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Impacts of land use conversion on soil properties and soil erodibility

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Abstract: *Land use conversion can affect natural ecological processes such as surface runoff and erosion. Therefore, it has potential to change soil stability. To investigate this process in depth, Iskalan creek catchment in the Black sea region, where excessive land use applications and erosion events have often occured, was selected as the study area. The objective was to determine the effects of land use conversion on soil properties, soil erodibility and the relationships among soil properties and some erodibility indices. Duplicate topsoil samples were taken by using steel cylinders at 100 different sampling points from three different land use types; 34 of them are in farmlands, 34 in rangelands and 32 in forestlands. Soil particle size distribution, loss of ignition, pH, electrical conductivity, skeleton percentage and three erodibility indices were determined. Data were analysed by using Pearson correlation analysis (at 95% and 99% significance level), ANOVA and Tukey's test at 95 % significance level. According to study results, land use conversion affects some properties of soils significantly. Loss of ignition of soils in forests was significantly higher than soils in farmlands and rangelands. Soil skeleton percentage in rangelands and farmlands were significantly different. The study results showed that there was significant difference between pH of soils in forests and farmlands (p< 0.05). Pearson correlation analysis results showed significant correlations among erodibility indices and certain soil properties such as clay and sand fraction of soils (p< 0.05 and p< 0.01). Topsoils of the study area were sensitive to erosion according to all three erodibility indices. The most sensitive soils were in farmlands.*

Key words: *Land use conversion, Soil physical properties, Erodibility*
PDF of full length paper is available with author ***(*yasarselma@yahoo.com)***

Introduction

The detrimental effects of humans on natural resources have been not only well documented by scientists but also well understood by societies in recent years. However, destruction of forests and rangelands to obtain farmlands is still a significant problem in many countries around the world. Land use changes affect many natural resources and ecological processes such as surface runoff and erosion and changes soil resilience to environmental impacts (Fu *et al.*, 2000; Hacisalihoglu, 2007). The increasing intensity of land use may cause erosion and soil compaction through changes in soil physical and chemical properties (Qygard *et al.*, 1999; Islam and Weil, 2000; Chen *et al.*, 2001; Caravaca *et al.*, 2002; Celik, 2005; Wang *et al.*, 2006; Misir *et al.,* 2007).

The Black sea region is one of the regions of Turkey where land use conversion and erosion are widespread problems. There is an increasing pressure on forests and rangelands although it is one of the green regions of Turkey. Iskalan creek catchment, representing the typical properties of the region, was selected as the study area.

Knowing soil properties and relationships between these properties it is important to assess erosion and to undertake land use planning. Topsoil properties and erodibility of soils provide very important clues for land use planning. The aim of this study is to determine the impacts of land use conversion on soil properties and to determine relationships between erodibility indices and soil properties.

Materials and Methods

Site description: The study was conducted at Bartin-Iskalan creek watershed in the Black sea region of Turkey, located at N 32°20'39"–E 32°28'32" (Fig. 1). The study area is 5498.5 ha. According to the Thorntwaite method, the climate type is $B^3B'_1r$ b'4, humid, mesothermal, no water deficit and similar to oceanic (Ozyuvaci, 2001). Annual mean temperature is 12.1°C and annual mean precipitation is 1245 mm. Considering vegetation the Western Black sea region is within the Euxine subflora area in Euro-Siberian floristic region. The natural vegetation is broad leaved mixed hardwood forest. The actual land use types are farmlands (1028.42 ha), rangelands (444.74 ha) and forests (4025.34 ha). Mean slope is aproximately 45%. Soil texture ranges from loam to clay and 70.41% of the area is formed noncalcerous brown forest soils. The lithology is flych (conglomerates, sandstones, sandy limestones, claystones and marls) of upper Cretaceous age (Sonel, 1988).

Soil sampling and analysis: Soil samples were collected from topsoils (0-20 cm) using steel cylinders at 100 different sampling points from three land use types: Farmlands, rangelands and forest cover, 18.70%, 8.08% and 73.22% of the total area respectively. In farmlands, wheat and maize have been grown without soil conservation measures. Soils have been cultivated by handle or plow. Farmlands have been converted from forests for a long time (over 80 years). In past, rangelands have been used for farming for years and today (for 10-15 years). They are also used for cattle grazing without soil conservation measures.

Soil samples were taken from three different land use types, three elevations (150-350 m., 350-550 m., and > 550 m.) and two aspects (major aspects of the study area were east and west). There were 34 sampling points in farmlands, 34 in rangelands and 32 in forests; 48 of them on east, 52 of them on west aspects. Two

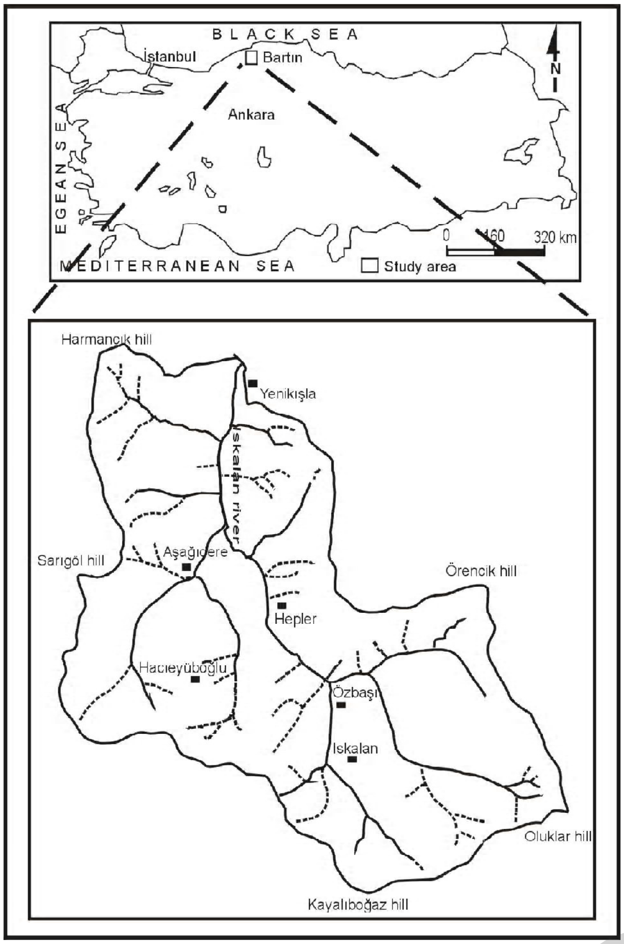

Fig. 1: Location map of the study area

Table - 1: Statistics of selected soil characteristics of the Iskalan watershed

Soil characteristics	Min.	Max.	Mean
Sand (%)	22.31	84.35	44.70
Clay (%)	6.59	60.17	32.00
Silt (%)	7.66	43.77	23.30
Loss of ignition (%)	2.97	19.96	6.08
pH (1:5 H_2O)	4.6	7.8	5.97
Elec. con. (µmhos/cm)	19	1581	92.71
>5mm frac. ratio (%)	0	62.2	12.60
2-5 mm frac. ratio (%)	0	99.61	5.51
<2mm frac. ratio (%)	0.1	99.29	81.70
Root ratio (%)	0	1.68	0.19
Dispersion ratio (%)	7.2	76.6	28.83
Coll moist eq. ratio	0.03	2.01	1.02
Erosion ratio	0.22	122.29	30.51

sets of soil samples (soil core samples and disturbed soil samples) were taken from each point. The sampling points were chosen adjacent to different land use types (farmland, rangeland and forest). Area 4982.80 ha had steep slopes. Therefore, soil sampling was done on approximately 40 % slopes. Samples collected from topsoils were air dried and passed through a < 2 mm sieve. The < 2 mm. fine earth fractions of the disturbed samples were used to determine loss of ignition, particle size distribution, pH, electrical conductivity and erosion indices. Undisturbed soil core samples were used to determine the soil skeleton. Loss of ignition was determined after ignition at 600°C and expressed as a percentage of oven dry soil mass. Particle size distrubition was determined by using the hydrometer method (Gulcur, 1974). Hydrogen ion concentration (pH) and electrical conductivity were determined in water (1:5 H_2O) on air-dried soil by using Multiline FSet-3 glass electrode. For skeleton content of soil, soil samples from the volumetric cyclinders were air-dried, sieved to a diameter of > 5 mm, 2-5 mm, < 2 mm and root fragments removed and weighed. Skeleton content of soils, fine fractions and root ratio were calculated as percentage of total weight (Ozyuvaci, 1976). Dispersion ratio was determined by dividing undispersed (silt+clay) percentage to dispersed (silt+clay) percentage (Middleton, 1930). Colloid- moisture equivalent ratio was determined by dividing clay percentage to moisture capacity of the soil samples (Baver, 1956). Erosion ratio was determined by dividing dispersion ratio to colloid- moisture equivalent ratio (Balci, 1996). Data were evaluated by using Pearson correlation analysis (at 95% and 99% significance level), ANOVA and the Tukey's test at 95% significance level (Zar, 1996).

Results and Discussion

General soil properties: Minimum, maximum and mean values of selected soil properties of the Iskalan watershed are shown in Table 1. Topsoil textures ranged from loam to clay. Loss of ignition representing a low amount of organic matter (3-20%) was moderately high. Soil pH ranged from (pH 4.6-7.8). Electrical conductivity of soil was mostly low indicating a low possibility of a salinity problem. Generally < 2 mm. fraction ratio of soil was high and soil skeleton was lower. According to three erodibility indices soils were very prone to erosion (Table 1).

Correlation between soil properties and erosion indices: Erodibility expresses the degree of soil resistance to erosion originating from its own characteristics (Balci, 1996). Evaluation of soil sensitivity to erosion and surface runoff by field observations is slow and costly. For this reason soil erodibility is commonly determined in the laboratory (Brunner *et al.*, 2004). In this study, erodibility was evaluated, according to dispersion ratio (D.R.), erosion ratio (E.R.) and colloid-moisture equivalent ratio (C.R.). An evaluation made for erodibility indices showed generally that, dispersion ratio was >15, erosion ratio was >10 and colloid-moisture equivalent ratio was < 1.5 (Balci, 1996). These values show that the soils in the study area are sensitive to erosion. Erodibility of the soils depends on some soil properties. Therefore Pearson correlation analysis was made to determine which soil properties affected soil erodibility. The Pearson correlation analysis results showed significant correlations among erodibility indices and soil properties (Table 2, 3 and 4).

According to evaluation made for different land use types for dispersion ratio. In farmlands, when sand, silt and 2-5 mm. fractions of soils increased, dispersion ratio increases, too. However, increasing clay fractions of the soils caused a decrease in dispersion ratio. For colloid-moisture equivalent ratio, when clay fraction of the soils increased, erodibility decreased. However, when sand, silt and pH of the soils increased, erodibility also increased. According

Table - 2: Pearson correlations between selected soil properties in farmlands

Correlation	L.O. I	Sand (%)	Clay (%)	Silt (%)	pH	E.C.	>5mm (%)	2-5 mm (%)	<2mm (%)	Root (%)	D.R.	C.R.
D.R.	0.041	0.423*	-0.553**	0.316	0.324	0.485**	-0.086	0.053	0.044	0.02	1	
C.R.	-0.185	-0.397*	0.568**	-0.402*	-0.35**	-0.208	0.204	-0.2	-0.07	0.087	-0.631**	1
E.R.	0.105	0.504**	-0.633**	0.321	0.23	0.328	-0.324	0.05	0.232	-0.031	0.814**	-0.686**

*Significant at the p<0.05 level (2-tailed), **Significant at the p< 0.01 level (2-tailed), D.R. = Dispersion ratio, C.R. = Col./Moi. Eq. ratio , E.R. = Erosion ratio

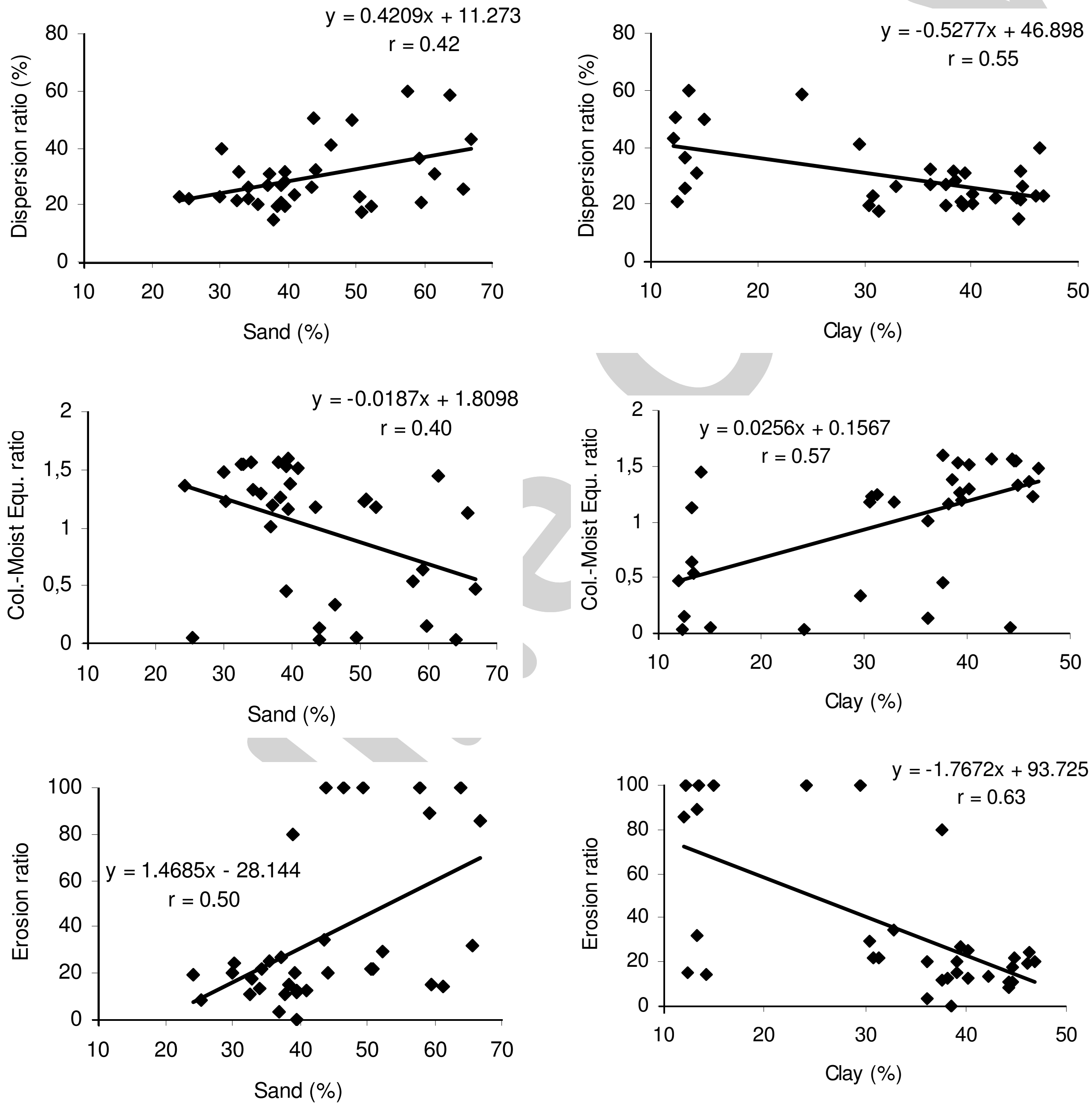

Fig. 2: Relationships between sand, clay content of soils and erodibility indices in farmlands

Table- 3: Pearson correlations between selected soil properties in rangelands

Correlation	L.O. I	Sand (%)	Clay (%)	Silt (%)	pH	EC	>5 mm (%)	2-5 mm (%)	<2 mm (%)	Root (%)	D.R.	C.R.
D.R.	0.178	0.265	-0.368*	0.221	0.068	-0.083	-0.222	0.368*	0.103	0.015	1	
C.R.	-0.379*	-0.499**	0.629**	-0.301	-0.068	0.014	-0.051	-0.084	0.075	-0.086	-0.148	1
E.R.	0.415*	0.431*	-0.562**	0.398*	0.189	0.101	0.026	0.188	-0.081	-0.047	0.142	-0.746*

*Significant at the p<0.05 level (2-tailed), **Significant at the p<0.01 level (2-tailed)

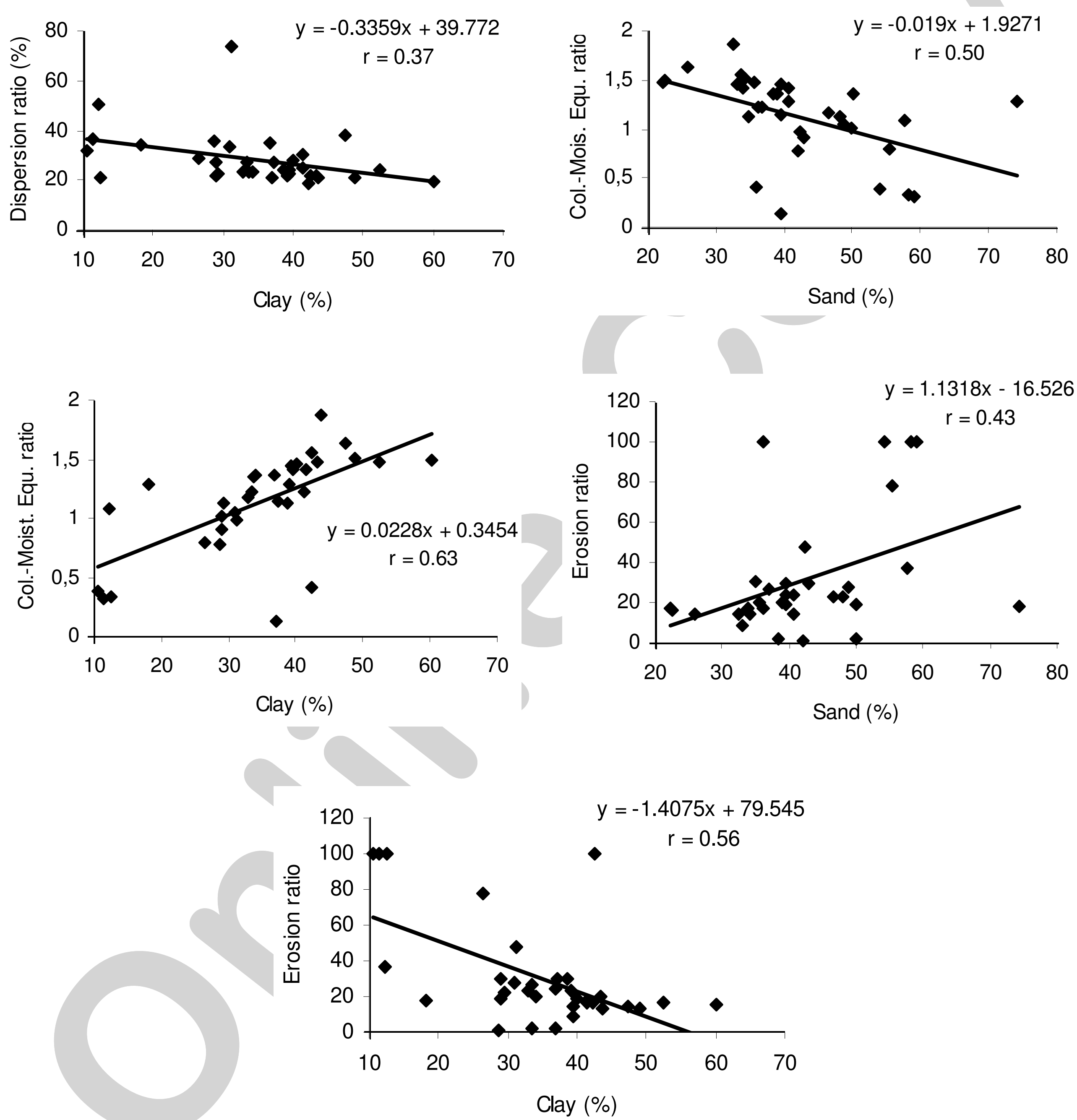

Fig. 3: Relationships between sand, clay content of soils and erodibility indices in rangelands

Table - 4: Pearson correlations between selected soil properties in forestlands

Correlation	L.O. I	Sand (%)	Clay (%)	Silt (%)	pH	E.C.	>5 mm (%)	2-5 mm (%)	<2 mm (%)	Root (%)	D.R.	C.R.
D.R.	-0.149	0.457**	-0.564**	0.102	-0.252	-0.466**	-0.049	0.059	-0.033	0.355	1	
C.R.	0.126	-0.339	0.533**	-0.269	0.058	0.12	0.094	0.114	-0.16	-0.014	-0.271	1
E.R.	-0.125	0.484**	-0.732*	0.335	-0.06	-0.171	-0.104	-0.085	0.138	0.056	0.538**	-0.648*

*Significant at the $p < 0.05$ level (2-tailed), **Significant at the $p < 0.01$ level (2-tailed)

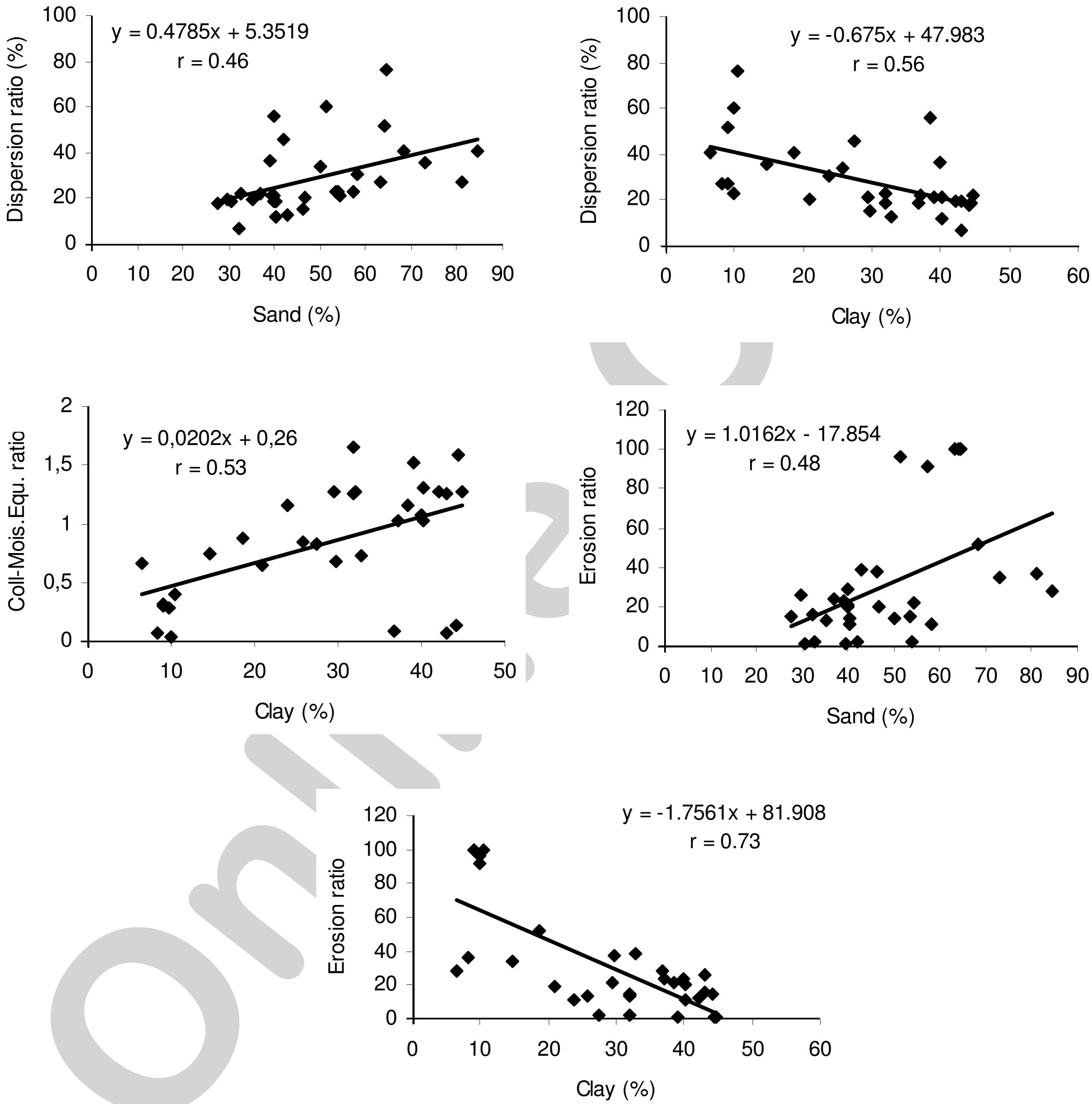

Fig. 4: Relationships between sand, clay content of soils and erodibility indices in forestlands

Table - 5: Effects of land use types on selected properties of soils

Soil properties*	Land use types			
	Forestlands	Rangelands	Farmlands	Significance (p)
Loss of ignition (%)	5.70 ± 0.37^{a}	5.40 ± 0.37^{a}	7.0 ± 0.38^{b}	0.001
Sand (%)	43.50 ± 1.28^{a}	41.74 ± 1.28^{a}	48.89 ± 1.32^{a}	0.07
Clay (%)	31.91 ± 1.4^{a}	33.94 ± 1.4^{a}	27.40 ± 1.4^{a}	0.12
Silt (%)	24.59 ± 0.69^{a}	24.32 ± 0.69^{a}	23.71 ± 0.72^{a}	0.75
pH (1:5 H_2O)	6.36 ± 0.13^{a}	5.96 ± 0.13^{ab}	5.56 ± 0.13^{b}	0
E.C. (µmhos/cm)	132.0 ± 26.63^{a}	69.0 ± 26.63^{a}	77.0 ± 27.45^{a}	0.19
> 5 mm fraction ratio (%)	14.30 ± 1.42^{a}	9.14 ± 1.44^{b}	9.91 ± 1.49^{ab}	0.05
2-5 mm fraction ratio (%)	6.61 ± 1.60^{a}	2.90 ± 1.62^{b}	5.43 ± 1.68^{a}	0.05
< 2 mm fraction ratio (%)	79.04 ± 1.8^{a}	87.91 ± 1.83^{b}	84.37 ± 1.9^{ab}	0.02
Root ratio (%)	0.05 ± 0.24^{a}	0.05 ± 0.25^{a}	0.29 ± 0.25^{b}	0
Dispersion ratio (D.R)	29.14 ± 1.35^{a}	27.84 ± 1.35^{a}	27.76 ± 1.39^{a}	0.87
Col./Moist. Eq. ratio (C.R)	0.87 ± 0.31^{ab}	1.08 ± 0.31^{a}	0.74 ± 0.32^{b}	0.05
Erosion ratio (E.R)	37.0 ± 4.2^{a}	31.0 ± 4.2^{a}	31.0 ± 4.33^{a}	0.77

*Note: Means with the same letter within a row are not significantly different at $p<0.05$ level of significance

to erosion ratio index, erodibility increased as a result of increasing sand and silt fractions of the soils, but decreased with increasing clay fractions of the soils (Table 2, Fig. 2).

In rangelands, according to evaluation made for dispersion ratio, the erodibility of the soils increased when 2-5 mm fractions of soils increased alternatively, decrease in with increasing clay content of the soils. According to colloid-moisture equivalent indice, soil erodibility increased because of decreasing loss of ignition and sand fractions of the soils. According to erosion ratio, soil erodibility increased with high amount of sand and silt fractions of the soils, but decreased with high amount of clay fractions of the soils (Table 3, Fig. 3).

In forestlands, according to evaluation made for dispersion ratio indice, when sand fractions of the soils increased, soil erodibility increased, too. However, increasing clay fractions and E.C. of the soils was associated with decrease in soil erodibility. For colloid-moisture equivalent indice, when clay fractions of the soils increased, erodibility decreased. According to erosion ratio, soil erodibility in forestlands increased, when sand fractions of the soils increased, but decreased with high amount of clay fractions of the soil (Table 4, Fig. 4).

Ozyuvaci (1978), found that generally, when loss of ignition, pH and E.C. of the soils increase, erodibility decreases. Moreover, when sand and > 5 mm fractions of the soils increase, erodibility increases, too. Karagül (1999) expressed that in farmlands, when pH, sand, silt fractions and skeleton content of the soils increase, dispersion ratio increases, but dispersion ratio decreases with increasing clay fractions and loss of ignition of the soil. He suggests that increasing sand, pH and skeleton content of the soils cause an increase in dispersion ratio of the soils in rangelands. But, increase in clay, silt fractions, loss of ignition and root ratio of the soils cause a decrease in dispersion ratio of the soils in rangelands. In forestlands the increase in sand and silt fractions, pH and skeleton content of the soil results in high dispersion ratio. The increase in clay fractions, loss of ignition and root ratio result in low dispersion ratio. Veihte (2002) notes that the concept of erodibility and how to asses it, is complicated since susceptibility to erosion is influenced by a large number of physical, mechanical, hydrological, chemical, rheological, mineralogical and biological properties. We found that according to land use types, soil erodibility was related to soil texture (clay fraction). Also, Yamanlar (1962) found that increasing colloid-moisture equivalent ratio was related to increase in clay fraction of soils. Karagül (1999) reported that the increase in clay fraction of soils cause decrease in dispersion ratio of soils.

The changes in soil properties and soil erodibility according to different land use types

Loss of ignition: Mean loss of ignition of soils in farmlands, rangelands and in forests were found to be 5.7%, 5.4% and 7.0% respectively (Table 5). Loss of ignition of soils in forests was different significantly from farmlands and rangelands (Table 5). Karagül (1999) also found that loss of ignition of soils in farmlands was significantly lower than soils in rangelands and in forests.

Soil texture: Soil texture is a property which shows proportional distribution of soil particles. Particle size distribution of soils affect soil water characteristics, erosion potentials, budget of plant nutrients and dynamics of organic matter. Soil texture ranges from loam to clay. It will be discussed below how sand, silt and clay content of soils were affected by land use conversion.

Sand: As seen in Table 5, statistical analysis indicated that there was no significant difference in sand fraction of soils when different land use types is considered in opposition to the conclusion of Nkana and Tonye (2003) and Braimoh and Vlek (2004). Also Wu and Tiessen (2002) found significant difference between sand fraction of soils in long term farmlands (for 40 years), rangelands and sligthtly and moderately degraded rangelands. VandenBygaart *et al.* (1999) indicated that sand fraction of the soils in tilled for 11 years are higher (277.4 g/kg) than in those no till for 11 years (221.1 g/kg).

Clay: According to statistical results there was no significant difference among clay fraction of soils from different land use types (Table 5). As described by Nkana and Tonye (2003) land use changes may affect clay fraction of the soils. Turudu (1981) found in a study that clay fraction of the soil in farmlands was higher significantly than in forestlands and in rangelands. In another study, Karagul (1999) found that clay fraction of topsoils in farmlands, forestlands and rangelands were to be 27.20%, 22.05% and 23.65% respectively but there was no significant difference in clay fraction of the top soils among different land use types. However, Wu and Tiessen (2002) found that there was significant difference in clay fraction of the topsoil between slight and moderately degraded rangelands and in tilled farmlands for a long time (for 40 years). Clay fraction of soils in rangelands was higher than in farmlands. Su *et al.* (2004) exposed that clay content of soils in ungrazed grassland fenced for 5 year was higher and significantly different from clay content of those in cultivated cropland for 3 years.

Silt: Silt fractions of soils did not show significant difference for different land use types (Table 5). Similarly, Wu and Tiessen (2002) described in their study that there was no significant difference between silt fraction of soils rangelands and tilled soils. Evrendilek *et al.* (2004) reported in their study that the cropland, forest and grassland soils had similar contents of silt, clay and sand.

> 5 mm. Fraction ratio: As seen in Table 5, statistics showed that > 5 mm. fraction ratio of soils in rangelands and farmlands were significantly different. This situation made us think skeleton remained since no permanent vegetation covers in farmlands and productive parts of soil may be remained. Fullen *et al.* (1998) found in their study that course fraction ratio in eroded lands was higher than in rangelands. Sauer and Logsdon (2002) indicated that total rock fragments in forest were more in rangelands and significantly different. In addition, Karagül (1999) reported in his study that the highest value of soil skeleton was in forests and the lowest value in rangelands.

2-5 mm. Fraction ratio: Statistical results shows that there was a significant difference between 2-5 mm. fraction ratios of soils in rangelands and in forests (Table 5). Also, 2-5 mm. fraction ratios of soils in farmlands were significantly different in rangelands. In addition Fullen *et al.* (1998) exposed in their study that 2-5 mm. fractions of soils in rangelands were lower than in eroded bare area.

< 2 mm. Fraction ratio: Statistics showed that < 2 mm. fraction ratio of soils in rangelands and farmlands were different significantly (Table 5). As exposed above skeleton part of soil in farmlands is higher than the other land use types and fine fraction is lower than the others. Thus, fine fractions of soils in farmlands were probably removed. Fine fractions of soils in rangelands were more than in farmlands. Sauer and Logsdon (2002) found that <2 mm. fractions of soils in forestlands were higher than in rangelands but not different significantly. Also, Karagul (1999) indicated that fine fractions of soils in forests were lower than in rangelands and farmlands.

Root ratio: Mean root ratios of soils in farmlands, in rangelands and in forests were found to be 0.05%, 0.05% and 0.29% respectively (Table 5). The root ratio of soils under forests was different from the others. Cultivated plants growth is more in farmlands and soil covers vegetation temporarily. For this reason, root ratio of soils in farmlands is lower than in forestlands (Turudu, 1997).

pH: Assessment of pH of soils related to different land use types showed that pH of soils in farmlands, in rangelands and in forests were found to be 6.36, 5.96 and 5.56, respectively (Table 5); indicating a significant difference between pH of soils in farmlands and in forests. Soils in farmlands belong to neutral and weakly acid reaction class; pH of soils in forests belongs to moderately acid reaction class. It is thought that soil tillage, which causes decrease in organic matter, may contribute to less acidity compared with forest. Likewise, Karagül (1999) and Tufekcioglu *et al.* (2005) states that there is a negative relationship between pH and organic matter content. Jiang *et al.* (2006) and Ovalles and Collins (1986) described their studies that continuous agricultural activities caused an increase in pH of soils. In addition Balesdent *et al.* (2000) states that soil tillage may cause an increase in pH of soils by effecting soil microclimate, natural carbon resources, microorganism activities and soil organizm. Schipper and Sparling (2000) say that soils in forests (pH=5.5-5.7) are more acidic than soils in rangelands (pH=5.3-6.9).

Electrical conductivity (EC): Mean EC of soils in farmlands, in rangelands and in forestlands were found to be 132 µS/cm, 69 µS/cm and 77 µS/cm respectively. Statistics indicated that land use types did not differ significantly in terms of EC of soils (Table 5).

Erodibility indices :

Dispersion ratio: The dispersion ratio of soils did not show significant difference (Table 5). But dispersion ratio of soils in farmlands was greater than in forests and rangelands. Similarly, Evrendilek *et al.* (2004) found that soil erodibility factor was greater in the cropland than in the forest site. Dispersion ratio depends on aggregation of soil particles. Soils in rangelands and forests are generally considered to have higher structural stability than soils in farmlands for soils in farmlands are cultivated continuously (Karagül, 1999). Soils in all land use types were found to be sensitive to erosion.

Colloid- moisture equivalent ratio: Colloid-moisture equivalent ratios of soils in farmlands, rangelands and forestlands were found to be 0.87, 1.08 and 0.74 respectively (Table 5). According to statistical results, there was significant difference between colloid moisture equivalent ratio of soils in rangelands and in forestlands (Table 5).

Erosion ratio: Erosion ratio of soils in farmlands, rangelands and forests was found to be 37, 31 and 31 respectively (Table 5). Soils did not show significant differences for different land use types.

In conclusion, different land uses are associated with different soil conditions: loss of ignition, soil skeleton percentage, < 2 mm fraction ratio, root ratio and pH show significant difference according to land use types. In farmlands, low values of loss of ignition and high values of > 5 mm. fractions and pH compared with the other land use types is important for evaluating land degradation.

It was determined that sand and clay proportion must be considered as significant indicators for erodibility evaluations in the research area. According to evaluation made for three erodibility indices, it was found that soils of the study area are susceptible to erosion. As to erodibility indices generally farmland soils were the most sensitive ones to erosion. Soil tillage generally breaks the soil aggregates. For this reason, the action of converting forestlands into farmlands and rangelands should be prevented. Preventive measures against erosion should be taken.

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