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Soil erosion status in Iran and clay minerals influence on soils interrill erodibility factor (a case study: Dasht-e-Tabriz)

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Abstract

Based on some estimation soil erosion in Iran is widespread problem (70% of the country) and susceptibility of the soils to erosion is mostly due to low organic matter, clay percentage, kind of clay, etc) and mismanagement of land has accelerated. For this reason, real estimation of different kind of clay influence on soils interrill erodibility factor is required for sustainable management. Clay with a wide variety of physical properties plays an important role in the soils and their erodibility. In order to investigate the effect of clay minerals on soil erodibility, this research work carried out on surface layer samples of eleven soil series with different families. After mineralogical analysis, the type and relative amount of clay minerals in each soil were determined based on qualitative and semi-quantitative methods. According to Pearson correlation coefficient, there is positive and significant correlation between soil erodibility and smectite groups, while quartz, kaolinite- chlorite and chlorite-vermiculite showed negative and significant correlation whit erodibility. Consequently there is a linear correlation $(k_i = 735323.79 + 45427.913\ \text{Smectite} \quad R = 0.76)$ between erodiblity and minerals based on stepwise multiple regressions in these soils. Also there is between clay, sand, saturation percentage, SAR and erodibility significant correlation ($P<0.01$) while silt, $CaCO_3$ and pH show lower one ($P<0.05$).

Key words: Minerals, Erodibility, Semi-quantitative , Correlation coefficient, Dashte-e-Tabriz

Introduction

Land degradation, in the form of soil erosion and nutrient depletion threaten food security and the sustainability of agricultural production in many developing countries. It is also estimated that more than 70% of the total area in Iran is exposed to soil erosion which gives a total amount of 1 to 2 billion cubic meters sediment per year and is increased by l0 tons/hectares/ year in comparison of the last l0 years. The susceptibility of the soils to erosion is mostly due to low organic matter, clay percentage, kind of clay, etc) and mismanagement of land has accelerated. Therefore survey of the present state and its accelerated factors are important for development of the country. One of the most important factors is soil erodibility, which affected by texture, structure, organic matter, infiltration rate, content and type of clay minerals in soils (Wischmeier and Smith, 1978). Lado and Ben-Hur (2004) reported that soil mineralogy, has substantial effects on clay dispersion and also influence aggregate stability, runoff, seal formation and soil loss. The mineralogical compositions of soils have a particular influence on the erodibility of soils in dry climatic conditions (Reichert and Norton, 1994). Imeson et al. (1982) believe that in marly lands area in which physical and mineralogical properties are the main factors controlling the shape and form of erosion. Stern et al. (1991) concluded that soil mineralogy has important effect on aggregate stability and capability of soil in seal formation. Singer (1994) reported decreasing aggregate stabilities with increasing smectite and inversely with kaolinite content. Wakindiki and Ben-Hur (2002) believed the soils contains smectite in contrast the soils contains kaolinite have more susceptible to water erosion. Romkesn et al. (1995) found that the presence of highly expansive smectite clay in the soil caused a rapid reduction in infiltration rate despite the high organic matter contents and coarse texture of the soil; this indicated the importance of soil mineralogical constituents for crust development. The results obtained by researches in Iran (Khormali & Abtahi, 2003; Abbaslou and Kormali, 2007; Rezapour et al., 2009) revealed the occurrence of kaolinite, chlorite, illite, palygorskite, smectite, quartz and interstratified minerals which are the dominant clay minerals in both soil and rock samples. The presence of illite, chlorite abundance could be attributed to the parent rock samples and inherited origin. Interstratified minerals of chlorite-smectite or illite-smectite are observed in clay fraction of soils.The soil available moisture plays the major role in the distribution pattern of palygorskite and smectite clay minerals in arid and semiarid areas. Also the occurrence vermiculate in the calcareous soils is mainly related to its lower stability under high pH, low Al activity and the presence of large amounts of Si and Mg in soils. According to many researchers results, such as Elliot et al. (1989) increased clay content lead to increased aggregate stability and decreased erosion, but Ahmadi (2010) in his research found the positive correlation between interrill erodibility and clay content and also Udeigwe et al. (2007) reached to the similar results, they expressed it may be difference of clay mineralogy. However clay mineralogy in comparing with other features has got less attention. The objective of present study is not only identification of different species of clay minerals, but also determines their effect and correlation with soil interrill erodibility factor in the study area.

Material and Methods

The study was carried out on soils of Dasht-e-Tabriz area (~ 92,600 ha) in the north west of Iran, which has located between 45° 28' to 46° 14' E longitude and 37° 56' to 38° 17' N latitude in East Azerbaijan Province. The area mainly characterized by the diversity of different materials, such as marl, gypsum, and salts with high erodibility and special effect on soil quality and water sources. The present climate of region is a Mediterranean type, with hot dry summers, cold and wet winters and temperate autumn and spring with highly seasonal precipitation. The average annual precipitation is 328 mm, with mean minimum and maximum temperate of -1.9ºC and 25.1ºC respectively. Also according to Newhall software results the soil moisture and temperature regimes of the region are Xeric border to Aridic (weak aridic) and Mesic. Soils were selected based on different series used by Ahmadi (2010) research in the region (Table 1). Samples from surface horizons (A or Ap) of 11 series were selected and analyzed for physicochemical properties and clay mineralogy. The practical size distribution was determined by the hydrometer method (Klute, 1992), organic matter (Walkey and Black, 1934), CCE (Nelson, 1982), CEC (chapman, 1965), gypsum (Bower, 1982; Soil Conservation Service, 1992), and soil pH and EC were determined in saturated paste and saturated extract respectively.

For mineralogical analysis clays separation was achieved by sedimentation of dispersed soil materials. Prior to mineralogical analysis, samples (<2mm) were treated with 1 M sodium acetate and buffered at pH 5 to remove carbonate. The H_2O_2 (30%) and Na-dithionite-citrate-bicarbonate were used to oxidize organic matter and remove Fe oxides, respectively (Kunz, 1986; Mehra and Jackson, 1960). Sand was separated from silt and clay by wet sieving and clay by centrifugation and decantation. The <2 µm fraction was treated with Mg- saturation, Mg-saturation plus gleyserol-saturation, K-saturation and K-saturation and heating at 550ºC. X-ray diffraction (XRD) patterns of oriented clay were obtained using a Ziemens 1D-500 diffract meter employing a Ni-filtered Cu- Kα source. Samples were scanned from 2 to 30º 2θ, at a scan speed of 2º 2θ/ min with a 2 s time constant.

Statistical analysis of the experimental data was accomplished using the SPSS software package (SPSS Inc., 2007). Also normality analysis of the data distribution using Kolmogorov-Smirnov test and correlation analysis by Pearson correlation coefficient were carried out.

Results and Discussion

The studied soil series (Table 1) were all calcareous with a relatively large clay content, in the range of 11- 50.2 %, which led to considerable variability in soil characteristics, especially, clay minerals (Table. 2 and figures 1-11). The XRD data for clay fractions of the studied soils showed (figures 1-11) that the clay minerals species were mainly illite, smectite, quartz, cholorite and kaolinite. Their relative abundance differences (Table.3) reflecting dynamic and variable soil environments with their properties. Smectite is characterized by the d value of 18 Aº in the glycerol-treated samples. The 10 Aº peak in the Mg-treated samples showed the presences of illite. The 14 and 3.3 Aº peaks that was unchanged by any treatments identified chlorite and quartz respectively and the presence of kaolinite was characterized by disappearance of the 7.0 Aº peak for the K-550ºC treatment.

According to the X-ray diffraction results and relative amounts of minerals from semi-quantitative analysis with their interrill erodibility factor (Ki) estimated by Ahmadi (2010), in soils with high erodibility rate, smectite minerals are dominant in comparison with soils that have low erodibility rate with dominant minerals of quartz, kaolinite and chlorite (Table 4).

Normalizing the data by the Kolmogorov-Smirnov test, for Pearson correlation coefficient, showed significant correlation between clay minerals and interrill erodibilty factor (Table. 5). Based on obtained results, smectite has positive and significant correlation while quartz has negative and significant correlation with interrill erodibility factor ($P< 0.01$), which confirm other researches (Romkens et al. 1995; Mermut, 1997) results about positive and significant effect of smectite and negative effect of quartz (Bain, 1977).

Table 1. The series and families of studied soil

Soil Series	Family
Aji Chay	Fine loamy, mixed, superactive, calcareous, mesic, Xeric Torrifluvents
Sofian	Fine, mixed, semiavtive, mesic, Xeric Haplocambids
Baranlo	Fine, mixed, mesic, Xeric Haplocambids
Koja Abad	Fine, mixed, active, calcareous, mesic, Xeric Torrifluvents
GHaramolk	Fine, mixed, mesic, Xeric Natrargids
Zeynab	Coarse loamy, mixed, calcareous, mesic, Xeric Torriorthents
SHabestatar	Coarse loamy over sandy skeletal, mixed, calcareous, mesic, Xeric Torriorthens
Satelo	Clayey over sandy, mixed, super active, calcareous, mesic, Xeric Torrifluvent
Tazeh Kand	Fine loamy, mixed, active, calcareous, mesic, Xeric Torriorthents
SHand Abad	Fine loamy, mixed, calcareous, mesic, Xeric Torrifluvents
Kozeh Kanan	Coarse loamy, mixed, active, calcareous, mesic, Xeric Torriorthents

Table 2. The physical and chemical properties of studied soils

Soil series	depth cm	Sand (%)	Silt (%)	Clay (%)	Texture class	SP (%)	EC (dS m^{-1})	pH	OM (%)	$CaCO_3$ (%)	Gypsum (%)	SAR	CEC (cmolc (+)/kg)
Aji Chay	0-30	29.6	44.8	25.6	L	52.4	1.7	7.9	2.42	25.7	0.2	7.8	22.4
Sofian	0-25	6.5	47.5	46	SiC	67.5	0.9	7.8	1.38	18.5	0.2	5.3	43.1
Baranlo	0-23	9.2	40.6	50.2	C	69.08	8.18	7.99	0.72	21.3	0.03	34.72	25.6
Koja Abad	0-25	23.2	41.6	35.2	CL	44	1	8	1.56	14.9	0.1	6.7	18
Gharamolk	0-25	26.7	41.5	31.9	CL	36.37	1.35	7.95	0.67	18.4	0.21	4.75	17.5
Zeynab	0-25	64	25.1	11	SL	24	2.3	7.9	2.9	12.4	0.2	3.2	14.8
Shabestatar	0-25	46.5	32.5	21	L	29.9	4.7	7.5	1.56	12.5	0.1	1.3	16.5
Satelo	0-20	13.5	48.1	38.4	SiCL	57	8.6	7.8	0.8	20.0	-	22.5	21.5
Tazeh Kand	0-30	59.7	24.6	15.7	SL	24.5	1.8	7.7	3.64	10.7	0.2	2	17.8
Shand Abad	0-25	47.8	29.8	22.4	L	25.85	1.72	7.79	1.02	12.6	0.13	5.49	20.7
KozehKanan	0-30	37.8	42.8	19.6	L	23.07	2.18	7.83	0.95	20.1	0.21	4.82	15.3

L: Loamy, C: Clay, SiC: Silty clay, CL: Clay loam, SL: Sandy loam, SiCL: Silty clay loam OM: organic matter, EC: electrical conductivity, CEC: cation exchange capacity, SAR: sodium adsorption ratio

Also mixture of chlorite -vermiculite minerals have a negative and significant correlation whit interrill erodibility factor ($P<0.05$), while chlorite, vermiculite and kaolinite have low dispersion capability (Van Olphen, 1977). Therefore the results show a linear correlation ($k_i = 735323.79 + 45427.913\ \mathrm{Smectite}, R^2 = 0.76$) between interrill erodibility factor and minerals species with respect to Stepwise multiple regressions. A wide variation in soil physiochemical properties and clay minerals corresponding to variation in their interrill erodibility factors (Table 6). Pearson correlation coefficient between SAR, SP and clay content with interrill erodibility factors showed a positive and significant correlation ($P<0.01$) which confirm Udeigwe et al. (2007), Ahmadi (2010) results and Williams et al. (1983) idea about presence of plentiful expansible (2:1) clay minerals with high tendency for moisture absorption. Also according to finding of levy et al (1995) increasing of SAR cause greater dispersion and soil loss that confirm this study results. There is a negative correlation between Ki and sand ($P<-0.01$) that indicate resistance of sand particle to erosion (Reichert et al. 2009). Based on Gunn et al. (1988) research, with increasing of silt content, erodibility become high which refers to obtained results in soils with large amount of silt in the present study ($P<0.05$). In addition there is a positive and significant correlation between calcium carbonate and soil erodibility ($P<0.05$), which Merzouk and Black (1991) have reported the high relative erodibility of the calcareous soils that partly attribute to the occurrence of $CaCO_3$ in the silt size fraction.

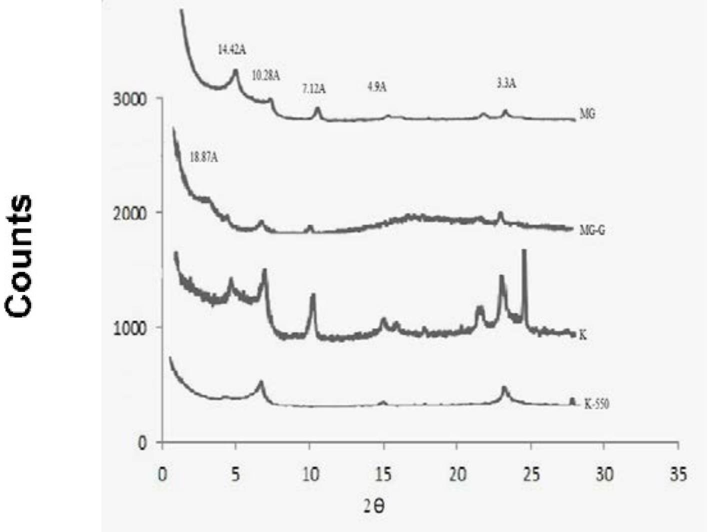

Figure 1. X-ray diffractgram of clay fraction from surface layer of Aji chay soil

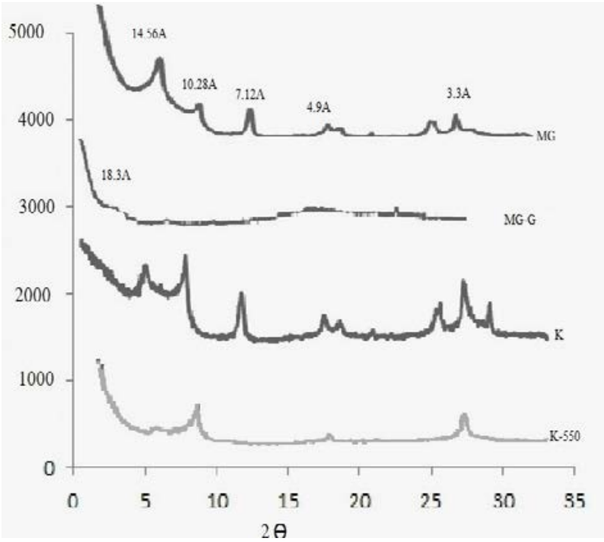

Figure 2. X-ray diffractgram of clay fraction from surface layer of Sofian soil

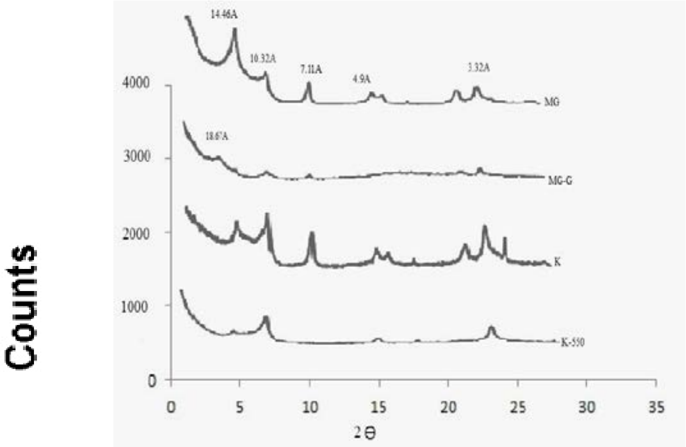

Figure 3. X-ray diffractgram of clay fraction from surface layer of Baranlo soil

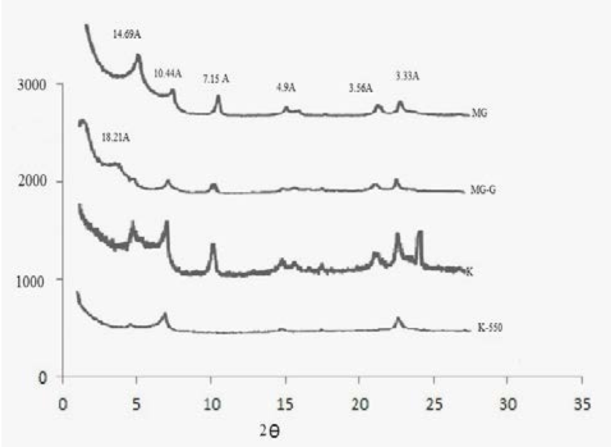

Figure 4. X-ray diffractgram of clay farction from surface layer of Koja abad soil

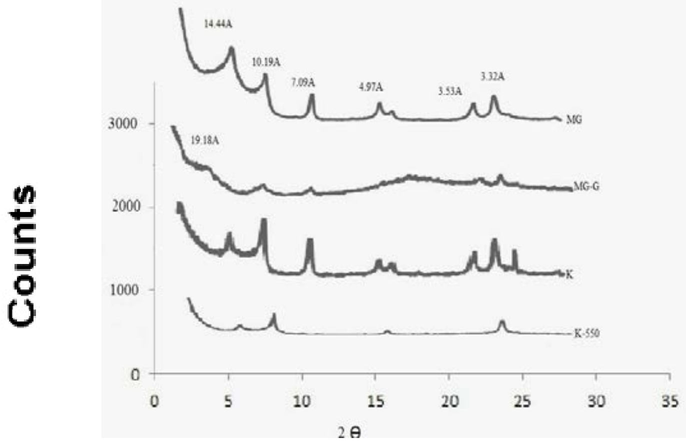

Figure 5. X-ray diffractgram of clay fraction from surface layer of Gharamolk soil

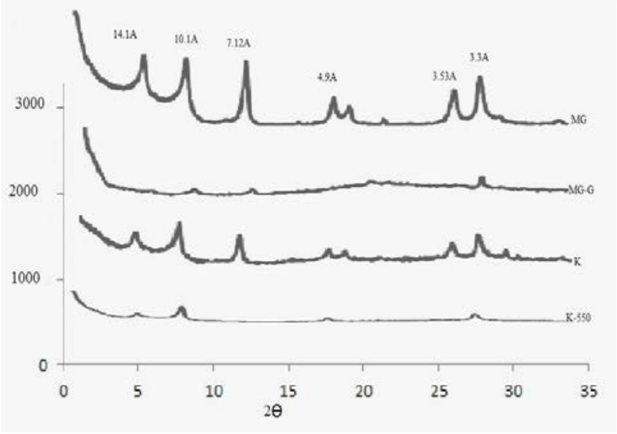

Figure 6. X-ray diffractgram of clay fraction from surface layer of Zeynab soil

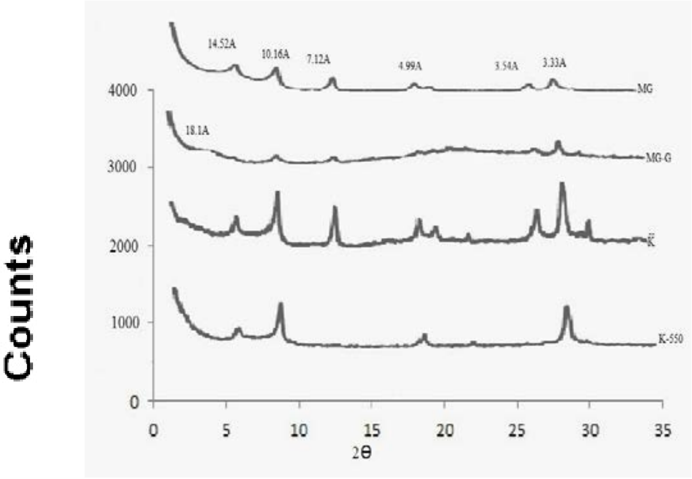

Figure 7. X-ray diffractgram of clay fraction from surface layer of Shabestar soil

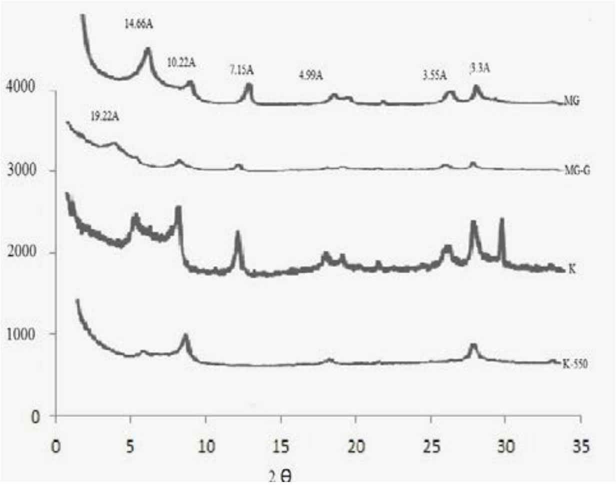

Figure 8. X-ray diffractgram of clay fraction from surface layer of Satelo soil

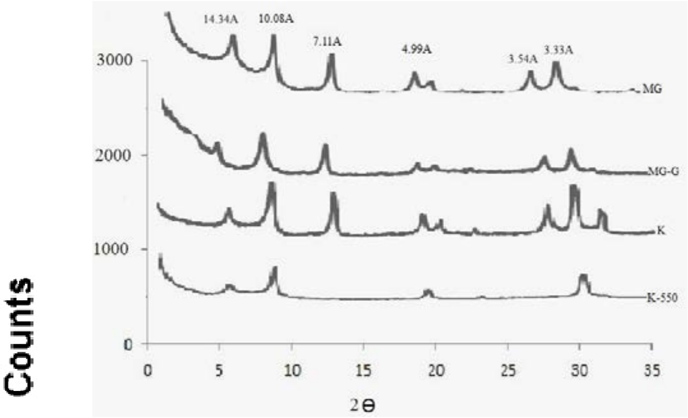

Figure 9. X-ray diffractgram of clay fraction from surface layer of Tazeh kand soil

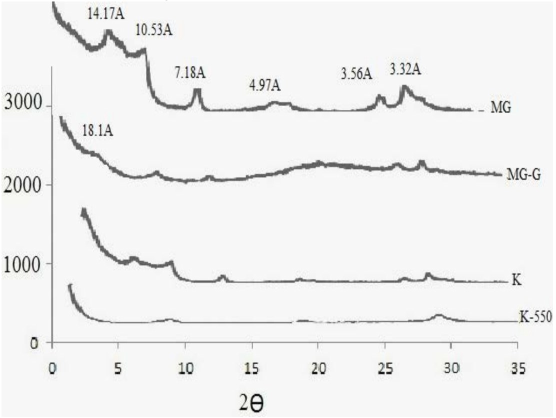

Figure 10. X-ray diffractgram of clay fraction from surface layer of Shand abad soil

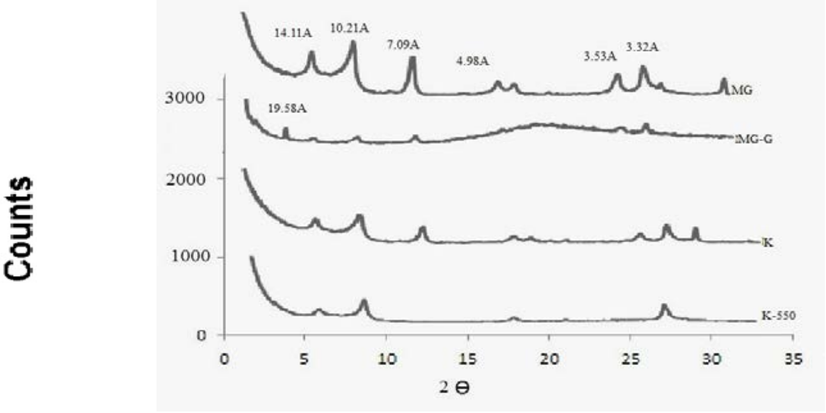

Figure 11. X-ray diffractgram of clay fraction from surface layer of Kozeh kanan soil

Table 3. the relative amounts of clay minerals in clay fraction of soils

Minerals Soil series	IL (%)	Q (%)	Sm (%)	Ka-Ch (%)	Ch-Ver (%)
Aji Chay	35	20	25	15	5
Sofian	55	20	10	10	5
Baranlo	35	15	40	10	-
Koja Abad	35	15	25	20	5
Gharamolk	40	20	30	10	-
Zeynab	30	40	-	20	10
Shabestatar	30	35	15	15	5
Satelo	30	15	40	15	-
Tazeh Kand	40	20	-	25	15
Shand Abad	40	25	10	25	-
KozehKanan	30	20	15	25	10

IL: illite, Sm: smectite, q: quartz, Ka-Ch: Kaolinite-Chlorite, Ch-Ver: chlorite-vermiculite

Table 4. Interrill erodibility factors and dominant clay minerals of soil series

Soil series	Minerals dominant	K_i (kg s m^{-4})	Soil series	Minerals dominant	K_i (kg s m^{-4})
Aji Chay	IL & Sm	1966691.058	Zeynab	Q	615192.1516
Sofian	IL	1540694.87	Shabestatar	Q & IL	8547376.4289
Baranlo	Sm & IL	2984929.921	Satelo	IL & Ka- Ch	865958.8717
Koja Abad	IL & Sm	2412283.384	Tazeh Kand	IL, Ka-Ch & Q	1291248.202
Gharamolk	IL & Sm	1721875.355	Shand Abad	IL & Ka- Ch	1187013.927
Zeynab	Sm & IL	2187799.209			

IL: illite, Sm: smectite, q: quartz, Ka-Ch: Kaolinite-Chlorite, Ch-Ver: chlorite-vermiculite, Ki : interrill erodibility factors

Finally, the results showed a positive and significant correlation between pH and Ki which is probably affected by presence of variable charge minerals and organic matter (Goldberg and Glaubig, 1987).

Conclusion

It is apparent from this study that soils with different relative amount and species of clay minerals and physical, chemical properties exhibit different correlation with soil interrill erodibility factor in all parts of Iran with different kinds of minerals(Khormali and Abtahi, 2003; Abbaslou and Kormali, 2007; Rezapour,et al. 2009). According to obtained results, soils with minerals such as quartz, kaolinate and chlorite are resistance to erodibility and in contrast soils with smectite minerals are susceptible to erosion. Therefore soils with faster infiltration rate, higher level of organic matter, developed soil structure, high sand content and so quartz and kaolinite minerals have a greater resistance to erosion in compression with soils that have higher content of silt, SAR, SP, with smectite minerals.

Table 5. correlation coefficient between clay minerals and erodibility factors (K_i)

Parameters	K_i(kg s m^{-4})	IL	Sm	Ka-Ch	Ch-Ver	Q
IL	0.036					
Sm	0.872**	-0.225				
Ka-Ch	-0.509	-0.297	-0.587			
Ch-Ver	-0.653*	-0.019	-0.706*	0.484		
Q	-0.772**	-0.261	-0.652*	0.188	0.295	

IL: illite, Sm: smectite, q: quartz, Ka-Ch: Kaolinite-Chlorite, Ch-Ver:chlorite-vermiculite, K_i :interrill erodibility factors, * and ** mean significant at the 0.01 and 0.05 level.

Table 6. values correlation coefficient between physicochemical properties and interrill erodibility factor

Parameters	K_i	Clay	Sand	Silt	SP	OM	pH	EC	CEC	SAR
Clay	0.836**									
Sand	-0.824.**	0.955** -								
Silt	0.667*	0.730*	-** 0.899							
SP	0.786**	0.919**	-** 0.926	0.783**						
OM	-0.591	-0.725*	0.764**	-0.692*	-0.553					
pH	0.631*	0.396	-0.402	0.349	0.374	-0.214				
EC	0.454	0.407	-0.356	0.211	0.43	-0.354	-0.077			
CEC	0.39	0.736**	-0.698*	0.529	0.755**	-0.351	0.162	0.016		
SAR	0.799**	0.798*	-0.625*	0.405	0.705*	-0.452	0.407	0.827**	0.203	
$CaCO_3$	0.632*	0.525	-0.692*	0.824**	0.71*	-0.424	-0.083	0.258	0.281	0.504

* and ** mean significant at the 0.01 and 0.05 level

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