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Spatial Variability of Soil Erodibility Factor (K) of the USLE in North West of Iran

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ABSTRACT

The soil erodibility factor varies spatially according to variations of some soil properties on the surface. This study was carried out to compare spatial variability of the soil erodibility factor as estimated and measured using the USLE. The study was conducted in an agricultural zone with an area of in 900 km^2 in Hashtrood, northwestern Iran. In the study area, 36 square grids with a dimension of 5 km were considered. In each grid, three unit plots were installed on the southern aspect with a slope of 9%. The soil erodibility factor was estimated using the USLE nomograph and measured as mean rate of soil loss from the unit plots per unit rainfall erosivity factor on an annual basis. The results indicated that the difference between the measured and estimated soil erodibility factor was significant (P< 0.001) and correlation between the two was very poor with r^2= 0.21. The spherical simulations were the best models to explain spatial variations of both the estimated and measured erodibility factors. The effective range of the spatial variations of the measured soil erodibility factor (2.43 km) was smaller than that in the estimated value (11.51 km). There was a considerable difference in the effective range (P< 0.001) of spatial variations between the estimated and measured soil erodibility factor on the study area. The map of the proportion of the estimated values to measured values of the soil erodibility factor was nearly uniform (between 7.4 and 9.6) on the study area. The study indicated that use of the USLE nomograph would considerably lead to over-estimation of the soil erodibility in the entire the study area.

Keywords: Erodibility, Spatial variability, USLE.

INTRODUCTION

Soil erosion is a major environmental problem worldwide. About 85% of land degradation in the world is associated with soil erosion, causing a 17% reduction in crop productivity (Oldeman *et al.,* 1990). Soil erosion also is a main factor in decreasing crop yield in the agricultural land of Iran (Rafahi, 1996). Erosion control under natural and agricultural conditions will be important for maintaining current agricultural production levels (Pagiola, 1990). Proper evaluation of main eroding factors in an area of interest (Rejman *et al.,* 1998) and determination of their variations in space should be taken into account in choosing a strategy for controlling erosion in critical areas.

The Universal Soil Loss Equation (USLE) developed by Wischmeier and Smith (1978) is the most frequently used empirical soil erosion model worldwide (Shi *et al.,* 2004). Soil erodibility is one of six factors affecting

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soil erosion in the USLE that reflects the ease with which soil is detached by splash during rainfall, surface flow or both (Renard *et al.,* 1997). The soil erodibility factor (K) is commonly predicted using the USLE nomograph on the basis of five soil and soil-profile parameters that include soil particles (% sand, % silt, % very fine sand and silt, and % clay), % organic matter, soil structure code and soil permeability class (Schwab *et al.,* 1993). Practically factor is measured as the mean rate of soil loss per unit of rainfall erosivity factor on the basis of one year in the field (Rejman *et al.,* 1998).

The soil erodibility factor is affected by different soil properties including physical, chemical, biological, and mineralogical properties (Veihe, 2002). Variations of these properties in space would lead to spatial variations in soil erodibility. Spatial variations of the soil erodibility factor can be simulated using the geostatistical method. The use of geostatistics in soil sciences began about 30 years ago. Many researchers had applied geostatistics in the determination of spatial variations of soil physicochemical properties (Greminger *et al.,* 1985; Lin *et al,* 2005), soil hydraulic properties (Vieria, 1981; Polhmann, 1993; Chien *et al.,* 1997), soil solutes (Kelleners *et al.,* 1999), soil gases (Oliver and Khayarat, 2001), soil organic carbon (Zhang *et al.,* 2004), soil erosion and sediment (Wang *et al.,* 2002; İrvem *et al.,* 2007), and soil erodibility (Rejman *et al.,* 1998; Parysow *et al.,* 2003; Sokouti Oskouie, 2005; Rodríguez *et al.,* 2007).

In geostatistics, the determination of spatial variations of properties is done using the semi-variogram tool that measures the spatial variability of a random variable. By sampling a random variable z in a study area, n observations $z(u_x)$ (α=1, 2,…, n) are acquired, and u_x is the vector of spatial coordinates of the individual observation. The experimental semi-variogram is generally calculated from samples using the following equation (Krige, 1966):

$$N(h) = \frac{1}{N(h)} \sum_{a=1}^{N(h)} \left(z(u_x) - z(u_x + h)\right)^2 \quad (1$$

where $N(h)$ is the number of data pairs used, h is a distance vector separating two values, and $z(u_x)$ and $z(u_x+h)$ are the two values at locations separated by a distance of h.

Generally, semi-variance increases with the separation distance, and reaches its maximum at a distance called the '*range*'. The maximum semi-variance value is the '*sill*'. Ideally, the value of the semi-variogram should be zero when the separation vector h is zero. In practice, this is usually not true because of measurement errors and spatial variability over short distances. In this case, the so-called '*nugget effect*' exists (C_0) and subtracting the nugget from the total variance (Sill) results in an estimate of the structural variance (C_1). Semi-variograms in different directions were obtained to determine whether the spatial variability is isotropic or anisotropic (Wang *et al.,* 2002). The Kriging method was used for interpolation and estimation values in the unknown points using their values in the known points.

There is no accurate study available on the soil erodibility factor and its spatial variations in the northwest of Iran. In this study, the soil erodibility factor (K) was determined both using the USLE nomograph and the field measured soil loss rate of runoff plots under natural rainfall events. The objectives of this study were to compare spatial variability of the estimated and measured soil erodibility factors and determine the error of spatial variations of the two.

MATERIALS AND METHODS

Description of Study Area

To investigate soil erodibility factor, a field study was conducted in Hashtrood, located in the southern part of East Azarbyjan Province in northwestern Iran.

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The study area was an agricultural zone with 900 km^2 in area (37° 18' 49" - 37° 35' 0" N, and 46° 46' 5" and 47° 6' 5" E). Agricultural soils are mostly located on 5-15% slopes and are mainly utilized for wheat dry farming. The climate is semi-arid with an average annual precipitation of 322 mm and a mean annual temperature of 13°C. Rainfalls mostly occur in spring (from March to April) and autumn (from October to November). Intensity of the rainfalls is usually lower than 20 mm h^{-1} (Hakimi, 1986).

Installation of Erosion Plots

The study area consisted of 36 square grids with a dimension of 5 km (Figure 1). In each grid, a dry farming land under the fallow condition located on a uniform southern slope of 9% according to condition of the unit plot in USLE (Wischmeier and Smith, 1978) was considered and plowed in the direction of the slope in March 2005. Then, three unit plots 1.83-m wide and 22.1-m long and 1.2-m spacing were installed. At the lower parts of the plots, runoff-collecting installations consisted of gutter pipes, pipes and 70-1iter tanks (Rejman *et al.,* 1998) were established. Soil loss was measured under natural rainfall events over a two-year study period from March 2005 to March 2007. After each rainfall event producing runoff, runoff volume was measured in the collecting tank, then mixed thoroughly and a sample (0.5 liter) was taken to determine sediment concentration (Guy, 1975). In the laboratory, the runoff samples were filtered and dried, and the sediment weighed to calculate sediment concentration. Soil loss in each rainfall event was determined using the product of runoff and sediment concentration (Zhang *et al.,* 2004). Annual soil loss was obtained using sum of soil loss in each rainfall event for a year. Mean annual soil loss was calculated using annual soil loss values over a 2-year study period.

Measurement of Rainfall Characteristics

Rainfall data were taken from four standard rainfall gauges on the study area (Figure 1). Homogeneity of the rainfall amounts on the study area on the basis rainfall events causing erosion was evaluated using the Kruskal-Wallis nonparametric test. On the basis of recording rain gauge data, the rainfall intensity and I_{30} (the maximum 30-minute intensity) of rainfall events was calculated for a two-year period. The rainfall erosivity index (EI_{30}) for each rainfall event in MJ mm ha^{-1} h^{-1} was then obtained by multiplying rainfall energy (MJ ha^{-1}) by I_{30}

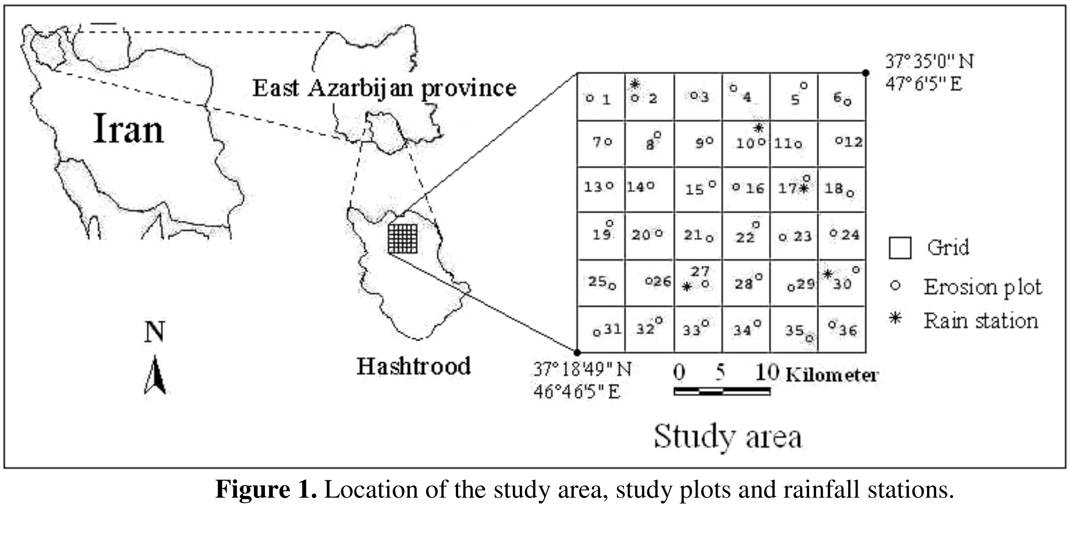

Figure 1. Location of the study area, study plots and rainfall stations.

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(mm h^{-1}). The rainfall energy was computed using the energy equation as follows (Wischmeier and Smith, 1978):

$KE = 210.3 + 87 \log_{10} I$ (2

where I is the rainfall intensity (cm h^{-1}) and KE is the kinetic energy per unit area and rain height (J m^{-2} cm^{-1}). The kinetic energy per unit area (E) was obtained by multiplying KE with the rainfall height (cm). The rainfall erosivity factor R (MJ mm ha^{-1} h^{-1} per year) was ultimately obtained using the sum of the EI_{30} index for the entire storm events occurring in one year.

Soil Physicochemical Analysis

Soil samples (0-30 cm) were taken at random from three locations within each plot before plowing. Then, the samples of each plot were mixed together and a representative sample was ultimately provided. After drying, soil samples were ground to pass through a 2 mm sieve and stored in sealed polyethylene bags in a cool, dry place until physicochemical analysis in laboratory. The particle size distribution consisted of coarse sand (0.1-2 mm), very fine sand (0.05-0.1 mm), silt (0.002-0.05) and clay (< 0.002 mm) was determined by the Robinson's pipette method (SSEW, 1982). Organic carbon was measured by the Walkley–Black wet dichromate oxidation method (Nelson and Somers, 1982) and converted to organic matter by multiplying it by 1.724. Soil structure was determined based on the size and shape of aggregates according to the USLE (Wischmeier and Smith 1978). Soil permeability was determined in the field based on the final infiltration rate for each study plot by measuring the one-dimensional water flow into the soil per unit time using double-ring infiltrometer (Harteg and Horn, 1989) in four replications. The soil structure code and profile permeability class were obtained from the National Soils Handbook No. 430 (USDA, 1983).

Determination of Soil Erodibility Factor (K)

The soil erodibility factor (K) of each plot in units of t h MJ^{-1} mm^{-1} was determined using mean annual soil loss (t ha^{-1}) per unit mean annual rainfall erosivity factor R (MJ mm ha^{-1} h^{-1}). The mean annual soil erodibility factor for each grid was obtained through taking average from the annual soil erodibility factors in three unit plots. To estimation of the soil erodibility factor (K) based on the USLE nomograph was used from the multi-regression equation developed by Wischmeier and Smith (1978) as follows:

$K= 2.8\times10^{-7} M^{1.14} (12\text{-}a)+4.3\times10^{-3} (b\text{-}2)+3.3\times10^{-3} (c\text{-}3)$ (3)

where K is the soil erodibility factor in t h MJ^{-1} mm^{-1}, M is (100-% clay) × (% very fine sand+% silt), a is % organic matter, b is soil structure code and c is profile permeability class.

Determining of Spatial Variability of the Soil Erodibility Factor

Semi-variograms of the estimated and measured soil erodibility factor were used to explore spatial variations in them. The semi-variograms were determined in different directions, whether the spatial variability is isotropic or anisotropic. Anisotropy means that semi-variograms have different range or sill parameters in different directions (Wang *et al.,* 2002). Experimental semi-variograms were fitted using different models (spherical, Gaussian, and exponential models). The best models to present spatial variability of both the soil erodibility factors were determined by the highest r^2 and minimum sum of square of the residuals (RSS). Parameters of the estimated and measured semi-variogram models of the soil erodibility were obtained

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including the effective range (R), nugget effect (C_0), structure (C_1) and sill ($C_0 + C_1$).

RESULTS

Rainfall Characteristics

Sixty rainfall events occurred in the first year and thirty-three in the second year of the study. Table 1 gives descriptive statistics of all rainfall that occurred in the study area from March 2005 to March 2007. The results indicated that rainfall intensities were 2.76 mm h^{-1} for average and 4.88 mm h^{-1} for maximum 30-minute rainfall. The rainfall erosivity index (EI_{30}) varied from 1.077 to 73.402, with an average of 14.658 MJ.mm.ha^{-1}.h^{-1}. The mean annual rainfall erosivity factor (R) was 334.543 MJ mm ha^{-1} h^{-1} in a 2-year period.

The mean heights of the rainfall events resulting sediment (41) in the stations located in grids 2, 10, 17 and 30 of the study area were 7.90, 5.81, 6.86 and 6.14 mm, respectively. The difference of the rainfall height among the different rainguage stations based on *p*-value was 0.11. In fact, there was no significant difference in the height of rain leading to sediment generation in the study rainguage stations and so the amount of rainfall erosivity factor value (R) was considered same for all plots in the study area.

Soil Physicochemical Properties

The study soils were mainly clay loam and have 36.7% sand, 31.6% silt and 32.0% clay (Table 2). The amount of organic matter in the soils was relatively low, with an average of 1.1%. Since soil aggregates were mainly granule with a mean diameter of 5 mm, the soil structure code was 3 for all the study soils. Soil permeability values were between 1.4 and 5.8 cm h^{-1}, with an average value of 3.5 cm h^{-1}. The soil permeability classification on the basis of final infiltration rate was mainly class 3 and, rarely, 2. Distribution of the physical and chemical soil properties on the study area was homogeneous.

Table 2. Soil properties in the study area.

Property	Mean	Standard deviation
Sand (%)	36.4	6.9
Coarse sand (%)	18.6	5.2
Very fine sand (%)	17.8	3.2
Silt (%)	31.6	7.1
Clay (%)	32.0	5.7
Organic matter (%)	1.08	0.2
Structure size (mm)	5	1.1
Structure code	3	-
Permeability (cm h^{-1})	3.50	1.2
Permeability class	2 and 3	-

Soil Loss and Soil Erodibility Factor

Soil loss in the study plots varied from 0.674 to 2.431 t ha^{-1} during the study period, with an average of 1.516 t ha^{-1}. Values for the soil erodibility factor measured in the study plots were between 0.00247 and 0.00717 t h MJ^{-1} mm^{-1}. On average, the measured soil erodibility factor in the study plots was 0.00486 t h MJ^{-1} mm^{-1}. Values of the estimated soil erodibility factor ranged from 0.025 to 0.049 t h MJ^{-1} mm^{-1}, with an

Table 1. Descriptive statistics of all rainfalls occurring in the study area from March 2005 to March 2007.

Descriptive Statistics*	Duration (hr)	Height (mm)	Intensity (mm h^{-1})	I_{30} (mm h^{-1})	EI_{30} index (MJ mm ha^{-1} h^{-1})
Mean	1.80	4.13	2.76	4.88	6.76
Minimum	0.50	1.00	1.00	1.00	0.01
Maximum	10.50	18.70	13.78	25.00	73.40
Standard deviation	1.54	4.14	2.55	4.99	13.78

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Table 3. Estimated and measured values of the soil erodibility factors (K) in th MJ^{-1} mm^{-1} in the study plots.

No.	Estimated *K* factor	Measured *K* factor	No.	Estimated *K* factor	Measured *K* factor	No.	Estimated *K* factor	Measured *K* factor
1	0.048	0.007	13	0.042	0.006	25	0.034	0.006
2	0.041	0.006	14	0.030	0.005	26	0.031	0.003
3	0.047	0.007	15	0.036	0.005	27	0.025	0.002
4	0.036	0.004	16	0.033	0.002	28	0.036	0.006
5	0.037	0.006	17	0.027	0.002	29	0.040	0.004
6	0.034	0.002	18	0.038	0.005	30	0.049	0.005
7	0.041	0.004	19	0.025	0.006	31	0.029	0.004
8	0.027	0.003	20	0.026	0.0058	32	0.036	0.002
9	0.031	0.005	21	0.029	0.002	33	0.042	0.003
10	0.036	0.006	22	0.044	0.004	34	0.035	0.004
11	0.033	0.005	23	0.049	0.005	35	0.037	0.004
12	0.027	0.003	24	0.040	0.004	36	0.041	0.004

average of 0.036 t. h MJ^{-1} mm^{-1}. Table 3 shows the estimated and measured values of the soil erodibility factor in the study plots.

Distribution of both the estimated and measured soil erodibility factors data on the study area was normal (Figure 2). There was a significant difference ($P< 0.001$) in the estimated and also the measured values of the soil erodibility factor among the study plots. A comparison between the soil erodibility factor (K) values measured in the plots and estimated values derived from the USLE nomograph showed that the measured soil erodibility factor values were from 4.40 to 17.64 times smaller than the estimated values. On average, the measured values of the soil erodibility factor on the study area were 8.77 times smaller than the nomograph-based estimates. The results indicted that the correlation between the measured and estimated *K* factor was significant with r^2= 0.22 between the two. Figure 3 shows the relationship between the measure and estimated soil erodibility factor in the study area.

Spatial Variations of the Soil Erodibility Factor

The spatial variations of the estimated and measured soil erodibility factor were

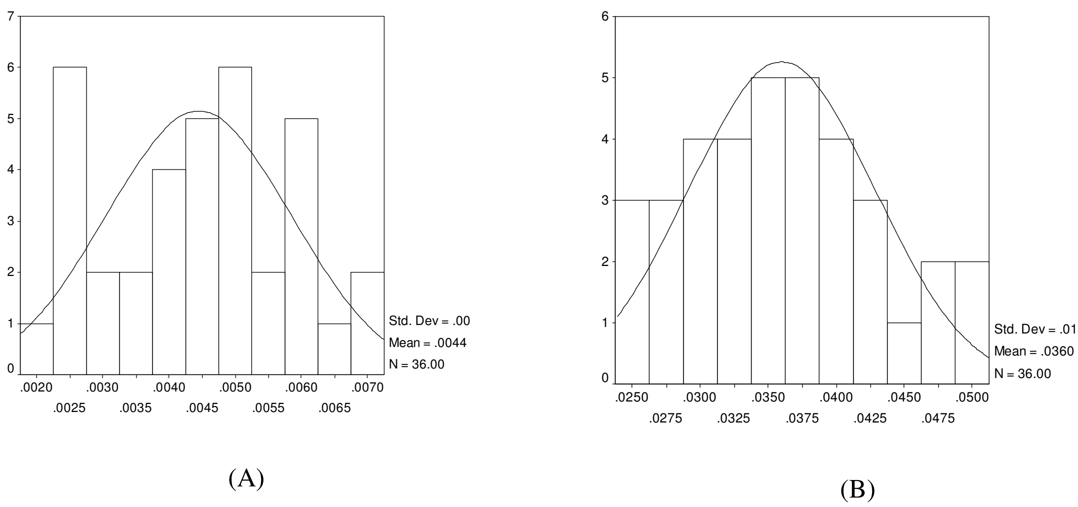


Figure 2. Distribution of the estimated (A) and measured (B) soil erodibility factors data.

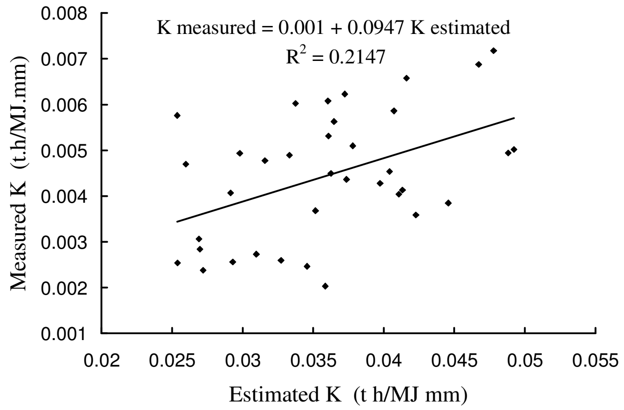


Figure 3. Relationship between the measured and estimated soil erodibility factors (K) in the study area.

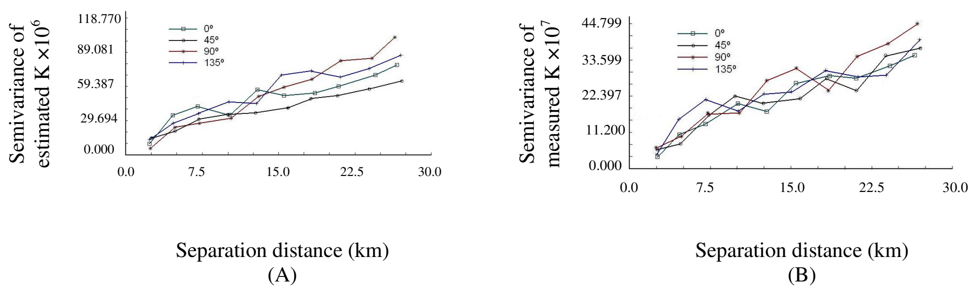


Figure 4. Experimental semi-variograms of the estimated (A) and measured (B) soil erodibility factors in the study area in the different directions.

analyzed by experimental semi-variograms in the directions of azimuth 0°, 45°, 90° and 135° (Figure 4). The semi-variograms of the two were almost similar for all directions and were considered isotropic. Experimental semi-variograms of the estimated and measured soil erodibility factors were fitted using spherical models. The isotropic semi-variograms of the estimated and measured soil erodibility factors and spherical models fitted to them are presented in Figure 5. Amounts of error of the models fitted to the semi-variograms were calculated using the proportion nugget (C_0) to the sill (C_0+C= 1). The amounts of error of the fitted models to the experimental semi-variograms of the estimated and measured soil erodibility factors were 0.020 and 0.010, respectively. Table 4 shows parameters of the models fitted to semi-variograms of the estimated and measured soil erodibility factor in the study area. Based on these results, the range values of spatial variations of the estimated and measured soil erodibility factors were 11.51 and 2.43 km, respectively.

Semi-variance maps of the estimated and measured soil erodibility factors were prepared using their exponential simulation model. The semi-variance values of the estimated and measured soil erodibility factors varied from 78.037×10^{-7} to 10.925×10^{-5} and from 29.429×10^{-8} to 41.201×10^{-7} on the study area, respectively. These are shown on semi-variance maps in Figure 6. The semi-variances of both soil erodibility factors had the lowest values in the central area and increased gradually with increasing intervals from the central on the study area.

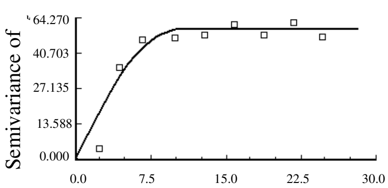
Kriging was used to develop maps of the spatial variations of the estimated and measured soil erodibility factors based on

Table 4. Parameters of models fitted to semi-variograms of the estimated and measured soil erodibility factors in the study area.

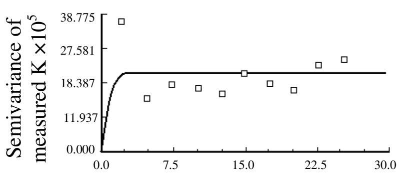
Parameter	Estimated K	Measured K
Nugget: C_0	1×10^{-7}	22×10^{-9}
Sill: C_0+C_1	499×10^{-8}	2134×10^{-9}
Structure: C_1	498×10^{-8}	2112×10^{-8}
Effective rang: R (km)	11.51	2.43
Error: $C_0/(C_0+C_1)$	0.020	0.010
r^2	0.903	0.710
Residual sum of squares: RSS	2.154×10^{-10}	3.826×10^{-12}
Model	Spherical	Spherical

the experimental semi-variograms. The spatial variations maps of the estimated and measured soil erodibility factors for the study area are shown in Figure 7. There was a considerable difference between the spatial variations of the estimated and measured soil erodibility factors on the study area. The estimated soil erodibility factor had the highest values (0.0364 to 0.0472 t h MJ^{-1} mm^{-1}) in the Northwest, South and Southeast. The lowest values of the soil erodibility factor were from the Southwest to Northeast. The highest values of the measured soil erodibility factor (45.014×10^{-4} to 66.468×10^{-4} t h MJ^{-1} mm^{-1}) occurred mainly in the Northwest and rarely as a point place in any other area. The spatial distribution of the measured soil erodibility factor on the study area except in the Northwest was almost uniform.

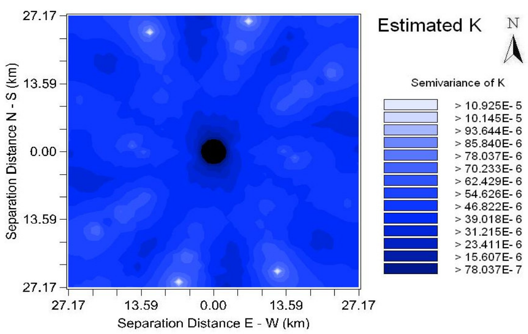
Considering the difference between the values of the estimated and measured soil erodibility factor in the study plots, information on the amount of difference between them was important on the study area. To access this objective, a map of



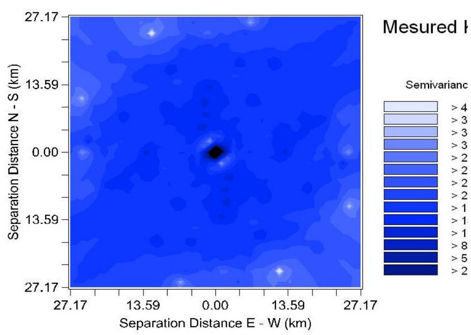
Separation distance (km)
(A)



Separation distance (km)
(B)



(A)



(B)

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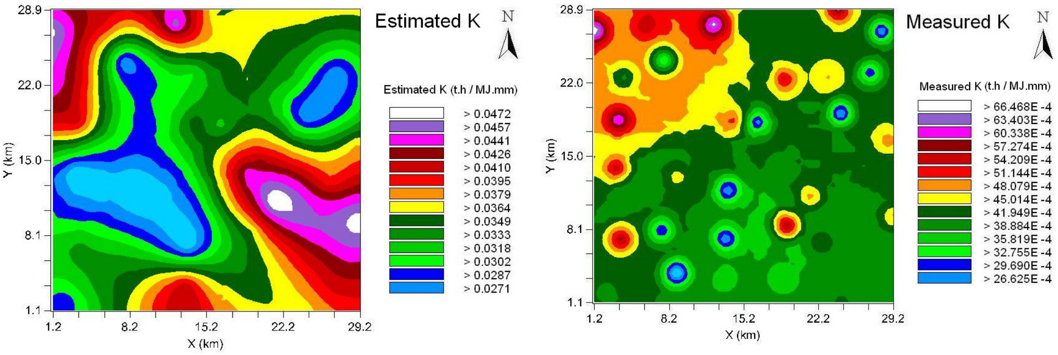

(A) (B)

Figure 7. Spatial variations maps of the estimated (A) and measured (B) soil erodibility factors for the study area.

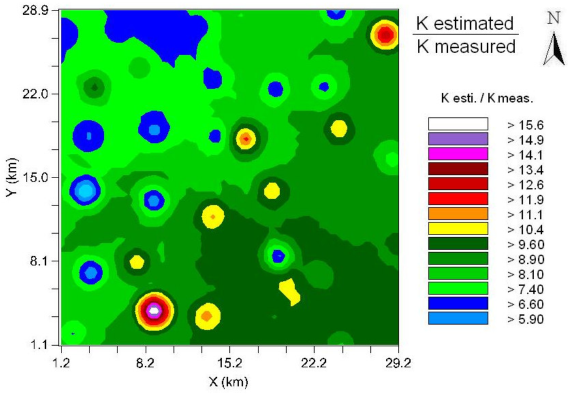

Figure 8. Map of proportion of estimated values to measured values of the soil erodibility factor on the study area.

proportion of the estimated values to measured values of the soil erodibility factor was obtained using its experimental semi-variogram (Figure 8). The same figure shows that the proportion of the estimated values to measured values of the soil erodibility factor on the study area was almost uniform. This proportion in most places in the study area was between 7.4 and 9.6.

DISCUSSION

The results of this study indicated that the relationship between the measured and estimated soil eroibility factors was very poor with an r^2 of 0.21. The measured values of soil erodibility were systematically lower than the nomograph-based estimates by a factor of 8.77. These results conform with those of Rejman *et al*. (1998) and Zhang *et al.* (2004) who found that the measured soil erodibility was 6-10 and 3.3-8.4 times smaller than values derived the USLE nomograph, respectively.

The semi-variograms of the both estimated and measured soil erodibility factors were almost similar in all directions. Experimental semi-variograms of the estimated and measured soil erodibility factors were fitted using spherical models. The error values of the spherical models fitted to the experimental semi-variograms of the estimated and measured soil erodibility factors were 0.020 and 0.010, respectively. In fact, measurement errors for both the soil erodibility factors in the study area were very low. The range of values of spatial variations of the estimated and measured soil erodibility factors were 11.51

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and 2.43 km, respectively. The study demonstrated that the measured soil erodibility factor in contrast to the estimated value varied at a short distance. The result on the spatial structure of the soil erodibility factor conforms with those of Sokouti Oskouie (2005), who found that the pattern of the spatial distribution of the *K* factor was spherical but the range of spatial variations and value of distribution error of the soil erodibility factor obtained were 0.086 and 100 meters, respectively.

The semi-variances of both the soil erodibility factors had the lowest values in the central area and increased gradually with increasing intervals from the centre of the study area. The semi-variance values were lower inside the study grids because there was the highest number of the study plots. These results are in agreement with Wang *et al.* (2002), who showed that the lowest variances of the rainfall-runoff erosivity factor were in the central area, where the high density of the rainfall stations exists.

The study showed that a considerable difference within the effective range of spatial variations ($P< 0.001$) between the estimated and measured soil erodibility factor in the study area. The estimated soil erodibility factor had the highest values in the Northwest, South and Southeast, while the highest values of the measured soil erodibility factor were in the Northwest and, rarely, as a small part in the other areas. The spatial distribution of the measured soil erodibility factor on the study area except in the Northwest was almost uniform. The map of the proportion of the estimated values to measured values of the soil erodibility factor showed that it was almost uniform on the study area and was usually between 7.4 and 9.6. The study indicated that use of the USLE nomograph would considerably lead to over-estimating the amounts of soil erodibility in the all places in the study area. Determination of the factors affecting soil erodibility and developing a model for predicting it is essential to proper evaluation of the spatial variations of the soil erodibility factor in the study area.

CONCLUSIONS

This study was conducted to determine spatial variations of the soil erodibility factors estimated using the USLE nomograph and measured in the unit plots under natural rainfall events. The results indicated that the difference between the measured and estimated soil erodibility factors was significant ($P< 0.001$) and the correlation between the two was very poor with $r^2= 0.21$. On average, the measured values for the soil erodibility factor were 8.77 times smaller than the estimated values in the study area. The spherical simulations were the best models to explain spatial variations of both the estimated and measured erodibility factors. The range of the spatial variations of measured soil erodibility (2.43 km) was smaller than that one for the estimated value (11.51 km). There was a considerable difference in the effective range of spatial variations between the estimated and measured soil erodibility factors on the study area. The estimated soil erodibility factor had the highest values in the Northwest, South and Southeast, while the highest values of the measured soil erodibility factor were in the Northwest and, rarely, in a small part in the other areas. The map of the proportion of the estimated values to measured values of the soil erodibility factor showed that this index was almost uniform (between 7.4 and 9.6) in the study. The study indicated that use of the USLE nomograph would considerably lead to over-estimated amounts of the soil erodibility in all the places in the study area.

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تغییرپذیری مکانی عامل فرسایش‌پذیری خاک USLE در شمال‌غربی ایران

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چکیده

فرسایش‌پذیری خاک به دلیل تغییر برخی ویژگی‌های خاک در نقاط مختلف یک منطقه به طور مکانی تغییر می‌کند. این مطالعه جهت مقایسه تغییرپذیری مکانی عامل فرسایش‌پذیری خاک برآورد شده و اندازه‌گیری شده در USLE انجام گرفت. آزمایش در منطقه‌ای کشاورزی به مساحت ۹۰۰ کیلومتر مربع در شهرستان هشترود واقع در جنوب استان آذربایجان‌شرقی انتخاب شد. در سطح منطقه مورد بررسی ۳۶ شبکه به ابعاد ۵ کیلومتر در نظر گرفته شد. در هر شبکه سه کرت واحد در زمینی کشاورزی با شیب جنوبی ۹ درصد احداث شد. فرسایش‌پذیری خاک با استفاده از نموگراف USLE برآورد و براساس میانگین سرعت هدررفت خاک از کرت واحد در عامل فرسایندگی باران به طور سالانه اندازه‌گیری شد. نتایج نشان داد که تفاوت بین مقدار فرسایش‌پذیری برآوردی و اندازه‌گیری شده معنی دار ($p< ۰/۰۰۱$) و همبستگی بین آنها ضعیف ($r^۲=۰/۲۱$) است. شبیه‌ساز نمایی مناسبترین مدل برای نشان دادن تغییرات مکانی فرسایش‌پذیری برآورد شده و اندازه‌گیری شده بود. شعاع تاثیر تغییرات مکانی فرسایش‌پذیری اندازه‌گیری شده (۲/۴۳ کیلومتر) کمتر از مقدار برآوردی (۱۱/۵۱ کیلومتر) بود. بین تغییرات مکانی فرسایش‌پذیری اندازه‌گیری شده و برآوردی در سطح منطقه تفاوت چشمگیری ($p< ۰/۰۰۱$) وجود داشت. نقشه نسبت فرسایش‌پذیری برآوردی به اندازه‌گیری شده روی سطح منطقه مورد مطالعه تقریبا یکنواخت (بین ۷/۴ و ۹/۶) بود. این مطالعه نشان داد که استفاده از نموگراف USLE موجب می‌شود مقدار فرسایش‌پذیری در تمام نقاط روی منطقه مورد بررسی، بیشتر ازمقدار اندازه‌گیری شده برآورد گردد.

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