

## The Sediment yield potential estimation of Kashmar urban watershed using MPSIAC model in the GIS framework

Hadi Meamarian<sup>1</sup>, Seid Mohammad Tajbakhsh<sup>2</sup>, Hamid Esmaeilzadeh<sup>3</sup>

<sup>1,3</sup>College of Natural Resources-University of Tehran-Iran,

PO box: 31585-4314,

fax: 00982612227765,

Email: [meamarhadimsc@yahoo.com](mailto:meamarhadimsc@yahoo.com),

<sup>2</sup> College of Agriculture University of Birjand

### Abstract:

With due attention to the relatively suitable compatibility of MPSIAC model with the arid and semiarid conditions of Iran and lack of hydrometric station in region, in order to estimating of sediment yield and providing sediment yield and erosion intensity map in this watershed, we used modified PSIAC model. At first to enter the available raw data into the GIS framework we digitized topography, geology, geomorphology, land capability, soil hydrologic groups and plant cover maps using on-screen method. In the second stage digitized maps were encoded based on the values of geology, soil erodibility, climate, land cover, land use, present status of erosion and channel erosion and sediment transport factors. Using the DEM layer, slope and rain (using the rain gradient equation) maps were provided and consequently topographic and runoff (using the logical method) factors maps were prepared. Then these factors maps were summed together and finally sedimentation score map was provided. We applied following equation on the sedimentation score map and therefore sedimentation map was obtained:

$$Q_s = 38.77e^{0.0353R}$$

Where:

$Q_s$ : specific sediment ( $m^3/km^2/y$ )

R: sediment yield score

And then with the applying Sediment Delivery Ratio (SDR) on the sedimentation map, erosion intensity map was obtained. Also to obtain the work unit map, we used geology, geomorphology and hydrologic units maps and with overlaying this maps work unit map was obtained. Considering the upper part of this basin is rocky, the small work units were eliminated, and at last 28 work unit was obtained. Then by Spatial Analyst module facilities in the ArcView 3.2 software, the average of sediment yield, erosion and in any work unit and subbasin was obtained. To mapping erosion forms was used from aerial photos interpretation and field surveying and 4 erosion forms ( $E_1$ ,  $R_1$ ,  $R_2$ , S) was distinguished. For the relatively high effect of slope and landuse factors on increasing of sediment yield specially in the upper part of basin, to decrease the effect of these factors, was applied the average filter (size: 100m·100m) on the slope map and also the score of landuse factor was adjusted. Considering the urban watershed of Kashmar has soil only in the lower part of watershed and the most part of that is rocky, 55.6% of watershed area was categorized in the third class (a class with medium erosion), 42.7% in the second class (a class with low erosion), 1.7% in the fourth class (a class with relatively high erosion). The class of high erosion there is in the lower part of this basin because this part has more sensitive formation. Also in this basin there is two sediment yield class. 79.4% of this basin was classified in the second class (a class with low sediment yield) and 20.6% in the third class (a class with medium sediment yield).

*Key words: MPSIAC, GIS, sediment yield, erosion, urban watershed.*

### Introduction :

Nowadays the degradation of renewable natural resources is one of the most important problems of mankind. Soil is one of the most important natural resources and the degradation of that is caused, the decline of fertility, weakening of plant cover and at last aggravation of desertification specially in the arid and semi-arid regions. In accordance with the estimation of FAO organization, in excess of 75 billion tons soil in the whole earth is eroded. In the neighborhood of 76 percent of Iran exposed to the erosion. In Iran, the climate variation and topographic conditions have important role on the increasing of erosion. This watershed has located on the north of Kashmar city (Khorasan province, Iran, between 58° 28' 30" to 58° 34' 00" E and 35° 17' 25" to 35° 23' 00" N). Torrential discharges of this watershed is entered from east into Kashmar city. In the study area there is two independent hydrologic subbasins, Kal-e-Asgir and Kal-e-Gorg. This region is high mountainous and its area

is 5153 hectare .This basin is located in kavir-e-namak basin .With due attention to the suitable compatibility of MPSIAC model to arid and semiarid conditions of Iran in the erosion and sediment studies of this watershed was applied .In this study we used newest GIS softwares to obtain a good and accurate result at the least time .

#### Materials and methods :

By reason of the great number of data, activity and changeability of these data in the natural resources , geographic information system , as a useful tool , is carried to solving many problems .In this study , effective factors in the erosion ( to MPSIAC model ) are gathered by using existing conditions maps , statistical information , field investigation , topographic maps and aerial photographs . Then by using geographic information system and Arc view , Arc/info , R2V and Auto CAD softwares ,the maps and tables was digitized and based on table 1 the erosion factors maps were encoded and with overlaying these maps ,the sediment yield and erosion maps in accordance with this equation were obtained

$$[1]Q_s = 38.77 e^{0.0353R}$$

where:

Qs : total sediment yield ( m<sup>3</sup> . km<sup>-2</sup> .y<sup>-1</sup> )

R: sediment yield score .

#### Surface geology :

To calculate this factor, at first geology map was digitized and then based on the stones sensivity to erosion , this map was encoded and a new data field in the geology map database ( based on X<sub>1</sub> factor ) was created .Using the facilities of Spatial Analyst module in the Arc View Software , the average of this factor in the whole basin was obtained 2.2 .

#### Soil :

With due attention to the soil studies and soil experiments , the effective factors on the K (k is erodibility factor in the USLE method ) , namely, silt + very fine sand percent , sand percent , organic matter percent, soil structure and permeability were determined and then by using nomograph1, K value and at last X<sub>2</sub> value in any land unit components was estimated.Then land units map was digitized and this map was encoded based on the soil erodibility factor and a new data field in the land units map database (based on X<sub>2</sub> factor) was created. The average of this factor in the whole basin was obtained 2 .93.

#### Climate:

To obtain 6-hour rainfall with 2-year return period, we used IDF (Intensity During Frequency) curves data and this factor (X<sub>3</sub>) for Kashmar watershed was obtained 2.52. Then basin border map was digitized and this map was encoded based on the climate factor value and at last a new data field in the basin map database ( based on X<sub>3</sub> factor ) was created .

#### Run off :

To providing this layer , two maps were provided , run off height map (R) and specific pick discharge map (Q<sub>p</sub>) . At first the DEM layer was prepared , then with applying the precipitation gradient equation on the DEM layer ,the precipitation map was obtained .

$$\{2\} P=2.157 + 0.172 H$$

Where :

P:precipitation (mm)

H: height (m)

Then,subbasins map (or hydrologic units map) was encoded based on the runoff coefficients of rational method(C<sub>r</sub>) and a new data field in the subbasins map (based on C<sub>r</sub>) was created . At the next step ,the structure of this map was changed to the raster structure , based on the run off coefficients , and then this map and rain map were multiplied together and the run off height in each pixel was obtained . To Providing Q<sub>p</sub> layer, we used the regional analysis method . In this method , discharges around study area were studied and the relation between specific discharge and basin area was obtained at the various return periods .These equations are significant at one percent level .

The relation between 1- year specific pick discharge and basin area is as following :

$$\{3\} Q = 0.55 A^{-0.393}$$

$$r = -0.98$$

where :

Q = 1- year specific pick discharge (m<sup>3</sup> / km<sup>2</sup> /y )

A = basin area ( km<sup>2</sup> )

r = correlation coefficient

And then the hydrologic units map was encoded based on  $Q_p$  and at last by using this equation ,  

$$\{4\} X_4 = 0.006R + 10 Q_p$$
 runoff factor value was obtained in each pixel . The average of  $x_4$  factor in this basin was obtained 4.31 .

#### Topography :

To providing this layer at first by using DEM layer , slope map was obtained and then this map was multiplied by 0.33 , and at last the topographic factor map was obtained .The average of this factor in the study area is 7.36 .

#### Ground Cover :

To providing this factor, at first we digitized plant cover map and then in this map based on the bare grounds percent, a new data field was created . The average of this factor in the studied basin is equal 9.88.

#### Land use :

With due attention to the crop canopy percent in each cover type , plant cover map based on  $X_7$  value was encoded and same as previous layers, in this map a new data field was created .The average of this factor in the whole basin is equal 14.04.

#### Erosion condition :

This factor was obtained based on the BLM method .In this method is used from 7 factor : surface erosion, land cover, rill erosion, surface litter, demolition traces on the ground surface, surface flows traces and gully erosion . By field surveying , the score of these factors in each geomorphologic facies was determined and then with digitizing geomorphology map , this map was encoded based on  $X_8$  factor value and a new data field (based on  $X_8$  factor) was created in this map . The average of this factor in Kashmar basin is equal 3.84 .

#### Channel erosion and sediment transport :

To determining of this factor, we applied the gully erosion score (or SSFg in the BLM method ) . Based on this factor, geomorphology map was encoded and a new data field in this map was created . The average of this factor in the urban watershed of Kashmar was obtained 0.21

#### Providing of sediment yield score map , sediment yield map and erosion map :

To providing sediment yield score map , at first  $X_1$  ,  $X_2$  ,  $X_3$ ,  $X_6$  ,  $X_7$  ,  $X_8$  , and  $X_9$  factor maps were intersected two by two and at last in the new map, these existing data fields ( 7 fields ) were summed together and a new field was created . Then this map was rasterized based on this new field and was summed with  $X_4$  and  $X_5$  factor maps (provided in the previous steps ) and at last sediment yield score map was provided .With applying the equation 1 on the sediment yield score map , the amount of sediment yield in each pixel was obtained . To providing erosion map, at first based on the following equations, the amount of SDR in each subbasin was obtained .

$$\{4\} SDR = 43.4(A)^{-0.1753} \quad \text{if basin area (A) is less than 10 square mile .}$$

$$\{5\} SDR = 46.7 (A)^{-0.2071} \quad \text{if basin area (A) is between 10 to 100 square mile .}$$

Then based on the table 2 and 3,the erosion and sediment yield maps were classified and vectorized and at last polygons with area less than one hectare because these polygons is not executive, were eliminated and their area was added to their adjacent polygons .To providing suspended load and bed load maps and to calculate suspended load and bed load in each subbasin and work units, at first considering the bed load is twenty percent of suspended load,the sediment yield map was divided by 1.2 and at last suspended load map of basin was obtained and then by subtracting suspended load from total load , bed load was obtained in each pixel . At final step by Spatial Analyst module facilities in the Arc View software and by introducing work units map and hydrologic units map as the background theme, the amount of sediment total load , erosion , suspended load and bed load was obtained in each pixel .

#### The providing of work units and erosion shapes maps :

To providing work units, only we used the intersection of geology , geomorphology and hydrologic units (subbasins ) maps and at last because the upper part of this basin is rocky and for executive limitation of tiny units in these region, these units were eliminated and at last 28 work unit were obtained in this basin . By interpretation of aerial photographs and the field surveying, 4 erosion shape in this basin were obtained (these shapes were described in table 6 ) .

**Results and discussion :**

With due attention to the studies and surveying of this watershed, the main reason of erosion in the lower parts of this basin is overgrazing . Thus with applying the reformatory programs, exclosing and grazing management, and considering the basin formation, is not sensitive to erosion , we can decrease the basin erosion .After providing sediment yield map, we saw in the rocky regions in spite of low sensivity of these regions to erosion, in some places the amount of sediment yield is high whereas with due attention to the existing witnesses, these regions should have low sediment yield . The reason of this problem is high effect of slope and land use factors on the amount of sediment yield . To adjucement the sediment yield in these places,we used a mean filter(size:100\* 100) on the sediment yield map and we adjusted the value of land use factor and at last by dividing the new sediment yield map by the previous sediment yield map, correction factor was obtained 0.92 .In this basin considering the higher part of basin is rocky only mechanical erosion form was saw .In the lower part of this basin, was saw light rill and surface erosion form . In this study to increasing the precision of maps overlaying, more speed in the operation, to prevent increasing of files volume and working with data tables of the maps databases, seven factor ( $X_1$  ,  $X_2$  ,  $X_3$  ,  $X_6$  ,  $X_7$  ,  $X_8$  ,  $X_9$  ) of nine factor of PSIAc model, were overlayed vectorial .In the rasteric mode to decreasing of files volume , best speed and precision, a best size (5\*5) for pixels was defined . with due attention to the obtained results and studied basin conditions, obtained sediment has good accuracy .

**Acknowledgement :**

The author thanks Mr . Ali Ershadi, the expert of Kavosh Pey company, since in this study was used form his guidances .

Description	Equation	Effective factors	No
$X_1$ =Stones sensitivity to erosion(0-10)	$Y_1=X_1$	Surface geology	1
K=soil erodibility	$X_2=16.67K$	Soil	2
$P_2$ =6-hour rainfall with 2-year return period	$X_3=0.2P_2$	Climate	3
R=runoff height $Q_p$ =1-year specific pick discharge	$X_4=0.006R+10Q_p$	Runoff	4
S=slope(%)	$X_5=0.33s$	Topography	5
$P_b$ =bare ground percent	$X_6=0.2P_b$	Land cover	6
$P_c$ =crop canopy percent	$X_7=20-0.2P_c$	Land use	7
SSF=the score of soil surface erosion in the BLM method	$X_8=0.25SSF$	Surface erosion	8
SSFg=the score of gully erosion in the BLM method	$X_9=1.67SSFg$	Gully erosion	9

Table1. effective factors on the erosion in the MPSIAC model

Sediment yield scores	The amount of sediment yield( $M^3/KM^2/Y$ )	Sediment yield intensity	Sediment yield class
>100	>1429	Very high	V
75-100	476-1429	High	IV
50-75	238-476	Medium	III
25-50	95-238	Low	II
<25	<95	Very low	I

Table2. sediment yield classes in the MPSIAC model

The amount of erosion( $M^3/KM^2/Y$ )	Erosion intensity	erosion class
>1900	Very high	VI
1300-1900	High	V
1000-1300	Relatively high	IV
615-1000	Medium	III
215-615	Low	II
<215	Very low	I

Table3.Erosion classes

R(sum of factors)	X9	X8	X7	X6	X5	X4	X3	X2	X1	Area(ha)	Kal-e-gorg
46.87	0.00	3.50	14.15	9.92	7.94	4.83	2.52	1.67	2.35	920.14	A1
46.59	0.15	3.74	14.13	9.79	7.45	4.31	2.52	2.72	1.78	1653.50	BO1

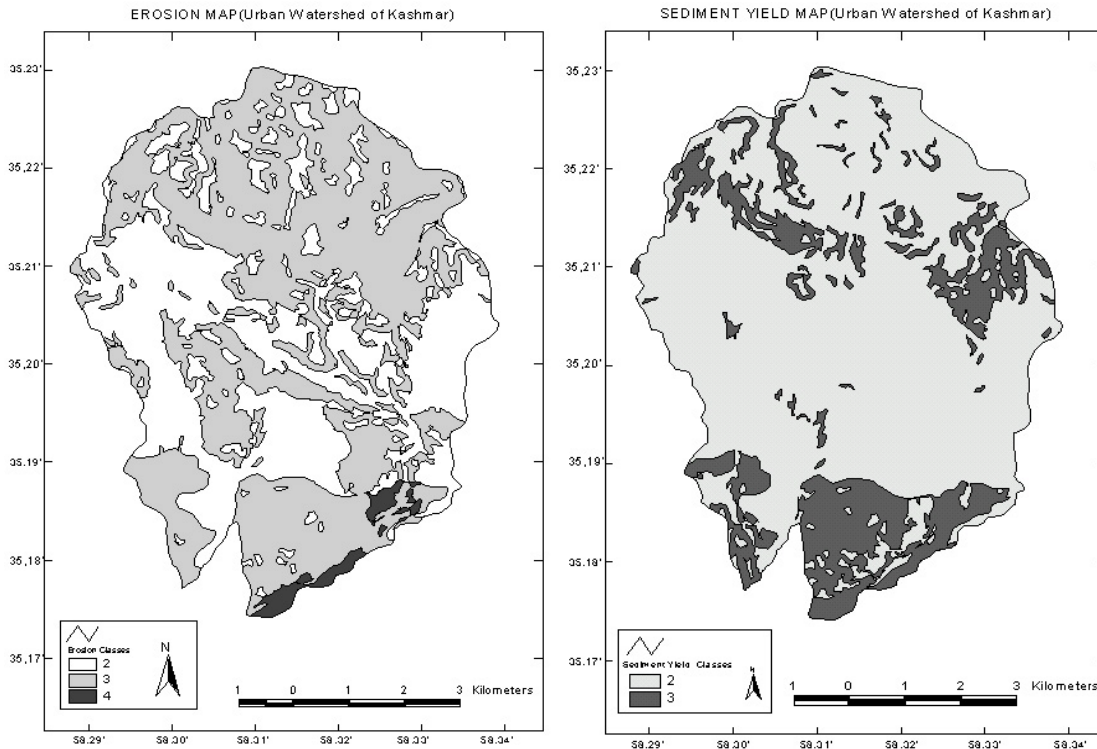
R(sum of factors)	X9	X8	X7	X6	X5	X4	X3	X2	X1	Area(ha)	Kal-e-asgir
46.76	0.00	3.50	14.35	9.96	8.13	4.05	2.52	1.67	2.59	1976.99	A2
49.41	0.00	3.50	13.92	9.98	8.13	6.09	2.52	1.67	3.61	426.37	A3
49.80	0.60	4.41	13.46	9.90	5.90	5.30	2.52	6.69	1.03	543.02	A4
41.57	0.24	3.89	7.94	9.93	7.33	4.31	2.52	3.03	2.39	3510.84	BO2
47.30	0.21	3.84	14.04	9.88	7.36	4.31	2.52	2.93	2.20	5165.13	Total

Table4. PSIAC factors scores in the subbasins

Erosion (m <sup>3</sup> /km <sup>2</sup> /y)	SDR	Bed load(m <sup>3</sup> /km <sup>2</sup> /y)	Suspended load(m <sup>3</sup> /km <sup>2</sup> /y)	Total load(ton/h/y)	Total load(m <sup>3</sup> /km <sup>2</sup> /y)	Kal-e-gorg
583.59	0.35	33.80	169.01	2.64	202.81	A1
640.28	0.31	33.47	167.33	2.61	200.79	BO1

Erosion (m <sup>3</sup> /km <sup>2</sup> /y)	SDR	Bed load(m <sup>3</sup> /km <sup>2</sup> /y)	Suspended load(m <sup>3</sup> /km <sup>2</sup> /y)	Total load(ton/h/y)	Total load(m <sup>3</sup> /km <sup>2</sup> /y)	Kal-e-asgir
664.45	0.30	33.67	168.33	2.63	201.99	A2
558.27	0.40	36.97	184.83	2.88	221.80	A3
589.82	0.38	37.48	187.41	2.92	224.90	A4
617.88	0.27	28.03	140.16	2.19	168.19	BO2
819.37	0.25	34.32	171.59	2.68	205.91	Total

Table5. the mount of sediment yield and erosion in the subbasins



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