The sediment yield potential estimation of Fariabad and Kordian watersheds using MPSIAC model in the GIS framework

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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 topography, geology, geomorphology, land capability, soil hydrologic groups and plant cover maps using on-screen method were digitized. 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 rational method) factors maps were prepared. Then these factors maps were summed together and finally sedimentation score map was provided.The following equation on the sedimentation score map was applied and therefore sedimentation map was obtained:

$Q_s=38.77e^{0.0353R}$

Where:
Q_s: specific sediment ($m^3/km^2/yr$)
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, geology, geomorphology and hydrologic units maps were used 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 in Fariabad and 19 work unit in the kordian basins were 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 sub-basin was obtained.

***Keywords**:MPSIAC,GIS,Sediment yield,Erosion.*

Introduction :

Nowadays, the degradation of renewable natural resources is one of the most important problems of human . 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, 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 . The study area has located in the northeast of Taibad town (Khorasan province, Iran, between 60? 00' to 60? 30' E and 34? 30' to 35? 00' N).This area locates into Qareqoom 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 these watershed was applied .In this study newest GIS softwares to obtain a good and accurate result at the least time were used.

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) were gathered using existing condition maps ? statistical information ? field investigation ? topographic maps and aerial photographs . Then, 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 ($m^3 . km^{-2} . yr^{-1}$)
R: sediment yield score

Surface geology :

To calculate this factor, at first geology map was digitized and then based on the rocks sensivity to erosion?this map was encoded and a new data field in the geology map database (based on X_1 factor) was created .Using the facilities of Spatial Analyst module in the Arc View software , the average of this factor in these basins(Fariabad and Kordian) was obtained 3.26 , 1.89 .

Soil :

With due attention to the soil studies and soil experiments,the effective factors on the K(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, using related nomograph, K value and at last X_2 value in any land unit components was estimated.Then, land units map was digitized and was encoded based on the soil erodibility factor and a new data field in the land units map database (based on X_2 factor) was created. The average of this factor in the Fariabad and Kordian basins was obtained 3.41 , 2.24.

Climate:

To obtain 6-hour rainfall with 2-year return period, IDF (Intensity Duration Frequency) curves data were used and this factor (X_3) for these basins was obtained 3.84. 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_3 factor) was created .

Runoff :

To providing this layer , two maps were provided , runoff height map (R) and specific peack discharge map (Q_p) . At first, the DEM layer was prepared , then with applying the precipitation gradient equation on the DEM layer ,the precipitation map was obtained .

{2} $P=64.28 + 0.1335\ H$ n=19 , r=0.88987

Where :
P:annual precipitation (mm)
H: elevation (m)

Then,sub-basins map (or hydrologic units map) were encoded based on the runoff coefficients of rational method(C_r) and a new data field in the sub-basins map (based on C_r) 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 runoff height in each pixel was obtained . To providing Q_p layer, the rational method was used. In this method ,at first with due attention to IDF curves and cocentration times, precipitation intensity of these basins was calculated and then using runoff coefficients in the rational fomula and the other parameters, the basins flood with different return periods were obtained.

{3} $Qp= 0.278\ CIA$
r= -0.98

where :
Qp = peak discharge (m^3 / sec)
A = basin area (km^2)
I = rainfall intensity(mm/hr)
C=runoff 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 X4 factor in these basins was obtained 9.33 , 9.12 .

Topography :

To providing this layer at first 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 these basins is 3.75 , 5.67.

Ground Cover :
To providing this factor, at first digitized plant cover map was used 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 basins is equal 7.62 , 6.72 .

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 similar to previous layers, in this map a new data field was created .The average of this factor in these basins is equal 12.67 , 12.08.

Erosion condition :
This factor was obtained based on BLM method .This method include from 7 factors :
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 Fariabad and Kordian basins is equal 7.73 , 5.53 .

Channel erosion and sediment transport :
To determining this factor, the gully erosion score (or SSFg in the BLM method) was applied . Based on this factor, geomorphology map was encoded and a new data field in this map was created .
The average of this factor in this area was obtained 4.49 ,2.88.

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 sub-basin was obtained .

{4} $SDR = 43.4(A)^{-0.1753}$ if basin area (A) is less than 10 square miles .
{5} $SDR = 46.7 (A)^{-0.2071}$ if basin area (A) is between 10 to 100 square miles .

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 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 (sub-basins) maps and at last 28 work unit in the Fariabad basin and 19 work unit in the Kordian basin were obtained . By interpretation of aerial photographs and the field surveying, 2 erosion form in the Fariabad and 5 erosion form in the Kordian basins were obtained .

Results and discussion :
With due attention to the studies and surveying of this watershed, the main reason of erosion in these basins is overgrazing . Thus, with applying the reformatory programs, exclosuring and grazing management, and considering the basin formation, is not sensitive to erosion , we can decrease the basin erosion .The erosion

quantity of Kordian basin is higher than Fariabad basin because the sensitive formation and high runoff. 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 factors of PSIAC model, were overlayed vectorically .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 .

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Description	Equation	Effective factors	No
X_1=Stones sensivity 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($M^3/Km^2/Yr$)	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($M^3/Km^2/Yr$)	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)	Fariabad
51.99	2.06	4.23	12.10	6.09	5.22	12.04	3.84	4.83	1.57	953.14	F1
54.79	1.88	4.02	12.21	6.28	5.52	14.90	3.84	4.78	1.35	512.05	F2
56.10	4.49	7.73	12.67	7.62	3.75	9.33	3.84	3.41	3.26	2705.45	TOTAL

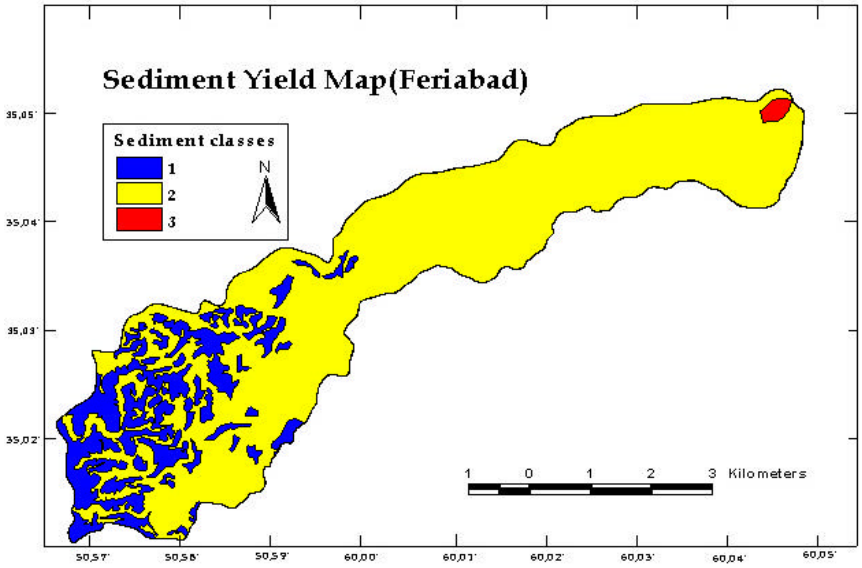
R(sum of factors)	X9	X8	X7	X6	X5	X4	X3	X2	X1	Area(ha)	Kordian
63.12	2.80	5.28	12.49	6.14	6.35	22.56	3.84	2.14	1.52	883.32	K1
59.96	2.88	5.53	12.08	6.72	5.67	19.12	3.84	2.24	1.89	1519.99	TOTAL

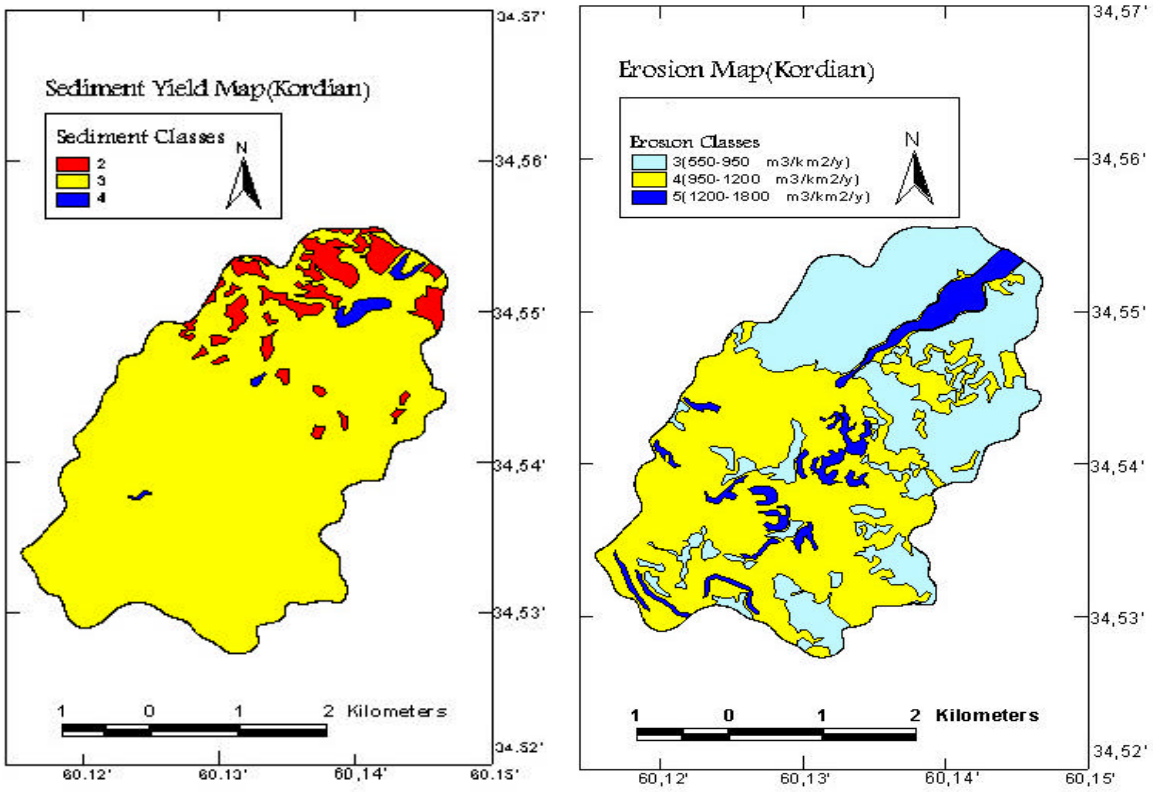
Table4. PSIAC factors scores in the subbasins

Erosion ($m^3/km^2/y$)	SDR	Bed load($m^3/km^2/y$)	Suspended load($m^3/km^2/y$)	Total load(ton/h/y)	Total load($m^3/km^2/y$)	Erosio
694.09	0.35	40.49	202.44	3.16	242.93	
687.72	0.39	44.70	223.51	3.49	268.21	
968.66	0.29	46.82	234.09	3.65	280.91	2

Erosion ($m^3/km^2/y$)	SDR	Bed load($m^3/km^2/y$)	Suspended load($m^3/km^2/y$)	Total load(ton/h/y)	Total load($m^3/km^2/y$)	Erosio
1028.40	0.35	59.99	299.95	4.68	359.94	
1005.94	0.32	53.65	268.25	4.18	321.90	1

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





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