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Analyzing the Changes of Soil Erodibility Index (K) in the Soils of Arid Regions and the Effective Factors in Central Iran (Case Study: Yazd-Ardakan Plain)

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Abstract

One of the main factors of water erosion is the natural characteristics of the soil called "erodibility" or "detachability". The present study aims to analyze the variations of soil erodibility factor in different plains and the factors related to it. Erodibility is one the key factors in some models of erosion and sediment such as Universal Soil Loss Equation (USLE), Revised USLE (RUSLE), and Modified USLE (MUSLE) and is a function of grain size distribution, organic matter, structure and infiltration. To this end, the index of soil erodibility was measured through field surveys in 37 spots in the faces of bare pediment, coalescing pediment, and concealed pediment plains using Wischmeier and Smith (1987) method. The infiltration of soil profile and the percentage of desert pavement in the field were measured as well. Soil grain size distribution, percentage of organic matter, soil structure, gravel volumetric content, lime, salinity, acidity, and sodium absorption rate were also measured in the laboratory. The statistical analysis indicated positive correlations of erodibility with silt, very fine sand (VFS), and negative correlation of this factor with gravel, sand, infiltration, organic matter, and lime. The results from Analysis of Variance (ANOVA) test also indicated that three factors of salinity, acidity, and sodium absorption rate are not significantly different in bare pediment, coalescing pediment, and concealed pediment plains. The results suggested that in natural conditions of soil surface, desert pavement plays its protective role and land use change through mixing the soil would thwart effect of the pavement. So, the erodibility of the soil in manipulated and mixed conditions increases up to 10 times.

***Keywords**:* Geomorphology faces; Desert pavement; Water erosion; Erodibility

1. Introduction

Soil is one of the most important natural resources of each country. One of the main and effective parameters in soil erosion is the natural characteristics of the soil which is erodibility. We can prevent various disadvantages resulting from erosion or reduce them to minimum through better recognition and evaluation. Erodibility is the part and parcel of soil erosion. This factor indicates, qualitatively and quantitatively, the natural sensitivity of separates of particular soil to being detached and transferred by erosion factors and specifies, in fact, the effects of many features and their interactions. Different methods have been introduced so far to determine the effective factor of erodibility either directly (measurement) or indirectly (using models). Although direct methods are accurate they are not economic, so models are used increasingly by the researchers (Ghorbani vagheie,2005). Different methods and equations have been presented to evaluate the amount of water erosion. The Universal Soil Loss Equation (USLE) is of great importance in evaluation of soil loss. This equation is one of the popular methods which are used extensively to predict and determine the factors affecting water erosion (Wischmeier and Smith, 1978). It is the

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simplicity of most of the variables in this equation that has led USLE to be the most extensively used method of evaluating soil loss. Various studies have been done considering water erosion especially with regard to soil erodibility factor. We refer to some of them here. Loch et al. (1998) have found that K has a strong correlation with the percentage of unstable aggregates (smaller than 0.25 mm) and sand (larger than 0.1 mm). Charman and Murphy (2000) suggested that clay usually reduces soil erodibility. The cation of Calcium plays a significant role in flocculation of soil colloid and reduction of erodibility (Charman and Murphy, 2000). Based on Gupta's report (2002) infiltration and stability of soil structures are two important features of soil that affect K (Gupta, 2002). The experiment done by Santos et al. (2003) indicated that soils having more percentages of sand can better reduce the effects of rain drops impact and because of higher infiltration velocity they produce less runoff. According to the study done by Ghasemi and Mohammadi (2003) in Chaghkhord watershed located in Chaharmahal Bakhtiari province by increasing the percentage of clay and organic matter, soil erodibility would decrease and it increases by the increase of silt (Ghasemi and Mohammadi, 2003). Zhang et al. (2004) suggested that there is significant negative correlation between amount of clay and soil erodibility factor in USLE (Zhang et al.,2003). The research done by Orendlick et al. (2004) investigated the effects of organic carbon on physical parameters of the soil. The results from this study indicated that the amount of organic carbon has a positive effect both on soil porosity and the capacity of water that can be used by plants and it decreases the erodibility the water. Ghaderi and Ghoddusi (2005) investigated the erodibility of soil in Talvarchai in kordestan province and concluded that soil erodibility would increase by the increase of sand to silt ratio (Ghaderi and Ghoddosi, 2005). Vaezi et al. (2008) analyzed the effective factors of erodibility in calcareous soil based on USLE and came to the conclusion that lime, as one of the most important features of soil, plays a significant role in increasing the infiltration and stability of aggregate and as a result in decreasing soil erodibility (Vaezi et al.,2007).

The primary purpose of the present study is to evaluate the factor of soil erodibility in dry regions' soil and analyze the factors effective in this regard. Erodibility factor (K) is a key factor in some of the erosion and sediment models such as MUSLE, RUSLE, and USLE and is a function of grain size distribution, organic matter, structure, and infiltration

2.1. Study area

2.1.1. General characteristics of the region

The region under study is 20 km far from Yazd in the northern latitude of 3526360.9 to 3551712.9 and eastern longitude of 215107.9 to 238865.6. The region is actually a longitudinal section between Khezrabad mountain and the cities of Ashkezar and Zarch and covers bare pediment, coalescing pediment, and concealed pediment plains. Maximum altitude of this transect is 1783m near mountain and minimum altitude is 1141m at the periphery of sand dune faces near Yazd-Ardakan road. The area of the region is 28 km^2. Figure1 shows the situation of field study in Yazd-Ardakan plain.

2. Materials and Methods

2.1. Field work

In the present study, firstly were the boundaries of the region determined using topography maps, air photographs, ETM$^+$ satellite images, Google earth images, and Arc GIS software. Then the maps of lithology, geology, and geomorphologic faces units based on UTM coordinate system were produced. Then by means of these maps and through systematic random sampling, the samples of soil in the faces up to 10cm depth were survived. In the same depth soil surface structure was recognized and recorded. Then the soil structure codes were determined based on shape and the size of the aggregates and infiltration of water in soil according to the table proposed by Wischmeier and Smith (1978). Soil infiltration was measured in the field according to ultimate infiltration velocity through double rings method. The percentage of desert pavement was measured in the field using plots.

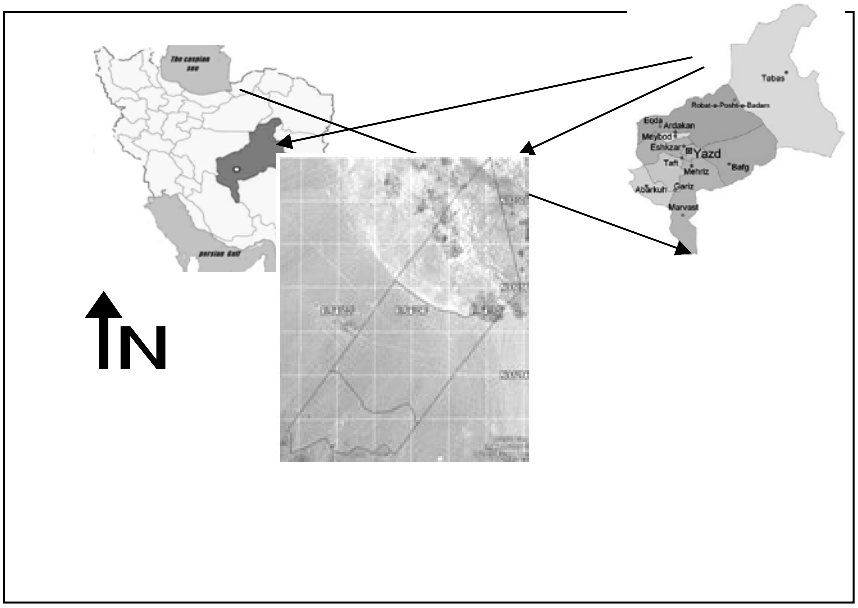

Fig. 1. Geographical position of the study area

2.2. Laboratory and calculational operations

Necessary experiments were carried out after transferring the samples to the lab. Soil gradation distribution, percentage of gravel and percentage of organic matter and very fine sand were determined though hydrometric method, Walky black method and wet sieve, respectively (Klut,1986). The amount of lime was calculated based on Total Neutralizing Value (TNV) through volumetric method from neutralizing reaction with HCl (Goh et al, 1993). After preparing saturated extract of the soil by means of vacuum pump,Then it was determined the amount of pH using pH meter-Jenway model, amount of salinity (ECe) using Jenway model conductivity meter, concentration of dissolved Sodium using Jenway model flame photometery, concentration of Calcium and Magnesium using Complexometric titrations with EDTA (Ghenge and Bray, 1951) and finally it was determined the amount of Sodium Absorption Rate (SAR) using the following formula:

$$SAR = Na^{+}/\sqrt{(Ca^{2+} + Mg^{2+})/2} \quad (1)$$

Where Na^{+}, Ca^{2+} and Mg^{2+} are concentration of Sodium, Calcium and Magnesium ions respectively in meq/l and then the index of erodibility was calculated using following formula

$$K = \{2.1M^{1.14}(10^{-4})(12 - a) + 3.25(b - 2) + 2.5(c - 3)\}/100 \quad (2)$$

$$M=(\%Silt+Vfs)(100-\%Clay) \quad (3)$$

Where *M*, *a*, *b*, and *c* are the product of sum of silt and very fine sand percentages to 100 subtracted from clay percentage, percentage of organic matters (*a*), structure code (*b*) and soil profile infiltration(*c*) respectively. In the equation soil erodibility factor (*K*) in American system is 0.01 ton hour to foot ton inch. In order to convert *K* from American system to the international system we used 0.1317 coefficient. In the international system *K* is ton.hr/MJ.mm (Miller and Donahue, 1990). In order to consider the effect of pavement on soil erodibility, it was determined and applied surface pavement percentage coefficient (Mccormack et al., 1984).

2.3. Statistical analysis

After calculating soil erodibility index, it was analyzed the data using SPSS16 software and achieved some indices such as average, minimum, maximum and standard deviation. To prove the assumption of normality, we used non-parametric Kolmogrov-Smirnov Test. It was used Tukey Test in order to analyze the difference in the amounts of erodibility in Bare pediment , coalescing pediment , and concealed pediment plains. Linear regression and correlation were used to determine the logical relationship between different variables. To analyze the strength of relationship between erodibility variable and other physical and chemical variables of soil we used Pearson Correlation Coefficient.

Sample size sufficiency was calculated by following equation (Tanji, 1994).

$$n = (t_{\alpha})^2 \times \frac{s^2}{d^2} \quad (4)$$

Where: t_{α}, s, d, and n are t test table in confidence level of α, standard deviation, permissible error and number of samples, respectively. In recent research, permissible error was considered 10%. Size samples of organic matter, silt and sand were calculated as the effective factors in erodibility as well as salinity, SAR, pH and lime.

3. Results

Sample size of effective parameters in erodibility were shown in table 1. permissible error were considered 10% for all parameters. For each parameter, number of samples and sample size sufficiency was compared.

Table 1: Sample size sufficiency of some soil properties

Soil properties	Sample NO	Sample Variance	t_{α}	Sample size sufficiency
ECe	16	5.21	1.75	16
pH	16	0.10	1.75	16
SAR	16	6.8	1.75	15
Sand	37	259.6	1.68	37
Clay	37	39.8	1.68	28
Silt	37	136.9	1.68	32
O.M	37	0.10	1.68	33
CaCO3	37	18.3	1.68	23

Analyzing chemical and physical parameters of the soil indicated that the soils are mostly of sandy to loam sandy texture with little organic matter and lime. Considering structure, the soils were granular to very fine crumb and their structure codes were based on USLE (1&2). Infiltration of soil profile was very rapid to rapid (18.4cm/ hr) and according to USLE it was placed in class one or two and sometimes three. The average of SAR and ECe for the soils of the region were 5.94 and 2.87 dS/m respectively. Considering acidity the soils were alkaline. Based on Wischmeier-Smith regressional relationship the estimated average of erodiblity in Bare pediment[1], coalescing pediment[2], and concealed pediment[3] plains were 0.0385, 0.03, and 0.019 ton.hr/MJ.mm, respectively. It was used non-parametric Kolmogrov-Smirnov test to check the normality of the variables. Percentage of organic matters, infiltration, and the index of erodiblity were normalized through square root conversion.

3.1. The effect of land use change and manipulating desert pavement on soil erodibility

Surface structure of the bare pediment plains are mostly covered by large stone components (80% to 100%), the reason for that is adjacency to mountain unit, in addition, erosion lead fine grained particles to detach and transfer and gradually it would be possible for large grained particles to accumulate in the surface. In bare pediment plains, desert pavement covers 60% to 80% of the surface (Table 2). concealed pediment plains have unstable average to small pavement covering 0% to 10% of the surface. The results from field operation suggested that, in bare pediment plains, two third of stone components volume are involved in soil and the remaining one third are free while in coalescing pediment and concealed pediment plains less volume of stone components are involved in soil. Erodibility was calculated using Wischmeier-Smith equation after physical and chemical analysis of the soil. It was determined the erodibility separately in natural and manipulated conditions. As far as in natural conditions of the soil surface pavement can play its protective role and land use change with soil mixing neutralize the effect of pavement, so soil erodibility in manipulated and mixed conditions increases up to 10 times (Table 2).

The results showed that the density of pavement in study region was 0% to 100%. The range of soil erodibility changes in bare pediment plain faces in natural conditions was 0.00014 to 0.02766 ton.hr/MJ.mm and in manipulated and mixed conditions it was 0.014 to 0.036. In this case it can be concluded that through mixing surface soil and pavement, erodibility up to 10.3 times on average.

The range of erodibility changes in coalescing pediment plains' faces in natural and manipulated conditions were 0.00132 to 0.0132 and 0.0307 to 0.0416 ton.hr/MJ.mm

1- Glacies de denudation (in French) : Coarse grain pediment
2- Glacies de epandage (in French): Medium grain pediment
3- Glacies de bajada(in French): fine grain piedmont

respectively. This indicates that, though mixing surface soil and pavement soil erodibility increases up to 8.6 times. Manipulation mostly occurs in coalescing pediment plains because they have better conditions considering reliefs comparing to bare pediment plains for the purpose of land use change. So, that's why erodibility resulting from land use change is of great importance in such plains.

The range of soil erodibility in concealed pediment plains' faces in natural and manipulated conditions was 0.002 to 0.046 and 0.002 to 0.046 ton.hr/MJ.mm, respectively. Due to the lack of pavement coverage, manipulation didn't considerably affect erodibility.

After analyzing amounts of erodibility in bare pediment , coalescing pediment , and concealed pediment plains using Tukey test was concluded that amounts of erodibility in bare pediment and coalescing pediment plains are not significantly different at the level of 5% but amounts of erodibility in bare pediment and coalescing pediment plains are significantly different from concealed pediment plains at the level of 5%.

Table 2. Erodibility in natural and manipulated conditions

Geomorphologic faces	Sample number	desert Pavement (%)	Soil erodibility		Disturbed to Natural erodibility ratio	Average of relative increase
			Natural	Disturbed		
Bare pediment	2	100	0.00014	0.0014	10.0	10.3
	5	90	0.00395	0.0585	14.8	
	6	90	0.00329	0.0530	16.1	
	7	90	0.00132	0.0062	4.7	
	8	80	0.00527	0.0577	11.0	
	19	80	0.00395	0.0374	9.5	
	20	90	0.00263	0.0492	18.7	
	21	80	0.00329	0.0343	10.4	
	22	10	0.02766	0.0360	1.3	
	27	70	0.00527	0.0365	6.9	
	30	80	0.00527	0.0490	9.3	
	37	80	0.00395	0.0426	10.8	
Coalescing pediment	1	90	0.00132	0.0307	23.3	8.6
	3	80	0.00263	0.0310	11.8	
	4	80	0.00395	0.0404	10.2	
	17	80	0.00158	0.0152	9.6	
	29	50	0.00790	0.0271	3.4	
	31	80	0.00263	0.0203	7.7	
	32	60	0.00790	0.0364	4.6	
	33	50	0.01320	0.0416	3.2	
	34	60	0.00320	0.0159	5.0	
	36	50	0.00560	0.0385	6.9	
Concealed pediment	9	5	0.01317	0.0139	1.1	1.2
	10	0	0.00200	0.0020	1.0	
	11	0	0.00870	0.0087	1.0	
	12	0	0.04600	0.0460	1.0	
	13	5	0.01320	0.0147	1.1	
	14	10	0.00320	0.0040	1.3	
	15	0	0.01050	0.0105	1.0	
	16	0	0.03710	0.0371	1.0	
	18	30	0.00710	0.0150	2.1	
	23	0	0.02580	0.0258	1.0	
	24	5	0.02500	0.0275	1.1	
	25	0	0.01100	0.0110	1.0	
	16	10	0.01580	0.0196	1.2	
	28	25	0.00740	0.0144	2.0	
	35	5	0.03420	0.0386	1.1	

Figure 2 shows the range of Wischmeier-Smith erodibility changes in bare pediment, coalescing pediment , and concealed pediment plains. The rang of changes in bare pediment , coalescing pediment plain, and concealed pediment plain were 0.034 to 0.056, 0.0152 to 0.0416, and 0.002 to 0.046 ton.hr/MJ.mm respectively. As mentioned before, the value of K coefficient in bare pediment plain is higher but the range of changes is very limited while the value of K coefficient is lower in concealed pediment plains but the range of changes is less limited than bare pediment plains. The reason for that is the soil texture of different faces. K coefficient in coalescing pediment plains has an average range between bare pediment and concealed pediment plains. Figure 3 shows the changes of modified index of soil erodibility (considering desert pavement and in natural conditions) in bare pediment , coalescing pediment , and concealed pediment plains which are 0.00014 to 0.00530, 0.00132 to 0.01320, and 0.002 to 0.046 ton.hr/MJ.mm, respectively.

Soil erodibility is affected, in addition to the factors mentioned in Wischmeier-Smith regressional relationship, by other parameters of the soil that are not present in regressional relationship. To determine such parameters we analyzed the effect of sand, lime, gravel, salinity, acidity and Sodium absorption rate on erodibility. To this end we achieved the matrix of correlation coefficient between erodibility and other physical and chemical parameters of the soil. Table 3 indicates the results from correlation coefficient between erodibility and other physical and chemical parameters of the soil in study region.

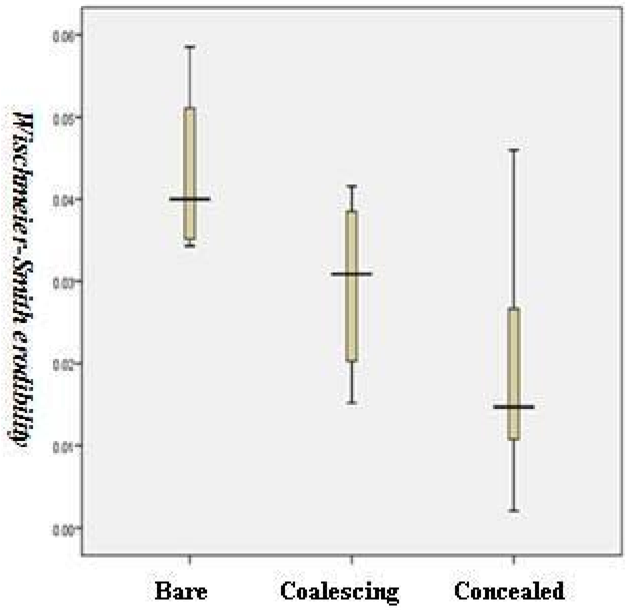

Fig. 2. Box plot of Wischmeier-Smith erodibility

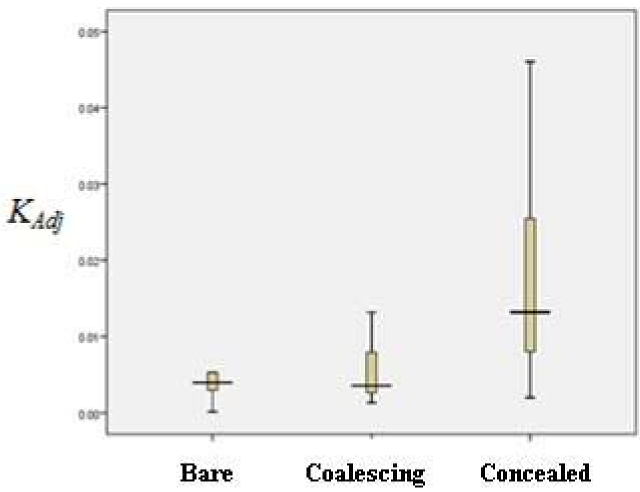

Fig. 3. Box plot of soil erodibility considering desert Pavement, K_{Adj}

The results suggested that among different properties of the soil, only negative correlation of sand and gravel with erodibility was significant. Positive effects of VFS, clay and silt on erodibility were not significant. Sand, in the present study, significantly reduced the erodibility of the soil while the effect of VFS was not significant (Figures 4-7). The negative effect of sand on erodibility is also clearly indicated in the study done by Santos et al.

(2003). Considering high percentage of sand in the soil of the region and although the soil can be easily detached because of lack of cohesion, as far as they have larger grains, they are resistant against being transferred through runoff and they produce less sediment in result.

Table 3. Correlation coefficint between soil erodibility and other chemical and physical parameters of the soil

Properties	Soil erodibility	Sand %	Clay %	Silt %	VFS%	Organic matter %	Lime %	Gravel%	Desert pavement%	infiltration (cm/hr)
Soil rodibility	1									
Sand %	-0.33*	1								
Clay %	0.28	-0.79**	1							
Silt %	0.31	-0.94**	0.56**	1						
VFS%	0.19	-0.39*	0.31	0.37*	1					
O.M%	-0.32	-0.32	0.15	-0.03	-0.39*	1				
Lime %	-0.32	0.29	-0.27	-0.26	-0.32	0.08	1			
Gravel%	-0.53**	0.20	-0.37*	-0.07	-0.27	-0.29	0.34*	1		
Desert pavement	-0.67**	-0.19	0.01	0.26	0.06	-0.48**	0.15	0.70**	1	
Infiltration	-0.29	0.91**	-0.84**	-0.79**	-0.34*	-0.02	0.32	0.27	-0.15	1

*: significant at the level of 0.05, **: significant at the level of 0.01

Increasing the percentages of clay and silt of the soil leads to decreasing this resistance and more sediment would be transferred. Besides, larger amount of sand increases infiltration of the soil and produces less runoff while by increasing the percentages of silt and clay resulting from the formation of surface crust, infiltration of the soil reduces and more runoff would be produced. Organic matter, lime, gravel and infiltration have also negative correlation with erodibility. Insignificant effect of lime on reducing soil erodibility is resulted from the percentage of Ca^{2+} and increase of particles cohesion that lead to increasing the resistance of the soil to rain drops' impacts. Organic matters have also an insignificant negative effect on soil erodibility (Figure 8). Increasing the amount of organic matters in soil protect aggregates from disintegration in such a way that by considerable increase of organic matters, disintegration of the aggregates reduces up to one third in a certain region (Ekwue, 1990).

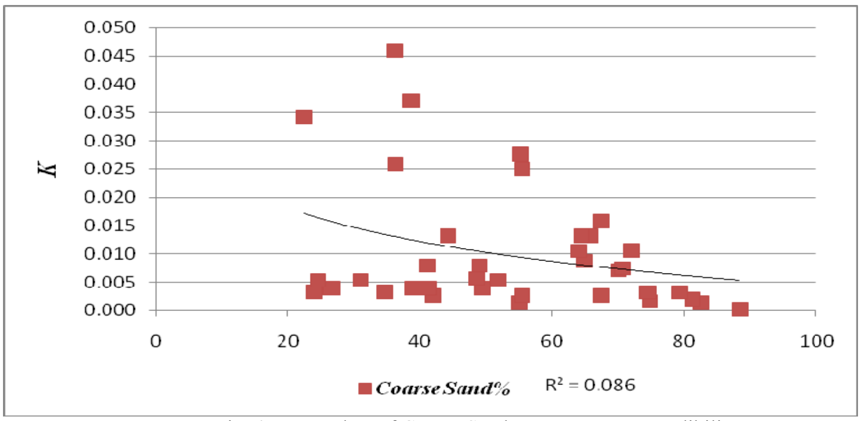

Fig. 4. scatterplots of Coarse Sand percentage vs. Erodibility

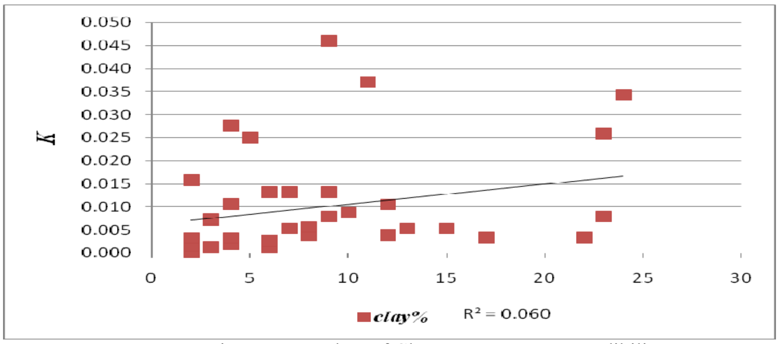

Fig. 5. scatterplots of Clay percentage vs. Erodibility

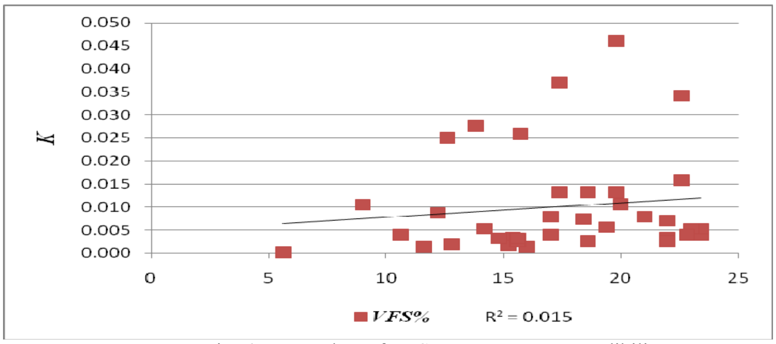

Fig. 6. scatterplots of VFS percentage vs. Erodibility

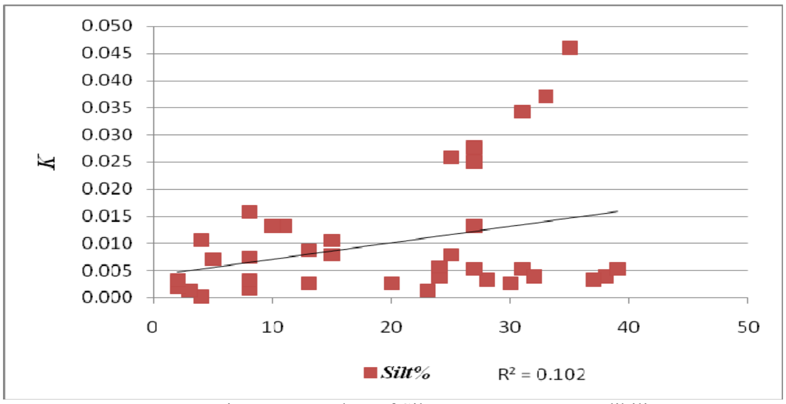

Fig. 7. scatterplots of Silt percentage vs. Erodibility

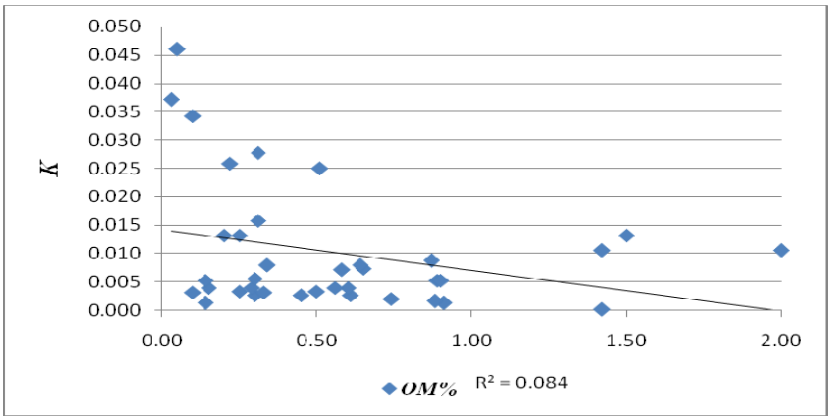

Fig. 8. Changes of O.M vs. Erodibility, about 80% of soil samples included low organic matter

Table 4 shows the results from correlation coefficient between erodibility and some chemical properties of the soil in the study region.

Table 4. Correlation coefficient between erodibility and some of the chemical parameters of the soil

properties	K_{adj}	ECe (dS/m)	pH	SAR
K_{adj}	1			
ECe (dS/m)	-0.24	1		
pH	-0.27	-0.47	1	
SAR	-0.10	0.38**	0.05	1

As it is indicated in Table 4, chemical parameters of the soil such as ECe, pH and SAR have negative correlation with erodibility, but the correlations are not significant. Positive and significant correlations of ECe and SAR are significant.

The results from ANOVA test also indicated that there is no significant difference between three parameters of ECe, pH and SAR in bare pediment , coalescing pediment , and concealed pediment plains. The reason is that all the salts in the soil surface were leached. When we go deeper from the surface substantial difference among of ECe, pH, and SAR in bare pediment , coalescing pediment , and concealed pediment plains would be observable. As far as erodibility is related to surface layer of the soil, so difference between percentages of ECe, pH and SAR is not significant in this layer, but it has an increasing trend from bare pediment plain to concealed pediment plain. As mentioned in 2.2, soil samples from collected from 10cm depth of surface soil. To analyze the effective parameters on soil erodibility, linear and multi-variable regression equation were used.

Table 5. Linear and Multi-variable regression equations

Equation No	Equation	R	R^2
4	$K_{Adj} = 0.174 - 0.001\ Gr$	0.58*	0.28
5	$K_{Adj} = 0.16 - 0.001\ Sand$	0.34*	0.11
6	$K_{Adj} = 0.18 + 0.07\ OM - 0.004\ TNV$	0.48*	0.22
7	$K_{Adj} = 0.0194 - 0.0002\ Pavement$	0.68*	0.45

In the above equations, the presented equations are: R; correlation coefficient, R^2; Coefficient of determination, K_{Adj}; soil erodibility with regard to desert pavement (modified K), Gr; percentage of gravel, Sand; percentage of sand, OM; percentage of desert pavement, TNV; percentage of lime, and pavement; percentage of desert pavement.

Considering Table 5, the results from multi-variable linear regression suggested that among different physical parameters of the soil, the only significant correlation was that of negative correlation between erodibility and percentage of sand, gravel, and desert pavement coverage. Equation 4 and 5 indicate the importance of gravel and sand as well as their negative effect on soil erodibility. In equation 6 were considered chemical parameters. Based on equation 6, 22% of the soil erodibility changes are controlled by lime and organic matter of the soil.

5. Discussion

Statistical analysis in the study region indicated the positive correlation of erodibility with silt and VFS that supports the findings from Duiker et al., (2001) and Parysow et al., (2003). The positive correlation between silt and erodibility was also suggested in the studies done by Wischmeier and Smith,(1978), Meyer and Harmon, (1994), and Reinks et al.,(1999). Soil erodibility showed negative correlation with lime. The amount of Carbonate is actually recognized as a cemented agent and plays the role of a resistant element against erudition. Ca^{2+}, on the other hand, causes soil colloids to flocculate and increases the resistance against erudition (Duiker, 2001). But in the present study, as far as the soil of the region had coarse texture, reducing the lime couldn't significantly increase erudition. Merzouk and Black,(1991) reported the positive relationship between lime and erodibility and believed that the reason can be instability of large aggregates in the presence of lime with similar size to silt that results in crusting and filling soil cavities. The negative correlation between erodibility and organic matter has been found in the studies done by Martz, (1992), Duiker et al.,(2001) and Feiznia et al.,(2005). Negative correlation of acidity with erodibility does not support Dongsheng et al.,(2006). In acidic soil with pH between 4 to7 the activity of Al^{3+} increases and causes soil separates to flocculate. When pH increases the percentage of saturated Aluminum would decrease and basic cations would increase and this causes soil separates to scatter in the soils with low electrical conductivity (Norton et al., 1999). Wischmeier and Monring, (1969) believed that the relationship between soil pH and erodibility depends on soil structure and amount of silt.

6. Conclusion

One of the main and effective parameters in soil erosion is the natural characteristics of the soil which is erodibility. We can prevent various disadvantages resulting from erosion or reduce them to minimum through better recognition and evaluation. The purpose of the present study is to evaluate the agent of erodibility that qualitatively and quantitatively indicates the natural sensitivity of soil separates to detach and transfer through erodibility parameters and reflects, in fact, the effects of many features and their interaction. In the present study were investigated the effect of land use change and manipulation of desert pavement on soil erodibility. The result indicated that in natural conditions of soil surface pavement plays its protective role and land use change and mixing the soil would neutralize the effect of pavement. We concluded that soil erodibility in manipulated and mixed conditions increases up to 10 times.

Land use change in dry regions with pavement coverage increases the erodibility and intensifies water erosion. Water erosion can, in turn, transfer the load of sediment to coalescing pediment and concealed pediment plains and as far wind velocity is higher in middle of the plain, appropriate ground would be prepared for the wind erosion. The results prove the importance of taking care of desert pavement as a natural protective factor. Human manipulation can result in irreparable damages in dry regions that have erosion potential. Desert pavement in such regions can considerably reduces the erodibility of the soil and makes it resistant against erosion. Increasing the percentage of surface gravel would decrease soil erodibility. The reason is that surface gravel and stone prevent the soil from direct impacts of rain drops. Statistical analysis in Khezrabad-Allahabad longitudinal section indicated positive correlation of erodibility with silt and VFS. Infiltration, percentage of organic matters, lime, gravel and sand have negative relation with erodibility. The effect of organic matter in reducing erodibility of the soil is due to its role in creation of aggregates and their stability. But in the present study, as we mentioned before, as far as the soil of the region has coarse texture, reduction of lime couldn't considerably change the texture and increase the erodibility of the soil. The results from ANOVA test also indicated that there is no significant difference among three parameters of ECe, pH, and SAR in bare pediment, coalescing pediment, and concealed pediment plains. The reason is that erodibility is a factor that largely depends on surface parameters of the soil and that's why all the salts in the soil surface have been leached.

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References

Charman, P.E.V., and Murphy, B.W. 2000. "Soils (their properties and management)". Second edition, Land and Water Conservation, New South Wales, Oxford. Pp : 206-212.

Dongsheng, Y., Xuezheng, S., and Weindorf, D.C., 2006. Relationships In Subtropical China, Soil Science Society of China, 16(3): 304-311.

Duiker, S.W., Flanagan, D.C. and Lal, R. 2001." Erodibility and infiltration characteristics of five major soils of southwest Spain". Catena 45: 103-121.

Ekwue, E.I. 1990. " Effect of Organic Mater on Splash Detachment and the Processes in Volved Earth Surf. Process. Land, 15: 175-181.

Feyznia, S. khajeh, M. and Ghayumian, V.J. 2005. "The study of the effect of physical, chemical, and climate factors on surface erosion sediment yield of loess soils (Case study in Golestan province)". in Natural Resources J, 66: 14-24.

Ghaderi, N., and J. Ghoddosi. 2005. "Study of soil erodibility in lands units from Telvarchai watershed". Proceedings of the Third National Conference of Erosion & Sediment (In Persian). Tehran. Iran. Pp: 367-372.

Ghasemi, A., and J. Mohammadi. 2003." Study of spatial variation of soil erodibility, A case study in Cheghakhor watershed in Chaharmahal-e-Bakhtiyari province". Proceeding of the Eighth Soil Science Congress of Iran (In Persian). Rasht. Iran. Pp : 864-865.

Ghenge, K.L. and Bray, R.H. 1951. " Determination of Calcium and Magnesium in soil and plant material". Soil Sci. 72: 449-458.

Ghorbani vagheie, H. and Bahrami, H.A. 2005. " Spatial changes of USLE and RUSLE soil erodibility index using GIS case study: North East of Lorestan province" .Proceedings of the Third National

Conference of Erosion & Sediment (In Persian). Tehran. Iran.
Goh, T.B., Arnaud, R.J.St. and Mermut, A.R. 1993." Aggregate Stability to Water". In : Cartner, M.R.(Ed.), Soil sampling and methods.
Gupta, O.P. 2002." Water in relation to soils and plants". Agrobios, India. Pp : 31-34.
Klut, A. 1986." Methods of Soil Analysis" Part : I. Physical and Mineralogical Methods. 2^{nd} Ed. Soil. Sci Soc. Am. J. 1188 PP.
Loch, R.J., Slater, B.K. and Devoil, C., 1998. "Soil erodibility (Km) values for som Australian soils", Aust. J. Soil Res., Vol. 36, Pp : 1045-1055.
Martz, L.W., 1992. The Variation of Soil Erodibility With Slope Position in a Cultivated Canadian Prairie Landscape. Earth Surf. Process. Landf. 17: 543-556.
Mccormack, D.E., K.K.Young, and G.M. Darby,1984. "Rock fragments and the k factor of the universal soil loss equation, Erosion and Productivity of soils Cantaining Rock Fragments", 73-81P.
Merzouk, A. and Blake, G.R., 1991." Indices for the Estimation of Interill Erodibility of Moroccan Soils". Catena, 18: 537-550.
Meyer, L.D. and Harmon, W.C. 1994. " Susceptibility of agricultureal Soil to Interrill Erosion, Soil. Sci.Soc. Am. J, 48: 1152- 1157.
Miller, R.W., and Donahue, R.L., 1990. "Soils: An introduction to soils and plant growth", Prentice- Hall Internasional, P:454.
Norton, D., Shainberg, I., Cihacek, L. and Edwards, J.H., 1999. Erosion and Soil Chemical Properties, Soil Water Conservation Society, pp 39-56.
Parysow, P., Wang, G., Gertner, G. and Anderson, A.B., 2003."Spatial uncertainly analysis for mapping soil erodibility based on joint sequential simulation", Catena., Vol. 736, Pp. 1-14.
Rienks, S.M., Botha, G.A. and Hughes, J.C., 1999. "Some Physical and Chemical Properties of Sediments Exposed in a Gully (Donga) in Northern KwaZulu-Natal, South Africa and Their Relationship to the Erodibility of the Colluvial Layers". Catena, 39: 11-31.
Santos, F.L, Reis, J.L., Martins, O.C., Castanheria, N.L., and Serralherio, R.P. 2003. "Comparative assessment of infiltration, runoff and erosion of Sprinkler irrigation soils". Bio.Syst. Eng, 86(3) : 355-364.
Santos, F.L, Reis, J.L., Martins, O.C., Castanheria, N.L., and Serralherio, R.P. 2003. "Comparative assessment of infiltration, runoff and erosion of Sprinkler irrigation soils". Bio.Syst. Eng, 86(3) : 355-364.
Tanji, K. K. (ed.).1994. "Agriculture salinity assessment and management". American Society of Civil Engineers, 199.
Vaezi, A.R., Bahrami, H.A. Sadeghi, H.R., and Mahdian, M.H. 2007. " Study of factors affecting erodibility based on the universal soil loss equation in calcareous soils" 4^{nd} Ed . Agricultural Science and natural Resources Vol. 14(5), Dec2007- Jan2008.
Wischmeier, W.H. and Mannering, J.V., 1969. "Relation of soil properties to its erodibility", Soil Sci. Soc. Am. Proc., Vol. 33, Pp: 131-136.
Wischmeier, W.H. and Smith, D.D. 1978." Predicting rainfall erosion losses : a guide to conservation planning". Agriculture Handbook NO. 537. US Department of Agriculture, Washington DC., pp. 13-27.
Zhang, K., Li, S., Peng, W., and Yu, B. 2004." Erodibility of agricultural soils and loess plateau of china". Soil. Till. Res, 76 : 157-165.