal to 54 millimeter); $P_{(60,10)}$ is the one hour rainfall with the return period of 120 years assessed as 29/8080 millimeteres

Then using the reformed equation, the 6 hour rainfall volume with the return period of 2 years was assessed and through this the final score was estimated in accordance with the related formula of this factor (relationship, 5)

$$P_{(i,j)} = 0.4847 + 0.2251Ln(T - 0.4112)(-0.0158 + 1.0198 * t^{0.375})p_{(60,10)} \qquad (5)$$

where T is the return period, T is the rainfall rate per hour, $P_{(360,2)}$ is the 6 hour rainfall with the return period of 2 years equal to 34/5 millimeters.

Then using the relationship (6) the climate factor was estimated

$$Y_3 = {}_{0/2} \, x_3 \qquad (6)$$

x_3 is the 6 hour rainfall with the return period of 2 years in terms of 6/9 mm for the basin.

3. 4. Surface runoff factor

To determine the surface runoff, first based on the type of each sub basin, the hydrological group of earth was determined on the basis of the Mahdavi's (2007) and then using the vegetation coverage percentage chart earth hydrologic groups, the CN of each of the basin sections was determined. Given the permeability of the basin compared to the estimation of rainfall, measures were done.

Here, the SCS method was used. The initial moisture surface storage shortage was estimated through the relationship 7 and through the relationship 8 the height of the runoff was estimated for each of the basins (Fig. 4).

$$S = \frac{(25400 - 254CN)}{CN} \qquad (7)$$

And through the relationship (8) the height iof the runoff was estimated for each of the sub basins.

$$Q = \frac{(P - 0.2S)}{P + 0.8S} \qquad (8)$$

Where P is the 14 hour maximum rainfall, S is the initial moisture surface storage shortage. Then using the California relationship, Tc (relationship 9), the basin's concentration time was determined

$$TC = (.885L3/h)0.385 \qquad (9)$$

where L is the length of the river per meter, H is the minimum and maximum difference of the basin. From the relationship (10) the time to peak of each sub basin was estimated.

$$\text{Tp} = \text{TC} + 0.6\text{TC} \qquad (10)$$

Then using the

$$Qmax = \frac{(2.083\ A.q)}{Tp}$$

Equations where A is the area of the basin per square kilometers And q is the height of the runoff per centimeter and Tpi = s the time to peak per hour.
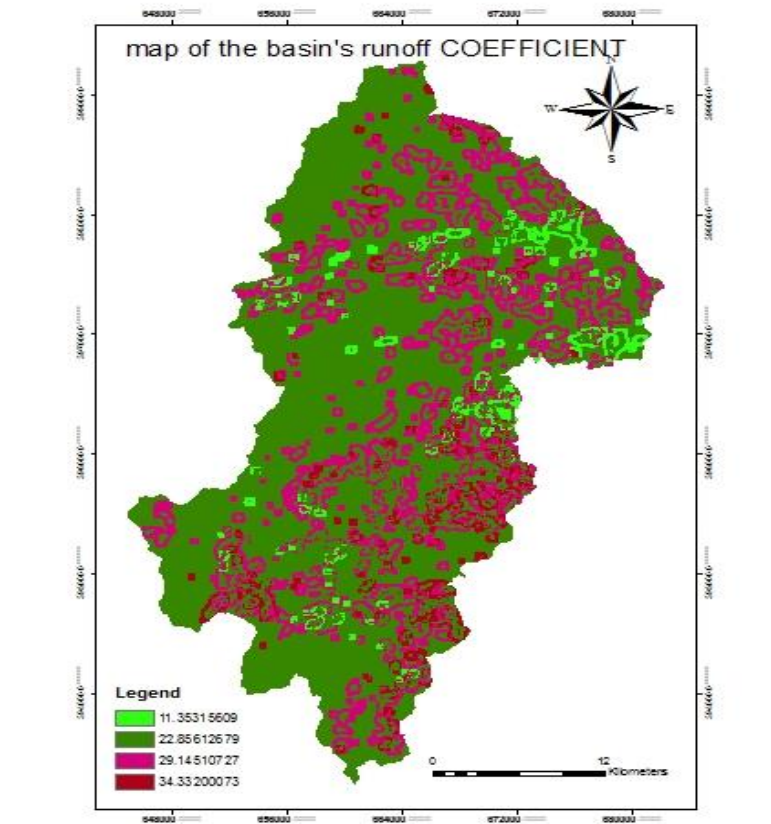
$$X4 = 0.006\ R\ +\ 10\ Qp \qquad (11)$$

Figure 4. Map of the basin's runoff.

3. 5. Topography factor (slope)

This layer has been estimated through analyzing the height quasi number (DEM) for the basin according to the relationship (12) (Figure 5)

$$X_5 = 0.33\ S \qquad (12)$$

where S is the average slope of the basin
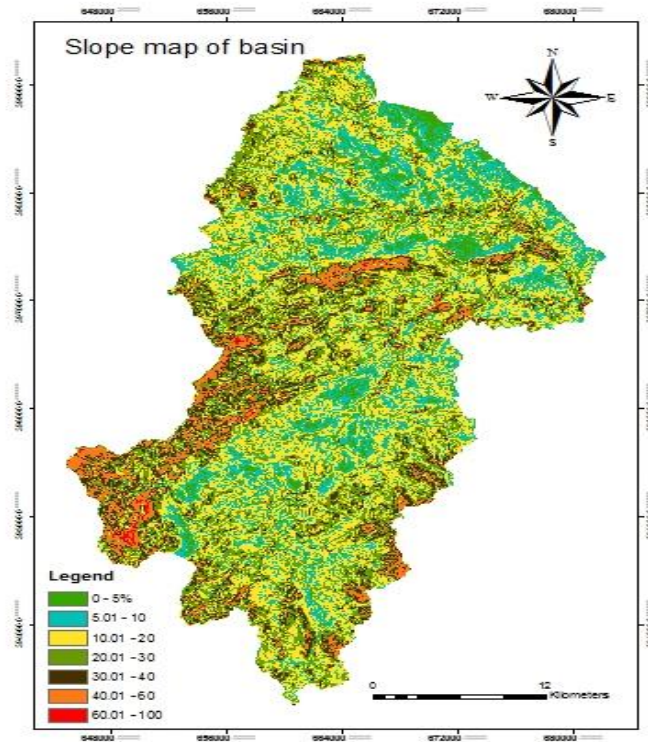
Figure 5. Slope map.
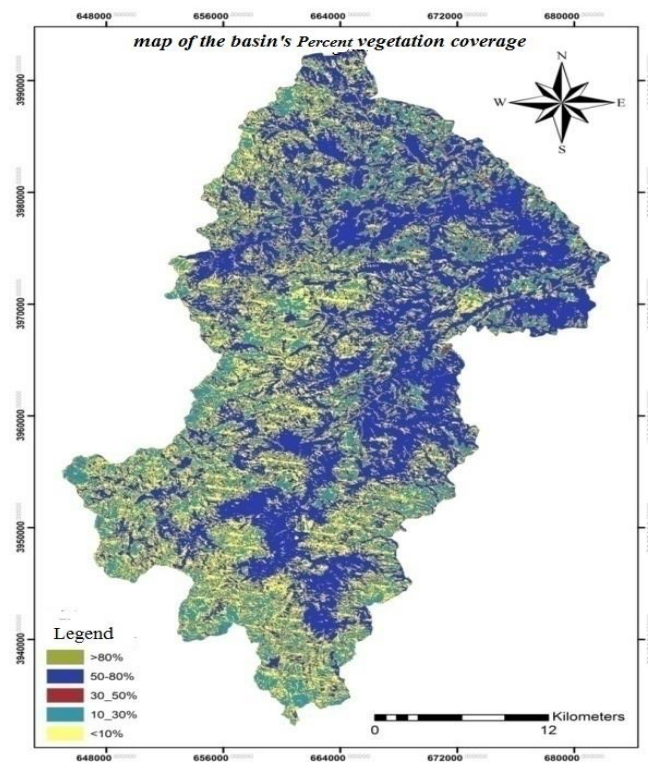
3. 6. Determining the vegetation coverage index

Figure 6. Map of the basin's vegetation coverage.

Using two bands 3 and 4 (Soleimani, 2007) and using the equation (8) in the ENVI space with the cutting of the basin and classification of the coverage in 5 groups , more than 80 %, 10-30, 30-50, 50-80 and less than 10 % were conducted (Figure 6)

$$Y_6 = 20 - 0.2 \, x_6 \qquad (13)$$

where x_6 is the percentage od = f the vegetation coverage in each sub basin
NDVI = (band 4-band3) / (band4 +band3) (relationshiop14)

3. 7. Land use factor

To formulate this layer, first with the field walking, various polygons were formulated for each of the basin applications and then using the combination of bands 2, 3 and 4, supervised classification has been defined for all types of land use (Figure 7)

$$Y_7 = 0.2x_7 \quad (15)$$

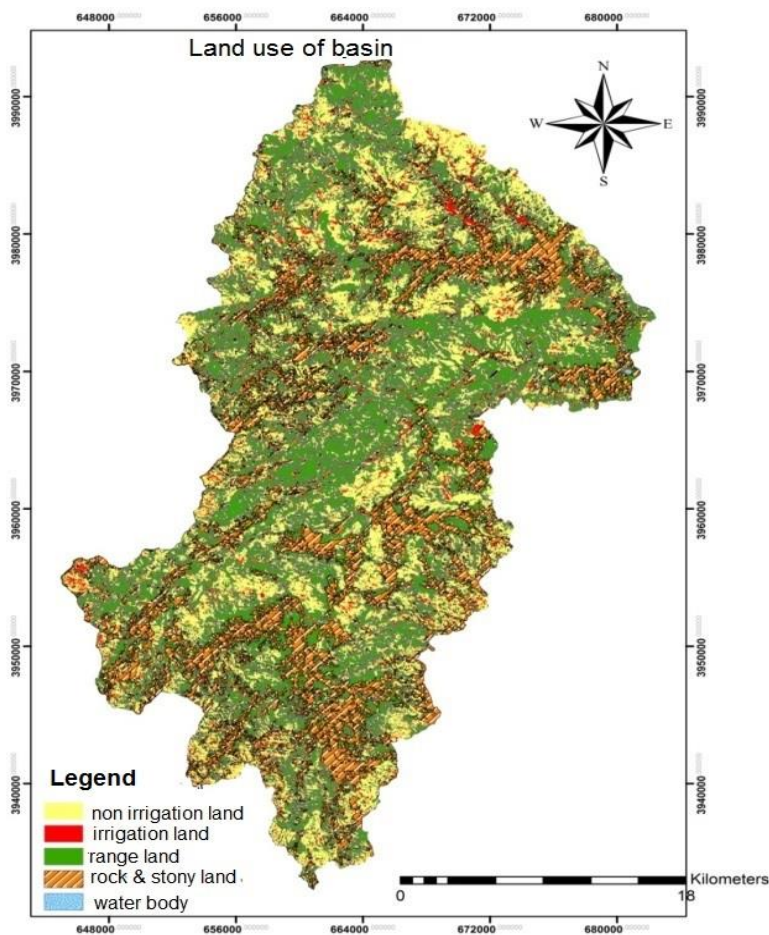where x_7 is the barren land (without vegetation) percentage on the sub basin.

Figure 7. Map of the basin's land use.

3. 8. Assessing the surface erosion factor

For determining this factor, using the field visits and disperse studies on the natural resources of Kurdistan and controlling the land points in the region and by using the B.L.M method, the surface earth factor was scored in 7 factors (Ahmadi, 2007). Through the relationship 16 the score of each of the basin sections was estimated (Figure 8).

$$X_8 = 0.25 \text{ S.S.F} \quad (16)$$

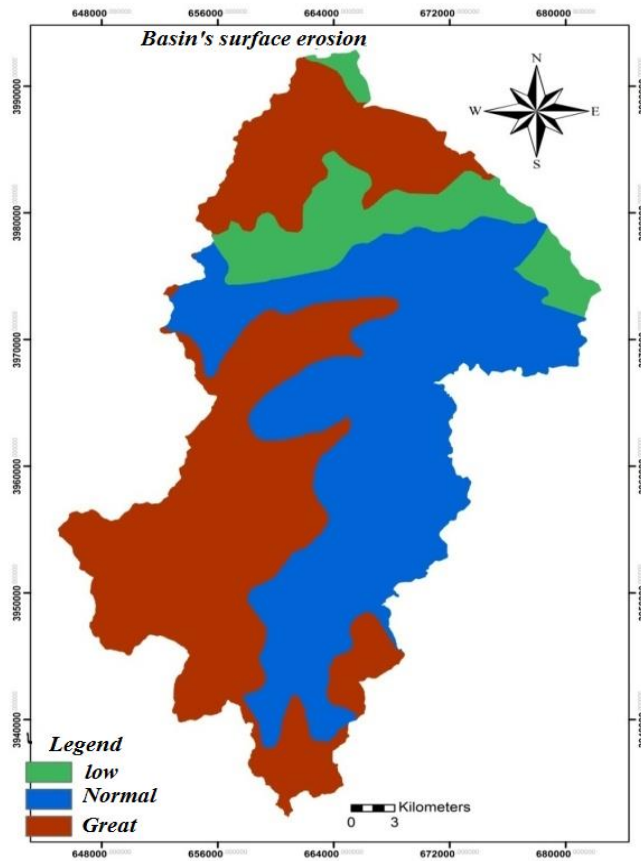where S.S.F is the score of the surface earth obtained from the sum of 7 factors of B.L.M

Figure 8. Basin's surface erosion map.

3. 9. Assessing the river erosion factor

To determine this factor, using the gully erosion score in the B.L.M method and according to the related equation to his factor, this factor was obtained for different sections of the basin through (relationship 17), (Figure 9).

$$X_9 = 1.67 \text{ SSF.g} \quad (17)$$

where in this relationship, SSF.g is the final score of the gully erosion of the earth surface factor in the B.L. M method.
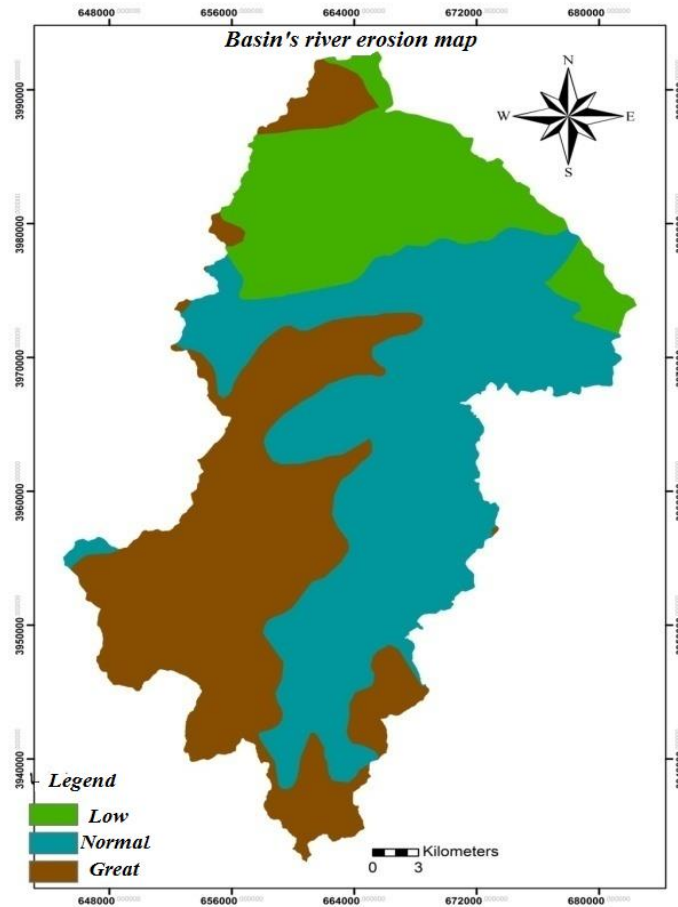
Figure 9. Basin's river erosion map.

3. 10. Estimating the soil's erosion and sediment yield

With combining the above layers of the final map of the basin's erosion was obtained (Figure 11). The annual specific sediment degree of the basin was assessed in accordance with the average soil volume density (1.3 grams per square centimeters) in terms of ton per square kilometers in a year (Equation 9).

Then using the S.D.R degree, the overall basin's sediment and erosion degree was estimated (Rastgoo, et al, 2006)

$$Q_s = 38.77 e^{0.0353R} \qquad (18)$$

where Q_s is the annual sedimentation degree in terms of cubic meters per square kilometers in a year, R: the sedimentation rate of each sub basin and e: the basic nepryn Logarithm

Also, to convert the sediment volume rate to weight, we use the following relationship (11)

$$Q_{SW} = Q_S \cdot P \qquad (19)$$

Q_s: the specific sedimentation $\quad m^3/ha \cdot year$

P: the sediment volume density $\quad Ton/m^3$

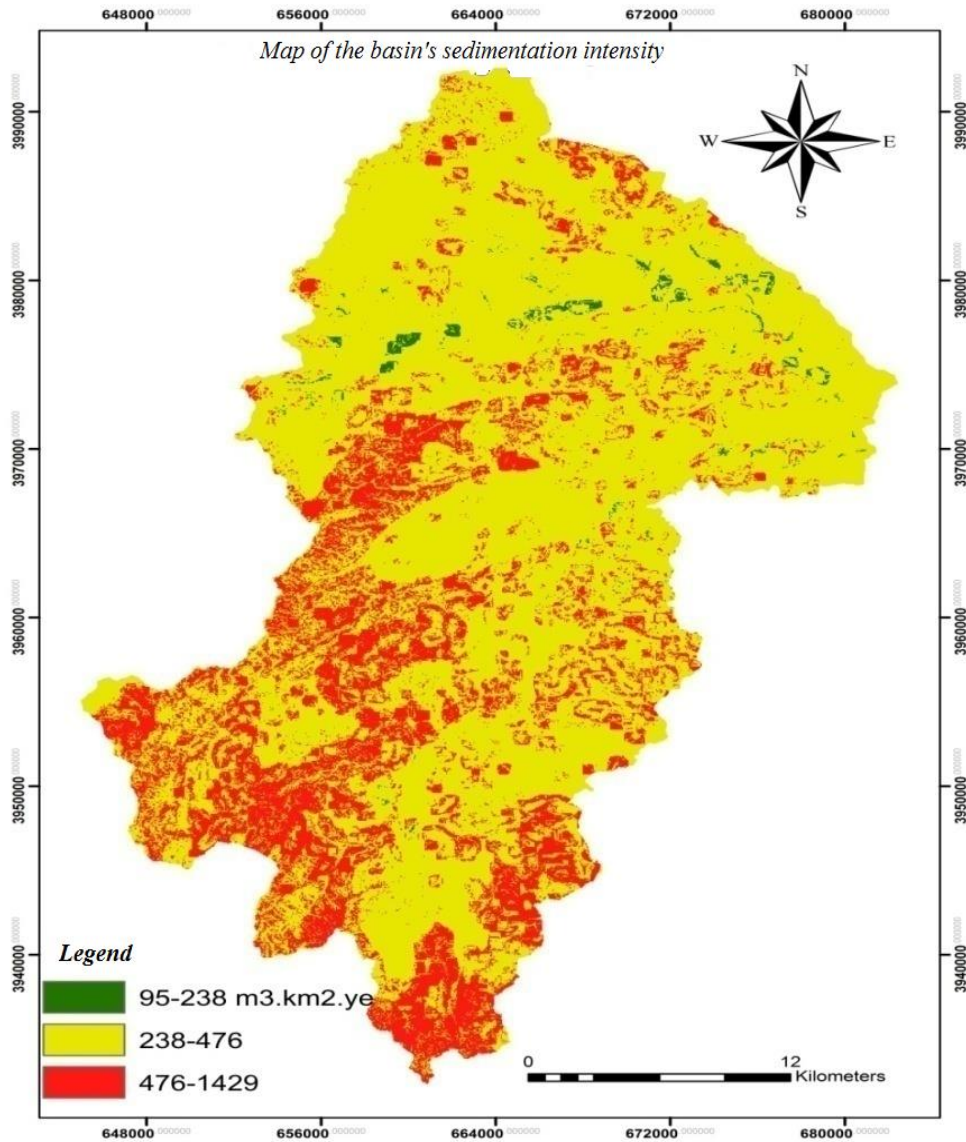Q_{SW} : the specific sediment degree $\quad Ton/ha \cdot year$

Figure 10. Map of the basin's sedimentation intensity.

4. DISCUSSION AND CONCLOSIONS

The efficiency and confidence level of each model is determined as a result of estimating the method needed with the registered values by the measuring devices (Asgari and Jafari, 2008). In this research the results of the sediment studies and Debi statistics were analyzed and compared to the resulting findings of the mentioned model. The overall basin's

sediment yield was estimated through analyzing the actual statistics of 5/19 tons in a year that is close with the overall sediment production of the basin in the MPSIAC model being equivalent to 5/16 tons per hectare in a year. Then, in the current conditions, this model is efficient for the basin under study. In accordance with the information layers and sediment statistics for each hydrologic unit as well as the sediment degree the sediment rate has been zoned and the intensity of the erosion has been ranked as three classes of low, average, and high. The overall basin's sediment yield was estimated through analyzing the actual statistics of 5/19 tons in a year that is close with the overall sediment production of the basin in the MPSIAC model being equivalent to 5/16 tons per hectare in a year. Then in the current conditions.
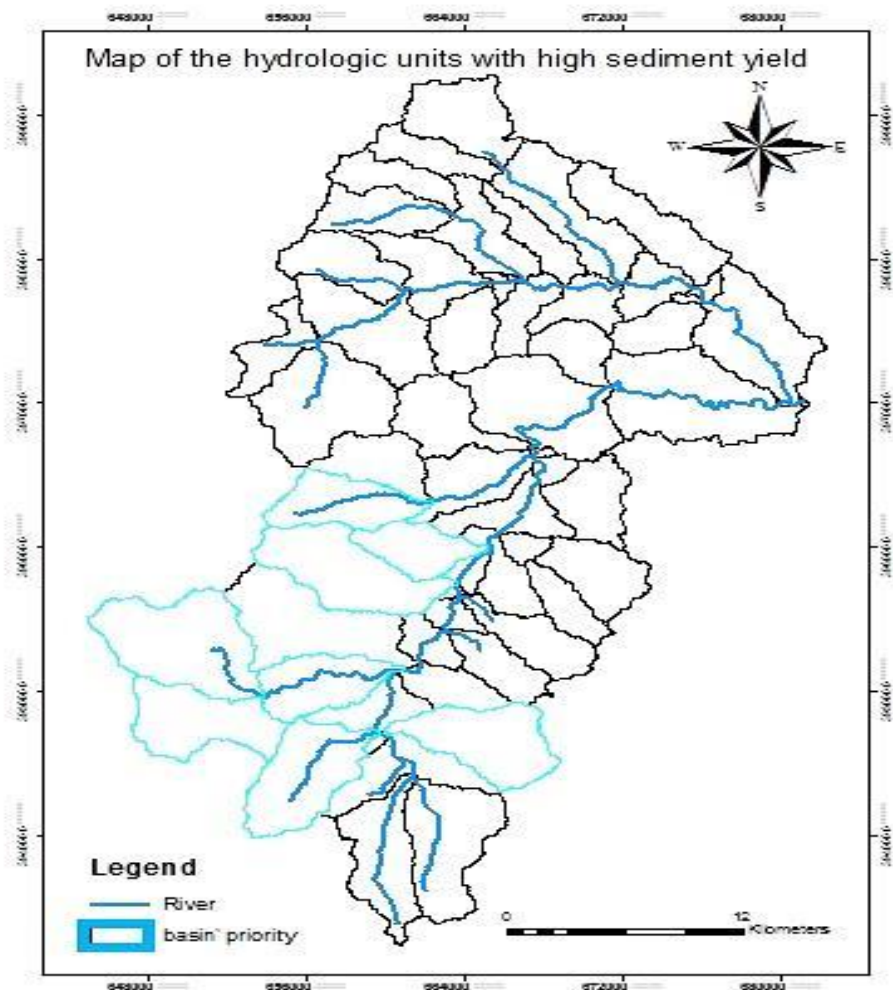

Figure 11. Map of the hydrologic units with high sediment yield, the basin' priority.

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