ASSESSMENT SPATIAL VARIABILITY OF SOIL ERODIBILITY BY USING OF GEOSTATISTIC AND GIS (Case study MEHR watershed of SABZEVAR)

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ABSTRACT

Soil erodibility is one of the key factors on some sediment and soil erosion models such as USLE, MUSLE, RUSLE, AUSLE (USLE modified in LS factor) and MMF and represents like K factor and is function of particle distribution, organic mater, soil structure and permeability. Traditional methods do not take spatial variability and estimate precision of variables in to consideration and amount of them are constant across the whole of soil series . This study was performed to assess spatial variability of soil erodibility and its relevant variables at MEHR watershed from Khorasan province, in northern Iran. Interested network was designed by 110 samples like nested- systematic with distance about 50, 100, 250 and 500 meter across the study area by preparing point map at GIS. Sampling points were identified in field by an Global Positioning system. Soil sampling was done at depth of 0-5cm of ground surface and permeability was studied at depth of 5-30 cm. Some soil properties such as particle distribution and organic mater were measured at laboratory. Particle size distribution was determined by Hydrometer method and Organic matter was measured by wet oxidation approach. Then spatial analysis was done. Variography analysis on soil attributes according to soil erodibility, showed that Gaussian, exponential and spherical models were the most models to predict spatial variability of soil parameters. The range of spatial dependencies was changed from 320 to 3200 m. Soil attribute maps prepared by kriging technique using models parameters. Then soil attributes were composed by Wischmeier (1978) formula in Illwis media to calculate K factor. Amount of soil erodibility changed from 0.13 to 0.91 that it's maximum and minimum was identified in east and southwest of studied

area. Soil spatial variability pattern, is similar to silt pattern due to high effect of silt on soil erodibility, Also that is partially confirmed with geology map, indicated which soil erodibility attribute controlled by parent material. High amount of soil erodibility in southwest area of given study area showed need to more attention for conservation the soil and control erosion.

INTRODUCTION

One of the factors affecting soil erosion is soil erodibility, the inherited susceptibility of soil to be lost to erosion. Soil erodibility expresses the soil's susceptibility to erosional processes and can be defined as " the ease with which soil detached by splash during rainfall and/or by the shear of surface flow". The concept of erodibility and how to assess it is complicated since the susceptibility of the soil to erosion is influenced by a large number of properties such as physical, mechanical, hydrologic, chemical, rheological, mineralogical and biological , not to mention the soil profile characteristics such as the depth of the soil and its influence on vegetative growth.(Veihe, 2003).

Several attempts have been made to devise a simple index of erodibility based on the properties of the soil determined either in the laboratory or in the field. Soil erodibility is, in turn, a function of diverse soil properties, including particle size composition, stability of aggregates, shear strength, permeability, organic matter content, and chemical composition (Morgan, 1986). Accordingly, soil erodibility has been incorporated into numerous soil erosion models. One of the most widely applied soil erosion models is known as universal soil loss equation (USLE, e.g., Wischmeier and Smith, 1978), and in USLE, MUSLE, RUSLE, AUSLE and MMF models; where soil erodibility is called the K factor. Furthermore, USLE is also composed of the topographic (LS), cover (C), rainfall/runoff (R), and support practice (P) factors. Specifically, the K factor is a function of particle size distribution, organic matter content, structure, and permeability. In the USA, K values may be estimated through either an equation or its corresponding nomograph (e.g., Wischmeier and Smith, 1978). The K factor equation is expressed as follows:

$$K = \frac{2.1 \times (\text{vfssi}^2 + \text{vfssi} \times \text{sand})^{1.14} \times 10^{-4} \times (12 - \text{om}) + 3.25 \times (\text{perm} - 2) + 2.5 \times (\text{struct} - 3)}{100} \quad (1)$$

where K = K factor, vfssi = percentage of very fine sand plus silt, sand = percentage of sand, om = percentage of organic matter, perm = permeability class, and struct = structure class. The soil survey is one of the main source of information on soil characteristics in Iran.

Assigns one K value to each soil mapping unit based on properties of the typical pedon which is believed to represent that soil series. This traditional approach assumes that one soil erodibility value represents the entire area of each soil series. Therefore these approaches, do not account for spatial variability of soil properties and processes (Goovaerts, 1997), including soil erodibility (Parysow et al., 2001; Wang et al., 2001). Modeling spatial variability based on kriging as well as on simulation has been developed for making predictions at unsampled locations using sample data sample data available only at a subset of locations**.**

The objective of this study was o evaluate spatial variability of soil erodibility factor in relation to spatial variability of soil properties by geostatistical technique in north of Iran, Sabzevar watershed**.**

METHODS AND MATERIALS

1- Soil Location and Sampling

The current study was conducted in the Sabzevar watershed, from Khorasan province, north of Iran (Fig 1). The study area, covered 25.29 km^2, is located where, mean annual precipitation is 265 mm, and mean annual temperature is 15 ° C. Elevation varies from 1158 to 2468 m above sea level.

Fig 1- Location of study area in North of Iran

We collected 115 soil samples on square grid across the watershed using nested systematic sampling scheme with 500, 250, 100 and 50 m apart by Global Positioning System (GPS). At each sampling site, surface soil samples were collected. Besides at each site, some soil properties such as gravel content and soil structure were determined in order to assess soil permeability and structure class based Wischmeier's method. Structure and permeability classes were assessed followed the guidelines in Exhibit 618-9 of the National Soil Survey Handbook (1997).

2- Laboratory Analysis

Soil samples in laboratory, first were sieved with 2 mm diameter. Then soil particle distribution was determined by Klute (1986) approach, as follows: Very coarse sand(2-1 mm), Coarse sand(1-0.5 mm), Medium sand(0.5-0.25 mm), Fine sand(0.25 -0.1) and Very fine sand (0.1-0.05 mm), on dispersed samples by wet sieving; silt and clay by the hydrometer method. Soil organic matter was obtained by the Walkly - Black method (Page et al , 1992).

3-Statistical and Geostatistical Analysis

Mean, standard deviation (S.D.), and coefficient of variation (CV) were computed for each soil parameter with the software package SPPS. The basic theory of geostatistics has been well established and reviewed (Goovaert, P. 1999). Experimental variogram estimator is asymptotically unbiased for any intrinsic random function; however it is very sensitive to outlying values because it is based on squared differences among data. Experimental semivariograms were used as a measure of spatial dependence. It is the mean-squared difference between samples at specified separation distances:

$$\gamma(\mathbf{h}) = \frac{1}{2N(\mathbf{h})}\sum_{i=1}^{N(\mathbf{h})}\left[z(\mathbf{x}_i) - z(\mathbf{x}_i + \mathbf{h})\right]^2 \qquad (1)$$

where c(h) is the semivariogram value, z(xi) is a measurement of a regionalized variable taken at location i, h is the separation vector and N(h) is the number of data-pairs separated by h. The stationary models, i.e. Gaussian (Eq. (2)), exponential (Eq. (3)) and spherical equation (Eq. (4)), was fitted to experimental semivariograms:

$$\gamma(h) = C_0 + C_1\left[1 - \exp\left(-\frac{h^2}{a^2}\right)\right] \quad (2)$$

$$\gamma(h) = C_0 + C_1\left[1 - \exp\left(-\frac{h}{a}\right)\right] \quad (3)$$

$$\gamma(h) = C_0 + C_1\left[\frac{3h}{2a} - \frac{h^3}{2a^3}\right] \quad \text{when } h \leq a \quad (4)$$

Where C0 is the nugget, and a is the range of spatial dependence to reach the sill (C0 + C1).The software package Variowin was used to perform all geostatistical computations. The so-called 'jack-knifing' cross-validation procedure was used to verify the validity of the selected semi-variogram models and their parameters. Following their procedure, we calculated mean error (ME) and mean square error (MSE) using the equations (5) and (6) to validate fitted models.

$$\text{ME} = \frac{1}{N}\sum(Zi^* - Z) \quad (5)$$

$$\text{MSE} = \frac{1}{N}\sum(Zi^* - Z)^2 \quad (6)$$

Block kriging then used to estimate the values of soil properties at unsampled places by Illwis software. Finally by using equation (1), kriged soil properties integrated to illustrate spatial pattern of soil erodibility in the given watershed.

RESULTS AND DISCUSSION

Table 1 shows the mean, standard deviation, coefficient of variation, minimum and maximum, range and skewness values for each of the soil properties determined. Normality test of Smirnov- Kolomogrof revealed that, very fine sand is normal and of clay, silt and organic matter variables do not show any adaptation with normality test. With regard to coefficient of variation minimum and maximum of spatial heterogeneity is belonging to silt and organic matter respectively. By using of surface variogram no heterogeneity was observed. Sample one of these variograms for clay content is illustrated in Fig 2. Homogeneity of all variables has similarity with results of Wang et al (2001).

Table 1- Statistical descriptive of soil parameters

Variable	Min	Max	Mean	S.D	C.V%	Range	Skew
%Clay	2.1	26.1	10.26	5.07	48.9	24	1.04
%Silt	0	49	41.19	7.8	18.93	41.19	-2.1
%VfS	7.7	45.7	24.7	8.9	26	28	0.11
%O.M	0	2.7	0.59	5.07	103.5	2.7	1.71

Min: Minimum, Max: Maximum, S.D: Standard Deviation, Skew: Skewness, VFS: Very fine sand, O.M: Organic matter

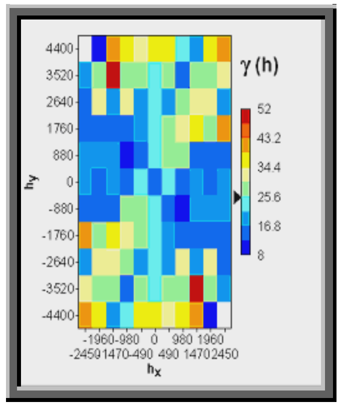

Fig2- Surface variogram for clay content

All of soil erodibility parameters could be fitted to bounded semivariogram using exponential, spherical and Gaussian functions. Fig 3 shows a Gaussian model which fitted to silt content in the study area.

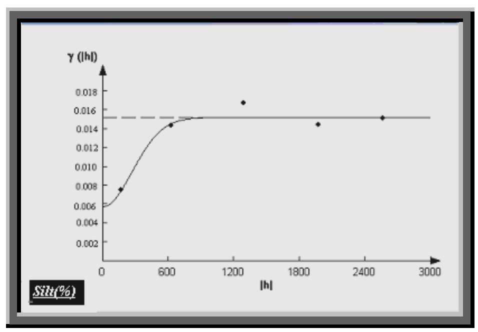

Fig3- Omni-directional semivariogram for the silt content fitted with Gaussian function

Table 2- Modeled semivariograms using models for individual properties and their validation criteria

Variable	Model	Nugget	Sill	Spatial dependency	Range	ME	MSE
%Clay	EXP	0.99	0.09	0.916	400	-0.0006	0.24
%Silt	GUS	0.006	0.009	0.4	320	0.0021	0.02
%VfS	SPH	28	41	0.405	420	0.0078	78.69
%O.M	SPH	0.4	0.62	0.292	320	0.0475	0.3
P. Class	GUS	0.7	1.45	0.225	3200	0.022	1.78

ME: Mean Error, MSE: Mean square error, VFS: Very fine sand,
O.M: Organic matter, P. Class: Permeability class

Parameters of all variables in addition to validation parameters are shown in table 2. None of the variables with regard to spatial dependency is shown strong dependency. Variables except clay have shown medium dependency and clay has shown weak spatial dependency. Minimum range is allocated to permeability class. Very fine sand and permeability class are followed from ordinary kriging and the other variables are followed from ordinary log kriging. By considering estimate error map, maximum estimated error for all variables were situated in the east of interested watershed that this subject is due to low samples in this part of the watershed.

Spatial pattern of soil erodibility factor in the given area, by integration of soil parameters, is shown in Fig 4.

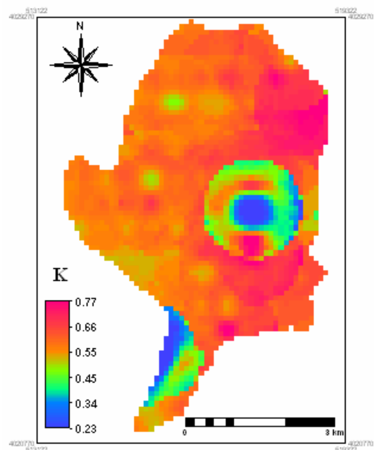

Fig 4- Predicted K values in the study area by integration of soil variables

Minimum and maximum of soil erodibility factor is 0.13 and 0.91 respectively, which are situated in the east and west south. There is high conformity between soil erodibility and silt maps from all of considered variables maps, which this issue is as high susceptibility of silt in soil erodibility factor (K). Comparison of k map with slope, geology and land capability maps shows that there is high adaptation between geology with k map in comparison with the other maps.

CONCLUSION

Estimation of K factor from soil types in general using traditional soil survey can be problematic because soil classification are often not based on those parameters reflecting erodibility (Roose and Sarrailh, 1990). Many soil maps in Iran do not contain detailed information on soil texture and during soil survey, emphasis is placed on map legend and soil classification schemes, whereas the interpretation of soils in terms of land evaluation in scarce. Results of this research, reveals that, it is useful to know the spatial distribution of different soil characteristics through geostatistical procedures. The accurate spatial distribution of soil properties and soil erodibility can be useful for precision management through the watershed. Soil maps do not have high scientific merit to determine soil erodibility factor and have high uncertainty, so it is suggested that interested technique in this research with regard to spatial variability, estimated error for increasing precision and more favorite management for preparing of base map is used.

REFERENCES

1-Goovaert, P. 1999. "Geostatistic in soil science: State of the art and prespective", Geoderma, Vol. 38, pp. 45-93.

2-Klute, A. 1986. Methods of soil analysis partI. Phisical and mineralogical methods . 2nd Ed. SSSA. Pub. 1188 pp.

3-Morgan,R.P.C.,1986. Soil Erosion and Conservation. pp-298.

4-National Soil Survey Handbook. 1997. Soil survey staff, National resources conservation service. Washington, D.C.

5-Page, A. L., R. H. Miller and M. Keeney. 1992. Methods of soil analysis. Part II: Chemical and mineralogical properties 2nd Ed. SSSA Pub. 1159 pp.

6-Pannatier, Y., VARIOWIN: Software for spatial Data Analysis in 2D, Springer-Verlag. New York, NY,1996

7-Parysow, p.,G. Wang., G.Gertner., A.B, Anderson., 2003. Spatial uncertainty analysis for mapping soil erodibility based on joint sequential simulation.Catena 736.1-14.

8-Roose, E., and J. Sarrailh. 1990. Erodibilitr de quelqes sols tropicaux. Pedologie. XXV(1-2), 7-30.

9-Veihe, A., 2002. The spatial variability of erodibility and its relation to soil types :A study from northen Ghana.Geoderma10:101-120.

10-Wang, G., Gertner, G. Z., Liu, X., Anderson, A. B., 2001. Uncertainty assessment of soil erodibility factor for revised universal soil losse equation. Catena 46, 1-14.

11-Wischmeier, W. H. and D. D. Smith. 1978. Predicting rainfall erosion losses. A guide to conservation planning. USDA. Agr. Res. Serv. Handbook 537.