Using GIS in Soil Erosion Control (Case study: Mousa Abad Basin, Isfahan, Iran)

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Abstract. Soil erosion is a process threatening natural resources such as water, soil, plant cover and climate both directly and indirectly and it is dangerous for human safety and his life. Erosion not only weakens soil, makes useless farms and a lot of damage, but also causes harm by sedimentation solid of materials in streams, sources, dams, ports and decreases the amount of their capacity.

In this project, we are studying soil erosion in Mousa Abad basin in Tiran, Isfahan in SLEMSA model using GIS. In this research, the factors and elements affecting erosion were studied using the capabilities of the model. To do so, we used data, local studies, map combination and interpolation.

We can find an index to calculate the difference between potential and practical erosion through estimating the erosion rate, identifying the reasons and kind of erosion as well as erosion hazards.

Keywords: SLEMSA model, Erosion, Environment Protection, Mousa Abad

1 Introduction

The word erosion in French and English and Abtreg in Germany, is derived from Latin word Erodere and means being worn away and eroded continuously by the action of water or wind (Kordavani, 1997, page 97). Erosion in basin areas causes superficial crust of soil to be eradicated and the arable lands to be reduced (Ale sheikh et al. , 2006, page 178). The first scientific research in soil erosion was conducted in 1877-1895 by Wollony, a German scientist, and erosion qualitative experiments began in 1915 in America. The efforts in 1928-1933 led to Universal Soil Loose Equation (U.S.L.E.) in order to estimate the washout in farmlands (Ahmadi, 1999, page 503). Different researches about erosion and sedimentation go back approximately to a century ago. In recent years, different agencies have taken some measures from different aspects directly or indirectly in order to combat against the erosion (Solaymani & Bayat, 2005, page 107). Different models are used to estimate erosion hazards such as SLEMSA developed by Elwell and Stoking (Ramesht, 1997, page 104).

Studying physiography of Barkili Rood basin and focusing on erosion and sedimentation in 2002, Mehrdad Kheirandish concluded that from one hand, the sharp slope of hillsides in upper region and, on the other hand, heavily rainfall and changes in lands and converting the woodlands to tea plantations play great role in different erosion types of soil such as groove, gully, slide, and solifluction at basin level.

Studying the efficiency of SLEMSA model in estimating the erosion and sedimentation in the basin of Zayandeh Rood Dam by GIS in 2002, Mansoor Eskandari concluded that regarding the regions having potential erosion the most important issue is their proximity to the lake behind the dam. The major factor in erosion is topographic factor in western regions and has the most impact and that the erosion is not controlled easily in these regions. Kianerthi examined the impact of intensity and duration of rainfall on erosion in basin of Panzdahe Khordad Dam in 2000 and found out that the most important factor in erosion is K factor and then C factor is considered as the dominant one. In regions where X factor is dominating, the erosion is lower than 10 ton per hectare.

2 Methodology

Composing the simple and major data, SLEMSA model focuses on certain environmental relationships, especially relations between vegetation, rainfall, and soil erosion (Ramesht, 1997, page 107). In SLEMSA model, the used variables are calculated for squares which are deployed as a grid on the studying region. To develop such a grid, at first, the dimensions of each square are determined and then the grid is implemented on the studying region. The topographic maps of Tyran, Ozoon Akhar, and Chermhin are used on a scale of 1:50000 and the dimensions of the grid are considered 1×1 m., and generally it is used a total number of 410 grids on the region. In this study, it is determined the elements of each square relevant to this model such as topographic, regional, vegetative factors, and factors relevant to the surface of the land and finally the erosion hazard is calculated for each square considering the present relations between the elements. Finally the map of erosion hazards is prepared by defining a special range for erosion rate.

This study aims at estimating the rate of erosion and sedimentation in Musa Abad basin, Tyran, by using SLEMSA model. This rate of erosion is not dominated by the same factor in all parts of the basin.

Aquiferous basin of Musa Abad, Tyran, is located at 50˚ 54´ 12˝ to 51˚ 11´ 25˝ of east longitude and 32˚ 20´ 48˝ to 32˚ 40´ 38˝ of north latitude and 75 km. of the west of Isfahan. This basin is 325.9 km2. Regarding the topography, this basin is divided into highland and lowland. This basin has the maximum and minimum altitude of 3340 m. and 1880 m., respectively. The mean rainfall is estimated about 242.5 mm. in this basin. Lithology of the basin is not very diverse, and the basin belongs to Precambrian, Permian, Jurassic, cretaceous, Quaternary ages (Jihad Keshvarzi Organization, 2007, page 178).

The used data in this study includes:

Topographic factor: To determine the topographic coefficient(X), it is calculated two factors, the slope (S) and the length (L) of the bank, for each of the longitudinal square and then the numerical value for (X).

Calculation of mean slope: The data of the high points of the basin is used to compute the slope by the following equation:

$$\left\|\bar{g}\right\| \approx \sqrt{\left(\frac{ZE - Zw}{2\Delta_x}\right)^2 + \left(\frac{ZN - ZS}{2\Delta_y}\right)^2} \qquad (1)$$

Where: g: mean slope ZW= the height of western point ZN= the height of northern point
Δx= the distance between the eastern and western points ZE= the height of eastern point
ZS= the height of southern point Δy= the distance between the northern and southern points

Length of the bank: Considering the relation and correlation between the slope and the length of the bank, and calculating the slope for each square, its numerical value is calculated as follows:

$$X = L^{0.5}\left(\frac{0.76 + 0.53S + 0.076S^2}{25.65}\right) \qquad (2)$$

Where: X=topographic factor L= length of the bank S=mean slope

Erodibility of soil and erosion factor: To achieve the above factors, two factors, erosion of soil (F) and kinetic energy of rain (E), are calculated as follows:

Calculation of senetic energy of rain (E): To calculate the rate of kinetic energy of rain, data from pluviometer is extracted and applied in the following linear correlation equation:

$$E = 18.84 \times \bar{p} \qquad (3)$$

Where: E= the rate of kinetic energy of rain in J.m/y P= mean rainfall in mm./y

This equation is used in rain showering regions.

Calculation of erosion of soil (F): Usually the erosion of soil is considered in the regions where there is no vegetation and the amount of erosion and soil sensitivity is calculated for each square meter of the soil and the sensitivity is determined according to 1-10 rating scale based on the sensitivity of various stones to erosion. By computing the amount of (E) and (F), it is possible to calculate K through the following equation:

$$K = \exp\{(0.4661 + 0.7663f)LnE + 2.884 - 8.1209F \qquad (4)$$

Where: K= the rate of eroded soil from the surface
E= the mean kinetic energy of rain in J/m2 F= erodibility of soil

Vegetation factor: To obtain the amount of (i), held energy by plant, in other words, the percentage of vegetation, it is used the amount of plant crown and the various species of plants in different seasons, and the soil coefficient is given by the following:

$$C1 = \exp(-0.06i) \qquad (5)$$

When it is $0 \le i \le 50$ for farmlands and natural grasslands.

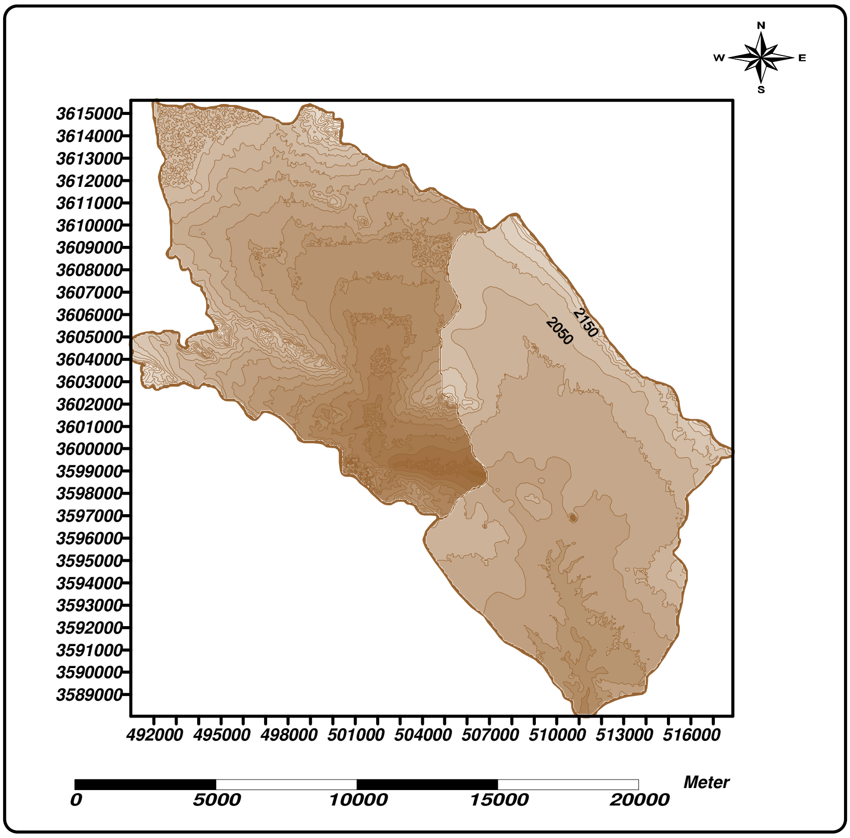

Fig. 1) Topographic map of aquiferous basin of Musa Abad, Tiran.

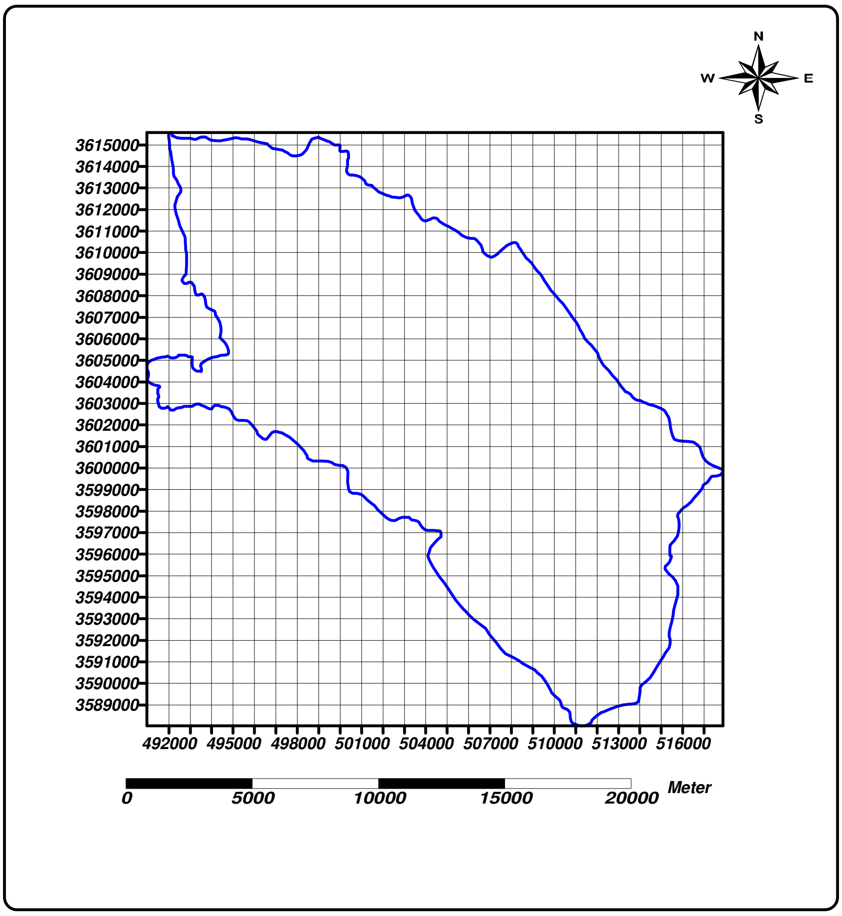

Fig. 2) Grid map of aquiferous basin of Musa Abad, Tiran.

$$C2 = \frac{(2.3 - 0.01i)}{30} \qquad (6)$$

When it is 0≤ i ≤ 100 for farmlands and natural grasslands.
Finally, by applying the above parameters in the following equation, the hazard rate of erosion is calculated for every part of the basin in tn/ha

$$Z = K \times C \times X \qquad (7)$$

Where Z is the estimated amount of eroded soil in tn/ha.

Implementing SLEMSA model in aquiferous basin of Musa Abad Tiran: At first, this basin is divided into squares in 1×1, which resulted in 410 squares. Then it was computed the parameters indicated in SLEMSA model.
Topographic factor: It was used the topographic maps from Tyran, Ozoon Akhar, and Chermhin at scale of 1:50000 to calculate the coefficient of (X) in Musa Abad basin in Tiran.
Calculation of mean slope: Regarding the calculations, the values of mean slope, maximum slope, and minimum slope were 8.48%, 77.91%, and 0%, respectively. This slope was distributed in most of the points of the basin.
Length of the bank: After calculating the rate of slope for each of squares, the length of the bank is considered as 100 meters for the whole basin regarding the topographic properties of the region. Then the rate of eroded soil which is resulted from actions of geomorphologic forces is calculated for each of squares.

Table 1) calculation of the mean and the sum of X factor in Musa Abad basin, Tiran

Variable	sum	Mean
X	2165.682	5.282151

Method of calculating the kinetic energy of rain (E): Because of the lack of pluviometer stations in the basin, it was used the statistics gathered during the last 30 years from the stations out of the basin and then a map was prepared showing the points having the same rain and the amount of rainfall was calculated for each of the squares and applied in the linear correlation equation to find the kinetic energy of rain. The sum, the mean, the maximum, and the minimum of kinetic energy were 1997431, 4871.78, 5972.28, and 2062.98 J/m2 in the whole basin, respectively.

Table 2) Features of pluviometer stations:

Station	Latitude	Longitude	Height	Rainfall/year
Chadegan	465345.1335	3625905.32	2100	6317
Singerd	446618.5311	3627097.105	2100	350.3
Najaf Abad	534709.0128	3610358.154	1649	150.9
Pol kalleh	521635.6167	3582634.506	1800	151.1
Zobeahan	528214.174	3584867.867	1768	157.5
Pol Zamankhan	490603.5944	3593700.911	1810	336.9
Felavarjan	546935.4586	3603783.638	1590	161.4
Kerd Abad	471948.7118	3642513.655	2350	391
Taad	548877.7867	3590489.924	1700	165.9

Method of calculating the erodibility of soil: Determining the geological status of the basin, a number is given to each sort of the material of the lands regarding the rate of their solidity. The region was categorized from solidity of 3 to 9, according to the stone diversity. It was given the number 3 to sedimentations from the Quaternary (Qt 1), the number 5 to thin limy layer containing fossils, ammonites, orobitoloin (k1, K3), the number 6 to shale in which it is seen the conglomerates and sandstones (J, JS, JC), the number 7 to lime and transformed dolomite (PEM) and schist, gneiss, and volcanic andesite (PE), and the number 9 to fusil lime (P), igneous rocks (am, gm). It was shown that the sum of and the mean of erodibility of the soil is estimated about 1203.35 and 2.93, respectively.

Table 3) Calculating the sum and the mean value of K factor in Musa Abad basin, Tiran.

Variable	Sum	Mean
K	1203.357	2.935017

Vegetation factor: The maps from agricultural ministry were used to estimate the vegetation factor. The maps were at scale of 1:10000. After determining the status of the grassland in Musa Abad, the amount of (i) was determined as 70 and then it was put into the equation C1 and the value of 0.17 was considered for the whole basin.
Calculating the rate of erosion hazards (Z): After determining all parameters used in estimating the erosion hazards in SLEMSA model, the whole erosion of the region is achieved by the following equation:
$Z = K \times C \times X$

The result from the above equation is the rate of erosion in each meter and in the whole region in tn/ha.

Table 4) calculation of factor Z in Musa Abad basin, Tiyran

Variable	Sum	Mean	Min.	Max.
Z	1252.412	3.054663	0.000012	707

3 Discussion and conclusion

Analysis of numerical map of factor X: Because this factor is dependent to slope and the length of the bank and is effective in erosion in vegetation, and due to rainfall and lack of vegetation, the major part of soil is at the risk of erosion and such region must not be used for grazing.
Analysis of local distribution of factor E: The mean energy is increasing from left to right of the region; that is 3756.26 J/m2 in the most eastern part to 5953.44 J/m2 in the most western part. These calculations were done regarding the data from the stations outside the basin gathered during a 30-year period.
Analysis of numerical map of factor F: According the ranking for F factor, this region has the ranking 6 to 8. In general, some part of the region has the resistance under the rank of 4, this indicates the sensitivity of the region to the erosion.
Analysis of numerical map of factor K: What is important for this factor is that the extent of changes is from 0.00032 to 25.75 for this factor in the region. These effects are resulted from the changes of two factors, ie. F and E factors. This issue is important from two aspects: ignoring this issue and dealing incorrect with the soil and consequently the increasing rate of erosion, and considering the issue and managing properly and creating appropriate vegetation in order to prevent the erosion.
Analysis of numerical map of factor C: Because the basin is located in a dry region with suddenly and heavily downfall of rain, yet having farmlands and grasslands, it is not in a bad status in terms of the vegetation and has a rate of less than a 100 day/grazing.
Analysis of numerical map of factor Z: Regarding the factor Z, the region has the minimum and the maximum amount of 0.000012 tn/ha and 707 tn/ha, respectively.

Finally, it isn’t useful to apply a special treatment in order to prevent the erosion in aquifers basin, but a set of actions can lead to desire result, therefore the following recommendation is offered regarding the findings, since this basin is facing heavily erosion and sedimentation, it is necessary to control the erosion of soil and to protect both the soil and the water inform of protective plannings.

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