Water Quality and Sediment Behaviour of the Future: Predictions for the 21st Century (Proceedings of Symposium HS2005 at IUGG2007, Perugia, July 2007). IAHS Publ. 314, 2007.

The effect of parent material and land-use on soil erosion: a case study of the Taleghan drainage basin, Iran

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Abstract The objective of this study was to investigate the effect of parent rock and different land-uses on soil erosion in the Taleghan drainage basin. For this purpose, a geological map of the area was prepared by photogeological studies and field control. Soil profiles were investigated and soil samples were taken on uniform morphological units of each lithological unit. Samples were then analysed for physical and chemical characteristics. Based on physical and chemical characteristics, they were classified and analysed using factor analysis. Three parent materials, including gypsum, alluvial deposits, and basalt, and three land-uses, including rangeland, agriculture and dry-farming cultivation were examined, and soil erodibility factors were derived for each and analysed by variance analysis. The results show that erodibility increases as lithology changes from basalt to alluvial deposits and to gypsum. Erodibility was also highest in areas of dry farming and least for rangelands.

Key words erodibility; factor analysis; Iran; land-use; parent material

INTRODUCTION

Almost all kinds of soils in Iran are eroding, and damage due to soil erosion is significant. Therefore, combating erosion in areas of different land-use is essential and the determination of the principal factors causing erosion is urgently needed. The most important factors related to soil erosion are parent rock, land-use and slope. Ozdemir *et al.* (1998) found that the soils formed on limestones are less erodible than the soils on basalts. Sfar Felfowl *et al.* (1999) concluded that the lithological characteristics of drainage basins are the most important factor effecting erosion, especially gully erosion. Soils developed on different parent rocks are different and soil characteristics depend on parent-rock characteristics. Pellek (1989) studied the morphological, chemical, mineralogical and textural characteristics of soils developed on intermediate tuffs and the time needed for formation of a particular depth of soil. This research showed that the pH of this soil is neutral and EC was low. Feiznia & Jafari (2002) studied the pedology of the Taleghan region Iran using geological methods, and they concluded that soil characteristics are dependent on chemical and physical characteristics of parent rocks.

There is a mutual relationship between soil erosion and parent rocks based on land-use type. Ozdemir & Ashkin (2003), in investigating the effect of parent rock and land-use on soil erodibility, concluded that erodibility of soils on gypsum, alluvium, andesite and basalt parent rock was affected by the type of agricultural land including grass, clover and maize. Land-use, depending on the diversity of vegetation and management practices and especially in agricultural areas, has an effect on the physical and chemical characteristics of soils (Roxo *et al.*, 1996).

Different techniques and tests have been used to determine the resistance of soil to erosion, which have involved the derivation of a soil erodibility factor (Wischmeier & Smith, 1978; Lal, 1988), the use of the ratio of percentage of dispersed soil aggregates to percentage of soil aggregates (Bryan, 1968; Lal 1988), and the investigation of the relationship of such indices to soil characteristics (Douglas & Goss 1982; Fullen *et al.*, 1993).

The present study focuses on the physical and chemical characteristics of soils and evaluates the effect of parent material and land-use on soil erodibility.

MATERIAL AND METHODS

Study area

The study area is the Taleghan drainage basin, which is located between longitude 50°20′–51°10′E and latitude 36°5′–36°23′N in the southern Alborz Mountains, 90 km northwest of Tehran, Iran (Fig. 1). The Taleghan River, which is the main drainage of the area, originates in the Asalak Mountain Ranges and after combining with some tributaries, flows into the Taleghan Dam Reservoir. There are five main fault lines in the area (Taleghan, Kandevan, Haranj, Hasanjoun and Hilehrood faults), and rocks of

Fig. 1 Location map of the study area.

varying lithology, ranging in age from Pre-Cambrian to Quaternary formations, out crop in the drainage basin.

Sampling and soil analyses

Lithological units of the Taleghan basin were defined by photogeological and field investigations. Forty-six soil profiles were sampled in lithological units with similar geomorphological characteristics. For each sample, the main soil properties comprising grain size (percentage of clay, silt and sand), percentage of $CaCO_3$, pH, electrical conductivity and organic matter percentage were determined. Factor analysis was then used to identify the most important and effective parameters influencing soil characteristics.

To investigate the effect of land-use and lithology on soil erodibility, nine soil samples from the surface horizon (0–20 centimetre depth), in three replications and based on three different kinds of land-use (agriculture, dry-farming cultivation and rangeland), were taken for determination of the *K* factor in the USLE.

Soil erodibility index and statistical analyses

The soil erodibility factor (*K*) in the USLE was calculated using the equation of Wischmeier & Smith (1978):

$$K = [(2.1 \times 10^{-4} (M)^{1.14}(12 - a) + 3.25(b - 2) + 2.5(c - 3)) \, 1.292]/100 \qquad (1)$$

where M is the particle size parameter: (% silt + very fine sand) × (100 – % clay), a is the percentage of organic matter, b is the soil structure code, and c is the profile permeability class.

Statistical analysis was carried out using SPSS v. 10.0 software (SPSS Inc., 1999). Data were tested for normality (Kolmogorov-Smirnov test) and homogeneity of variance (Levene test) before undertaking statistical analyses, and were transformed using arcsine $\sqrt{\%}$ as necessary. Statistical analyses included a two-way ANOVA (F-test) and the Tukey HSD post-hoc test.

RESULTS AND DISCUSSION

The results of the factor analyses are presented in Table 1 and show that two principal components, with Eigenvalues greater than 1, account for 74.4% of the variance in the data. The first component, with an initial Eigenvalue of 3.8, explained 54.3% of variance, and a second factor with an initial Eigenvalue of 1.43, explained 20.4% of variance. The results of applying a Varimax rotation are presented in Table 2 and suggest the first component is related to particle size, i.e. the percentage of sand, and the second component is related to the percentage of organic matter. This analysis suggests that sand percentage and organic matter percentage are the most important factors determining soil characteristics in the Taleghan basin.

Table 1 Total variance of explained values of physical and chemical characteristics of soils.

Components	Initial Eigenvalues:		
	Total	% of Variance	Cumulative %
1	3.8	54.3	54.3
2	1.43	20.4	74.7
3	0.91		
4	0.51		
5	0.22		
6	0.11		
7	0.009		

Extraction method: Principal Component Analysis (PCA).

Table 2 Rotated component matrix.

Variables	Components:	
	1	2
Clay	0.8	–0.496
Silt	0.9	0.33
Sand	0.95	0.26
pH	0.68	0.06
EC	0.2	–0.59
%CaCo3	0.86	–0.24
%OM	0.49	0.9

Rotation method: Varimax, Extraction method: Principal Component Analysis (PCA).

Table 3 Variance analysis results of the effect of parent material and land-use on the soil erodibility factor.

Source	F	Significant value
Parent material (PM)	2382.9	0.000*
Land-use (LU)	239.5	0.000*
PM × LU	12.5	0.000*

* p value < 0.005.

Table 4 The effect of parent material and land-use on soil erodibility (in three replicates, mean ± SD).

Land-use	Parent material (lithological group):		
	Gypsum	Alluvial	Basalt
Dry-land farming	0.973±0.0036 a	0.627±0.043 a	0.425±0.0064 a
Agriculture	0.936±0.0045 b	0.549±0.029 b	0.261±0.008 b
Range	0.796±0.005 ab	0.479±0.013 ab	0.61±0.041 ab

The means with different letters in each column are significantly different at the 1% level based on the HSD test.

The results relating to the soil erodibility factor (K) suggest that gypsum lithologies are most erodible, followed by alluvial sediments and then basalt lithologies, while erodibility decreases from dry-land farming to agriculture and to rangeland-uses. The variance analysis of the effect of parent material and land-uses on the *K* factor, separately and in combination at the 1% level, is shown in Table 3, while Table 4 presents mean *K* values based on the effect of parent rock and land-use in three replicate and pair comparisons according to the Tukey-HSD test.

CONCLUSION

In the Taleghan drainage basin, different lithological units consisting of sedimentary rocks (limestone, shale, mudstone, marl, conglomerate and gypsum), igneous rocks (basalt, andesite, tuff and agglomerate) and Quaternary deposits (landslip, gravel, alluvial fan and alluvium) are present. Soil characteristics are related to chemical and physical characteristics of parent rocks.

Parent rock and the type of land-use are very important factors in soil formation in different regions, and by using lithological and land-use maps and field surveys, their mutual effects may be investigated. According to the results of factor analysis, the percentage of sand as a physical characteristic and the percentage of organic matter as a chemical characteristic are the most important factors of the studied soils. These two factors are the most effective factors in soil erodibility.

The *K* factor of the USLE method is related to soil structure, organic matter percentage and soil hydraulic conductivity. As *K* decreases, so does erodibility (Wischmeier & Smith, 1978). In addition, the type of land-use, especially soil surface cover, influences the *K* factor. Tukey-HSD pair comparisons have shown that in three parent materials of the Taleghan drainage basin, paired means are significantly different at the 1% level ($p < 0.005$). Also, in the study area the means for land-use types are significantly different at the 1% level ($p < 0.005$).

The consideration of the mutual effects of parent material and land-use variables indicates the combination of gypsum lithology with dry-land farming gives rise to the most erodible conditions, alluvial deposits with agriculture land-use is associated with medium erodibility, and basalt with rangeland is the least erodible combination.

Therefore, in the Taleghan basin, parent material of soils and land-uses can be used to index soil erodibility, and this approach may be applicable in other regions.

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