African Journal of Agricultural Research Vol. 7(2), pp. 183-193, 12 January, 2012
Available online at http://www.academicjournals.org/AJAR
DOI: 10.5897/AJAR11.737
ISSN 1991-637X

Full Length Research Paper

The determination of the relationships between physical and chemical properties of soils to water erosion and crust strengths in Menemen Plain Soils, Turkey

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Accepted 5 January, 2012

This study was carried out to determine the relationships between soil pyhsical and chemical properties to water erosion and crust strengths. The two consecutive rain storm (65 mm h^{-1}) were applied on the experimental soils. Erosion plots were waited under a platform, which included 4 infrared lamps (4 × 250 W) at 16 h between the two consecutive simulated rainfalls for crust forming. Results showed that soil physical and chemical properties affected runoff and soil loss significantly (p ≤ 0.05 and 0.01). In experimental soils, sand content, clay ratio and erosion ratio were negatively correlated with both runoff and soil loss, while soluble salt, C.E.C., silt and clay contents, field capacity were positively corelated with both of runoff and soil loss. In this research, no relationships between soil properties to crust strengths were found. By running stepwise multiple regression analysis, suspension percent and sand content were found effective on runoff significantly (r^2 = 0.53 to 0.72), and runoff, soluble salt were found effective on soil loss significantly (r^2 = 0.80–0.90), respectively.

Key words: Crust strength, rain simulator, runoff, soil loss, soil properties.

INTRODUCTION

In generally, after heavy rainfalls, crusts on soil surfaces based on some soil physical and chemical properties, are formed by wind and sunshine effects, directly. Nearly 90% of Turkey soils have been affected by water erosion. Crust formation and water erosion are also serious problem in the Gediz Basin, Western Anatolia in Turkey. Intensive agricultural practices are applied in this region, and the Menemen plain is located in the Gediz Basin. For this reasons, soil samples were selected from this region in this experiment.

In recent years, many researchs have been investigated to the relationships between soil erosion and crust formation. Erpul and Çanga (1999) found that consecutive rainfall increased runoff and soil loss, whereas, decreased percolation significantly, based on crust formation. Ndiaye et al. (2005) determined that crusting and the time to ponding on soil surfaces were significant effective on erosion, and crusting reduced infiltration. Yönter (2006) found that crust strengths were effective on runoff and, runoff was also effective on soil loss significantly (p ≤ 0.05), respectively. As it is known, there are significant relationships physical and chemical properties of soils to runoff and soil loss. Therefore, many researchers have been investigated this relations. In recent years, relationships between soil properties to erosion have been investigated using statistical methods by many researchers. Felix and Johannes (1995) emphasized that grain size distributions and a chemical analysis of soils confirmed the validity of the models of soil erosion by using the multiple regression analyses. Battany and Grismer (2000) found significant correlations (at the 95% confidence level) between the physical characteristics of slope, cover and surface roughness,

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Table 1. Means of soil samples in the 7th approaximation soil classification system (Altınbaş et al.,1990; Soil Survey Staff, 1998).

Sample number	Means of soil samples in the 7th approaximation soil classification system
1	Typic Xerofluvent, loamy on sandy, mixed (calcerous), thermic
2	Typic Xerofluvent, clay on sandy, mixed (calcerous), thermic
3	Typic Xerofluvent, clay, mixed (calcerous), thermic
4	Typic Xerofluvent, loamy on clay, mixed (calcerous), thermic
5	Typic Xerofluvent, loamy, mixed (calcerous), thermic
6	Aquic Xerofluvent, clay, mixed (calcerous), thermic
7	Aquic Xerefluvent, loamy on sandy, mixed (calcerous), thermic
8	Aquic Xerofluvent, loamy, mixed (calcerous), thermic
9	Aeric Halaquept, loamy, mixed (calcerous), thermic
10	Aeric Halaquept, loamy on sandy, mixed (calcerous), thermic
11	Aquic Xeropsamment, mixed, thermic
12	Typic Xeropsamment, mixed, thermic

with total infiltration, runoff, sediment discharge and average sediment concentration were obtained by using a portable rainfall simulator. Sheridan et al. (2000) developed 4 equations to predict rill and interill erodibility by using artificial rainfall and by using correlation and stepwise multiple regression procedures. Agua (2001) found that, the coefficient of determination, R^2 on peak rate of runoff, peak sediment concentration were 0.79 to 0.95 and 0.70 to 0.92 and 0.70 to 0.92, by using a stepwise multiple regression analysis at the watershed level respectively. Klik and Zartl (2001) applied the simulated rainfalls (40, 60, and 80 mm h^{-1}) at 60 to 120 min on 6 different soils (for initial dry and wet conditions) under laboratory conditions. According to the study, runoff (R) coefficients were lowest for initial dry soil surface condition with values between 0.496 and 0.795. For initial wet condition significant higher runoff coefficients were measured for all investigated soils (0.683 to 0.876). Soils with less than 31% clay content showed no significant runoff increase from wet to crust run. Fufa et al. (2002) applied rainfall simulation at an intensity of 75 mm h^{-1} was used to investigate runoff generation and sediment yield characteristics of the three soil types. They found that, the three soil were not significantly different in their sediment yield and runoff generation characteristics. Veihe (2002) analysed to determine erodibility parameters and surface characteristics in the field from 136 test sites. In the study, it was found poor relationships between soil types to erodibility parameters. Phippen and Wohl (2003) emphasized that physical factors appear more significant than land use in producing high sediment loads. Brandao et al. (2006) applied the artificial rainfall on soils to evaluate the decrease of infiltration rate in crusting. In the research, significant relations were found between crust hydraulic resistance to the chemical and physical characteristics of each soil by using the multiple regression analysis. Fristensky and Grismer (2009) found significant correlations between aggregate stability to runoff, but no correlation between aggregate stability to soil loss. Wuddivira et al. (2010) emphasized that clay content, organic matter content, exchangeable sodium percentage (ESP) and cation exchange capacity (CEC) to be important in slaking sensitivity and structural degradation under intense rainfall.

The objectives of this research were (i): to determine of the relationships between physical and chemical properties of soils to water erosion and crust strengths in Menemen Plain Soils, Turkey, where makes intensive agricultural production, and (ii): to estimate of runoff and soil loss from pysico-chemical properties of soils by using multi-regression equations.

MATERIALS AND METHODS

The selection and preparation of soil samples

The total 12 experimental soils of each other soil families (Altınbaş et al., 1990; Soil Survey Staff, 1998) located in Agriculture Faculty's Research Farm of Ege University in Menemen-Izmir-Turkey (latitudes 38°34'12.96"-38°35'17.00" N; longitudes 27°01'01.74"-27°02'40.19" E; total area: 4100 da), based on soils spreads areas, were taken to use the simulated rainfall experiment under laboratory conditions. Soil samples types are given Table 1. It seems that there are different soil types of 5 soil families (5 numbers of Typic Xerofluvent, 3 numbers of Aquic Xerofluvent, 2 numbers of Aeric Halaquept, 1 number of Aquic Xeropsamment, and 1 number of Typic Xeropsamment). Soil samples taken from

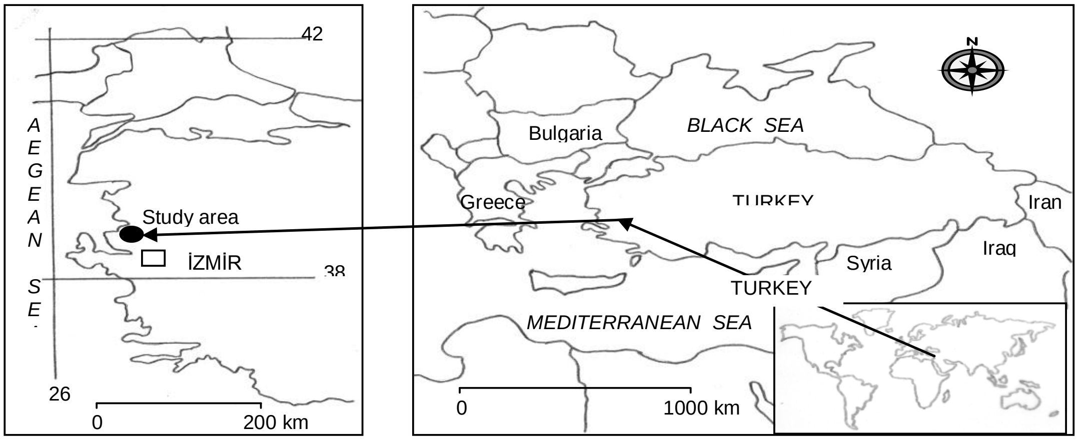

Figure 1. A map of location, where were taken experimental soils (Delibacak et al., 2009).

area is in the Western Anatolia region of Turkey (Figure 1), where the Mediterranean climate prevails with a long-term mean annual temperature of 17.9°C. Long-term mean annual precipitations are 689.8 mm (DMI, 2009).

In this experiment, around 50 to 80 kg of 12 soil samples (0 - 30 cm) were taken and dried at normal atmospheric conditions in the laboratory conditions. A part of experimental soils, air-dried were passed through a 2 mm sieve (Richards, 1954) to be used in some pysical and chemical analyses, and other part of experimental soils were also passed through an 8 mm sieve for erosion research (Mollenhauer and Long, 1954; Byran, 1969). Some physical and chemical characteristics of soils were determined as follows, respectively. Soil scelation (%), (Soil Survey Staff, 1951), texture (Bouyoucos, 1962), clay and silt rates (%) (Neal, 1938), field capacity (%) and pH, (US Salinity Lab. Staff, 1954), dispersion rate (Middleton, 1930), percolation rate (%) (Lal, 1988), erosion rate (%) (Akalan, 1967), lime (%) (Schlichting and Blume, 1966), soluble total salt (%) (Soil Survey Staff, 1951), and organic content (Black 1965) of the soil samples were analyzed. Aggregate stabilities of the soil samples were analyzed by Yoder's Wetting Sieved Methods (U.S. Salinity Lab. Staff, 1954) and calculated using Kempler's formula (Black, 1965).

The preparation and application of treatments

The perforated erosion plots sized 30 × 45 × 15 cm (Abrahim and Rickson, 1989; Gril et al., 1989) were used in this experiment. Erosion plots were filled a 5 cm very coarse sand layers and this layers were smoothed by hand carefully. After a fine cloth (cheese cloth) was lay on the sand layer, erosion plots were filled by soil samples passed through an 8 mm sieve.

Rainfall event simulation

A laboratory types rain simulator (Veejet 80100 types nozzle) (Bubenzer and Meyer, 1965) was used to simulate the rainfall in this experiment. Firstly, the 1st simulated rainfall (65 mm h^{-1}) was applied on erosion plots, at 9% slope for 1 hour from a height of 2.50 m. Then, the time to ponding on soil surfaces were measurement by using a stopwatch and recorded (Taysun, 1986; Ndiaye et al., 2005; Yönter and Uysal, 2007). During the artificial rainfall experiments, runoff and sediment samples were taken in each 10 minutes. After the 1st simulated rainfall, these plots were again waited under a infrared lamps platform at 24 h, and crust strenghts were measured by a hand type penetrometer (EL 516 - 030) (Page and Quick, 1979; Levy and Rapp, 1999; Yönter, 2006). Finally, the 2nd simulated rainfall (65 mm h^{-1}) was applied on these plots again. The same methods were used again to measure runoff and sediment during the 2nd simulated rainfall applications. In this experiment, tap water (EC: 875 µmhos/cm; SAR: 2.50%) was used.

The measurement of parameters and analysis of the data

At the end of the rainfall applications (1st and 2nd), the runoff containers were left for 24 hours in order for the sediment to settle in the containers. Then the sediment samples were dried in an oven at 105°C. Runoff and sediment amounts were recorded and tabulated (Taysun, 1986; Yönter and Uysal, 2007). A completely randomized experimental parcel, designed with 2 replications was used for statistical analysis of the data. Data were analyzed by using an SPSS statistical package program (SPSS, 1999) in this experiment.

RESULTS

Soil characteristics

Some pyhsical and chemical properties of soil samples in used the experiment are given in Table 2. In the experiment, dispersion rates varied from 32.59 to 47.74% in Typic Xerofluvent soils, varied from 24.81 to 49.92% in Aquic Xerofluvent soils, varied from 38.37 to 61.83% in Aeric Halaquept soils, and 20.89 and 35.53% were taken from Aquic Xeropsamment and Typic Xeropsamment soils, respectively. Erosion rates also varied from 60.63 to 94.77% in Typic Xerofluvent soils, varied from 70.39 to 94.01% in Aquic Xerofluvent soils, varied from 56.26 to 56.79% in Aeric Halaquept soils, and 87.53 and 72.48% were taken from Aquic Xeropsamment and Typic Xeropsamment soils, respectively.

Runoff

Total runoff, total soil loss and crust strengths are given

Table 2. Some chemical and physical properties and descriptive statistics of soil samples in used experiment.

Sample No	pH	Total salt (%)	$CaCO_3$ (%)	OM (%)	C.E.C (me 100g^{-1})	Sand (%)	Silt (%)	Clay (%)	Texture	CR (%)	SiR (%)	FC (%)	Susp. (%)	Disp. (%)	DR (%)	PR (%)	ER (%)	AS (%)
1 (TXfl)	7.60	0.049	6.37	1.72	10.65	46.92	46.00	7.08	L	13.12	6.50	17.47	19.92	51.92	38.37	40.53	94.77	5.07
2 (TXfl)	7.75	<0.030	4.42	1.60	6.52	73.92	21.00	5.08	SCL	18.69	4.13	9.71	16.92	51.92	32.59	52.32	62.23	5.61
3 (TXfl)	7.70	0.063	11.49	1.41	18.74	13.92	53.00	33.08	SiCL	2.02	1.60	41.54	17.92	47.92	37.40	79.63	47.12	14.17
4 (TXfl)	8.00	0.079	7.79	2.50	14.02	26.92	52.00	21.08	SiL	3.74	2.47	26.83	21.92	45.92	47.74	78.57	60.63	8.37
5 (TXfl)	7.70	<0.030	5.67	1.14	7.79	59.38	33.00	7.72	SL	11.97	4.27	13.04	7.92	17.92	44.20	59.20	74.70	4.92
6 (AqXfl)	7.60	0.052	6.90	1.28	12.71	53.28	34.00	12.72	L	6.86	2.67	20.79	8.92	17.92	49.78	61.18	81.14	10.25
7 (AqXfl)	7.30	0.035	6.09	0.71	8.80	53.28	40.00	6.72	SL	13.88	5.95	25.46	7.92	31.92	24.81	26.39	94.01	9.30
8 (AqXfl)	7.75	0.073	23.60	1.62	19.07	17.00	50.64	32.36	SiCL	2.09	1.56	45.90	24.92	49.92	49.92	70.50	70.39	3.50
9 (Ae Hq)	7.95	0.210	6.98	1.28	11.74	38.56	45.00	16.44	L	5.08	2.74	24.28	19.92	51.92	38.37	67.71	56.79	3.07
10 (AeHq)	7.45	0.098	4.52	0.81	8.37	82.26	9.00	8.72	LS	10.47	1.03	7.94	25.92	41.92	61.83	109.82	56.26	2.79
11 (AqXps)	7.80	<0.030	3.77	1.07	6.07	83.28	14.00	2.72	LS	35.76	5.15	11.40	7.92	37.92	20.89	23.86	87.53	7.30
12 (TXps)	8.05	<0.030	4.68	0.90	6.51	77.28	16.00	6.72	LS	13.18	2.38	13.70	9.92	27.92	35.53	49.05	72.48	4.24
Mean	7.75	0.065	7.69	1.34	10.92	52.16	34.47	13.37	-	11.40	3.37	21.51	15.84	39.59	40.12	59.90	71.50	6.55
Max.	8.05	0.210	23.60	2.50	19.07	83.28	53.00	33.08	-	35.76	6.50	45.90	25.92	51.92	61.83	109.82	94.77	14.17
Min.	7.30	0.030	3.77	0.71	6.07	13.92	9.00	2.72	-	2.02	1.03	7.94	7.92	17.92	20.89	23.86	47.12	2.79
Range	0.75	0.180	19.83	1.79	13.00	69.36	44.00	30.36	-	33.74	5.47	37.96	18.00	34.00	40.94	85.96	47.65	11.38
Std.	0.20	0.051	5.41	0.49	4.52	24.46	15.90	10.37	-	9.31	1.80	12.15	6.95	12.84	11.41	24.08	15.54	3.44
Skewness	-0.56	2.38	2.69	1.09	0.85	-0.26	-0.41	1.19	-	1.68	0.53	1.00	0.04	-0.76	0.10	0.37	0.17	1.01
Kurtosis	1.20	6.48	7.87	1.85	-0.34	-1.18	-1.42	0.19	-	3.84	-0.96	0.23	-1.71	-0.85	0.06	0.47	-1.06	0.61

(OM: Organic material; CR: clay ratio; SiR: silt ratio; FC: field capacity; Susp.: suspension; Disp.: dispersion; DR: dispersion ratio;PR: percolation ratio; ER: erosion ratio; AS: aggregate stability: TXfl: Typic Xerofluvent: AqXfl: Aquic Xerofluvent: AeHq: Aeric Halaquept: AqXps: Aquic Xeropsamment: TXps: Typic Xeropsamment).

in Table 3. In the 1st simulated rainfall, runoff varied from 1.63 to 39.26 mm h^{-1} in Typic Xerofluvent soils, varied from 16.84 to 36.28 mm h^{-1} in Aquic Xerofluvent soils, varied from 27.31 to 37.47 mm h^{-1} in Aeric Halaquept soils, 7.45 and 14.49 mm h^{-1} of runoff were obtained from Aquic Xeropsamment and Typic Xeropsamment soils, respectively. During the 2nd simulated rainfall, runoff varied from 10.21 to 50.03 mm h^{-1} in Typic Xerofluvent soils, varied from 28.63 to 37.79 mm h^{-1} in Aquic Xerofluvent soils, varied from 32.80 to 51.67 mm h^{-1} in Aeric Halaquept soils, 16.81 and 24.24 mm h^{-1} of runoff were obtained from Aquic Xeropsamment and Typic Xeropsamment soils, re spectively. Correlation coefficiens of some pysico-chemical properties of soils in used the experiment are given in Table 4. Data from the experiment were analysed for the normality test (Table 5). Runoff regression equations according to the coefficients of correlations are given in Table 6. For multiple regression analyses, all of soil samles were evaluated in statistical analyses, because of theirs distrubitions on the Menemen Agriculture Faculty's Research Farm is seen different numbers (Table 1). For example, Aquic Xerepsamment and Typic Xerepsamment soils are one numbers on the farm. In this study, stepwise multiple regression method was used to explain to the significant factors effects on runoff by correlations coefficients. Model summary, ANOVA tests and coefficients of models are given in Tables 7, 8 and 9. According to Table 9, models were explained as Equations 1 and 2:

$$R = 16.421 + 2.591*Sus. (\%) \quad (1)$$

$$R = 52.928 + 1.886*Sus. (\%) – 0.486*Sand (\%) \quad (2)$$

Equation (1) was found similar Equation 8 in Table

Table 3. Runoff, soil loss and crust strengths obtained from erosion plots in the experiment and theirs descriptive statistics.

Sample number	Runoff (mm h^{-1})			Soil loss (g m^{-2})			Crust strength (kgf cm^{-2})
	1st	2nd	Total	1st	2nd	Total	
1 (TXfl)	19.44	37.82	57.26	292.00	582.60	874.60	1.48
2 (TXfl)	21.41	37.31	58.72	194.08	399.33	593.41	0.97
3 (TXfl)	39.26	50.03	89.29	827.70	1420.75	2248.45	1.60
4 (TXfl)	37.52	46.84	84.36	458.74	678.45	1137.19	1.33
5 (TXfl)	1.63	10.21	11.84	27.19	190.75	217.94	1.40
6 (AqXfl)	22.36	33.87	56.23	277.63	444.53	722.16	0.98
7 (AqXfl)	16.84	28.63	45.47	187.11	251.70	438.81	3.25
8 (AqXfl)	36.28	37.39	74.07	536.23	719.91	1256.14	2.60
9 (Ae Hq)	37.47	51.67	89.14	549.63	1232.68	1782.31	1.68
10 (AeHq)	27.31	32.80	60.11	330.82	427.25	758.07	1.50
11 (AqXps)	7.45	16.81	24.26	112.96	224.14	337.10	1.50
12 (TXps)	14.49	24.24	38.73	342.07	380.15	722.22	1.35
Mean	23.46	34.01	57.46	344.68	579.35	924.03	1.64
Max.	39.26	51.67	89.29	827.70	1420.75	2248.45	3.25
Min.	1.63	10.21	11.84	27.19	190.75	217.94	0.97
Range	37.63	41.46	77.45	800.51	1230.00	2030.51	2.28
Std	12.44	12.65	24.69	220.43	388.74	598.92	0.65
Skewness	-0.22	-0.42	-0.38	0.79	1.34	1.16	1.73
Kurtosis	-0.95	-0.29	-0.50	0.77	1.06	0.95	2.89

(1st and 2nd: Rain simulations: TXfl: Typic Xerofluvent: AqXfl: Aquic Xerofluvent: AeHq: Aeric halaquept: AqXps: Aquic Xeropsamment: TXps: Typic Xeropsamment).

6. Equation 2 was explained 72% of runoff by addition of suspension and sand percentages. 28% of runoff were explained by other factors. Residual statistics of runoff models are given in Table 10 and graphically explanations are given in Figure 2.

Soil loss

It is seen that soil loss in the 1st simulated rainfall varied from 27.19 to 827.70 g m^{-2} in Typic Xerofluvent soils, varied from 187.11 to 536.23 g m^{-2} in Aquic Xerofluvent soils, varied from 330.82 to 549.63 g m^{-2} in Aeric Halaquept soils. 112.96 and 342.07 g m^{-2} of soil loss was taken from Aquic Xeropsamment and Typic Xeropsamment soils. During the 2nd simulated rainfall, soil loss varied from 170.75 to 1420.75 g m^{-2} in Typic Xerofluvent soils, varied from 251.70 to 719.91 g m^{-2} in Aquic Xerofluvent soils, varied from 427.25 to 1232.68 g m^{-2} in Aeric Halaquept soils. 224.14 g m^{-2} and 380.15 g m^{-2} of soil loss was taken from Aquic Xeropsamment and Typic Xeropsamment soils (Table 3). Regression equations of soil loss, based on coefficients of correlation, are given in Table 11. Stepwise multiple regression method was used to explain the significant factors effects on soil loss by correlation coefficients. According to the residual analyses, case no: 3 was excluded from calculations to determine the the best fitted model. Model summary and ANOVA were given in Tables 12 and 13. There were proposed two models (Table 14) Residual analyses results were given in Table15 and Figure 3. Proposed models were explained as Equations 4 and 5:

$$SL = -125.09 + 17.02*R \quad (4)$$

$$SL = -41.31 + 10.95*R + 3798.91*Salt (\%) \quad (5)$$

Crust strengths

Crust strengths measured from soil surfaces varied from 0.97 to 1.60 kgf cm^{-2} in Typic Xerofluvent soils, varied from 0.98 to 3.25 kgf cm^{-2} in Aquic Xerofluvent soils, varied from 1.50 to 1.68 kgf cm^{-2} in Aeric Halaquept soils. In Aquic Xeropsamment and Typic Xeropsamment soils, 1.50 and 1.35 kgf cm^{-2} of crust strengths were measued, respectively.

DISCUSSION

Soil characteristics

The experimental soils have different pysico-chemical properties in both of same and different groups from soil

Table 4. Coefficients of correlations of some soil properties, runoff, soil loss and crust strengths in the experiment.

Coefficients	pH	Salt	Lime	OM	CEC	Sand	Silt	Clay	CR	SiR	FC	Sus	Disp	DR	PR	ER	AS	CS	R	SL
pH	1																			
Salt		1																		
Lime			1																	
OM				1																
CEC			0.83**		1															
Sand			-0.74**		-0.93**	1														
Silt			0.59*	0.59*	0.80**	-0.96**	1													
Clay			0.83**		0.97**	-0.89**	0.72**	1												
CR					-0.76**	0.76**	-0.67*	-0.75**	1											
SiR								-0.62*	0.59*	1										
FC			0.86**		0.93**	-0.92**	0.82**	0.92**	-0.65*		1									
Sus												1								
Disp												0.77**	1							
DR									-0.64*	-0.68*		0.61*		1						
PR									-0.65*	-0.84**		0.71**		0.87**	1					
ER										0.81**					-0.80**	1				
AS																	1			
CS																		1		
R		0.64*			0.73**	-0.70*	0.60*	0.73**	-0.69*		0.62*	0.73**	0.69*			-0.61*			1	
SL		0.61*			0.77**	-0.75**	0.62*	0.81**	-0.66*		0.70*					-0.66*			0.87**	1

(*Correlation is significant at the 0.05 level (2-tailed); ** correlation is significant at the 0.01 level (2-tailed); R: runoff; SL: soil loss; CS: crust strength).

Table 5. Tests of normality of depentent variables from experiment.

Variable	Kolmogorov-Smirnov(a)			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
CS	0.307	12	0.003	0.783	12	0.006
R	0.147	12	0.200*	0.946	12	0.575
SL	0.200	12	0.200*	0.901	12	0.163

Table 6. Regression equations from experimental data according to the bilateral relations in runoff.

Dependent variable (Y)	Independent variable (X)	Regression equations	Equation number	r^2
Runoff (R: mm h^{-1})	Soluble salt (%)	Y = 37.31 + 310.31*X	1	0.41
	C.E.C (me 100 g^{-1})	Y = 14.09 + 3.97*X	2	0.53
	Sand (%)	Y = 94.32 – 0.71*X	3	0.49
	Silt (%)	Y = 25.16 + 0.93*X	4	0.36
	Clay (%)	Y = 34.36 + 1.73*X	5	0.53
	CR (%)	Y = 78.30 - 1.83*X	6	0.48
	FC (%)	Y = 30.35 + 1.26*X	7	0.38
	Susp. (%)	Y = 16.42 + 2.59*X	8	0.53
	Disp. (%)	Y = 5.14 + 1.32*X	9	0.47
	ER (%)	Y = 127.08 – 0.97*X	10	0.38

Table 7. According to stepwise multiple regression, Model Summary(c).

Model	r	r^2	Adjusted r^2	Std. error of the estimate	Durbin-Watson
1	0.729(a)	0.532	0.485	17.71939	
2	0.851(b)	0.724	0.662	14.34365	1.125

Table 8. ANOVA of runoff models in experiment.

Model		Sum of squares	df	Mean square	F	Sig.
1	Regression	3564.667	1	3564.667	11.353	0.007(a)
	Residual	3139.766	10	313.977		
	Total	6704.434	11			
2	Regression	4852.771	2	2426.386	11.793	0.003(b)
	Residual	1851.662	9	205.740		
	Total	6704.434	11			

Table 9. Coefficients of runoff models from experiment.

Model		Unstandardized coefficients		Standardized coefficients	t	Sig.
		B	Std. error	Beta	B	Std. Error
1	(Constant)	16.421	13.209		1.243	0.242
	Sus	2.591	0.769	0.729	3.369	0.007
2	(Constant)	52.928	18.089		2.926	0.017
	Sus	1.886	0.683	0.531	2.759	0.022
	Sand	-0.486	0.194	-0.481	-2.502	0.034

Table 10. Residuals statistics.

Parameter	Minimum	Maximum	Mean	Std. Deviation	N
Predicted value	27.4178	91.6641	57.4567	21.00383	12
Residual	-27.18480	17.37518	0.00000	12.97432	12
Std. predicted value	-1.430	1.629	0.000	1.000	12
Std. residual	-1.895	1.211	0.000	0.905	12

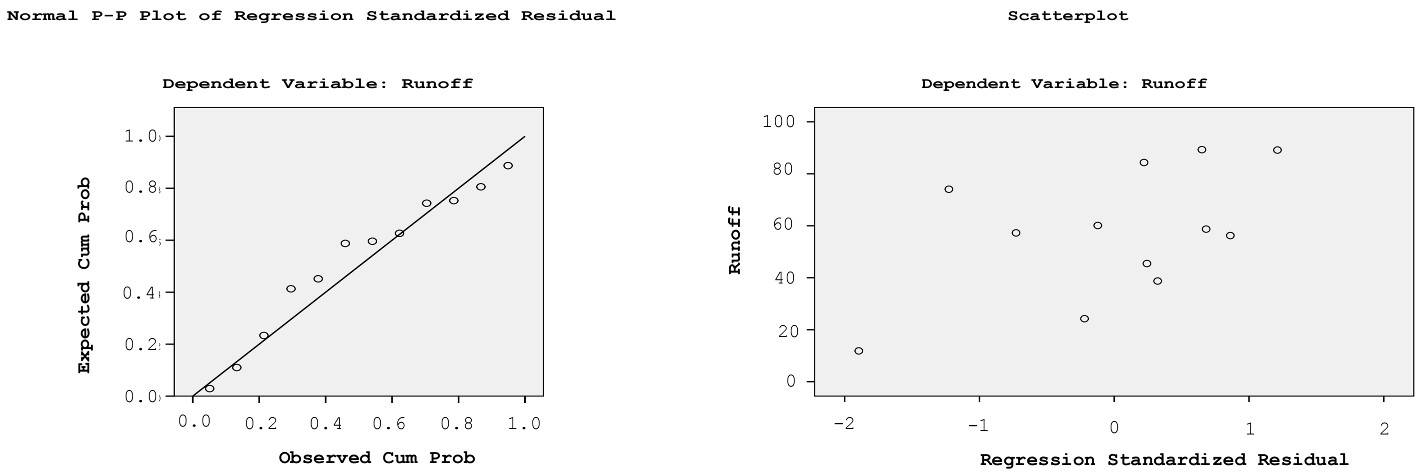

Figure 2. Graphically views of residual analyses of runoff model.

Table 11. Regression equations from experimental data according to the bilateral relations in soil loss.

Dependent variable (Y)	Independent variable(X)	Regression equations	Equation number	R^2
Soil loss (SL: g m^{-2})	Soluble salt (%)	Y = 461.43 + 7126.20*X	1	0.37
	C.E.C (me 100 g^{-1})	Y = -192.26 + 102.26*X	2	0.59
	Sand (%)	Y = 1879.20 – 18.31*X	3	0.56
	Silt (%)	Y = 118.01 + 23.38*X	4	0.39
	Clay (%)	Y = 294.84 + 46.11*X	5	0.66
	CR (%)	Y = 1405 – 42.19*X	6	0.43
	FC (%)	Y = 179.13 + 34.64*X	7	0.49
	ER (%)	Y = 2750.60 – 25.55*X	8	0.44
	R (mm h^{-1})	Y = -286.85 + 21.08*X	9	0.76

Table 12. According to stepwise multiple regression, model summary.

Model	r	r^2	Adjusted r^2	Std. error of the estimate	Durbin-Watson
1	0.893	0.798	0.776	213.45028	
2	0.949	0.900	0.875	159.46824	1.648

Table 13. ANOVA of soil loss models.

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1622139.404	1	1622139.404	35.604	0.000(a)
	Residual	410049.213	9	45561.024		
	Total	2032188.617	10			
2	Regression	1828747.653	2	914373.826	35.956	0.000(b)
	Residual	203440.964	8	25430.121		
	Total	2032188.617	10			

Table 14. Coefficients of soil loss models from experiment.

Model		Unstandardized coefficients		Standardized coefficients	t	Sig.
		B	Std. error	Beta	B	Std. Error
1	(Constant)	-125.093	168.427		-0.743	0.477
	R	17.021	2.853	0.893	5.967	0.000
2	(Constant)	-41.308	129.219		-0.320	0.757
	R	10.954	3.012	0.575	3.636	0.007
	Salt	3798.908	1332.782	0.451	2.850	0.021

Table 15. Residuals statistics of soil loss models.

	Minimum	Maximum	Mean	Std. deviation	N
Predicted value	202.3515	1732.8782	803.6318	427.63859	11
Residual	-231.3437	225.32271	0.00000	142.63273	11
Std. Predicted value	-1.406	2.173	0.000	1.000	11
Std. Residual	-1.451	1.413	0.000	0.894	11

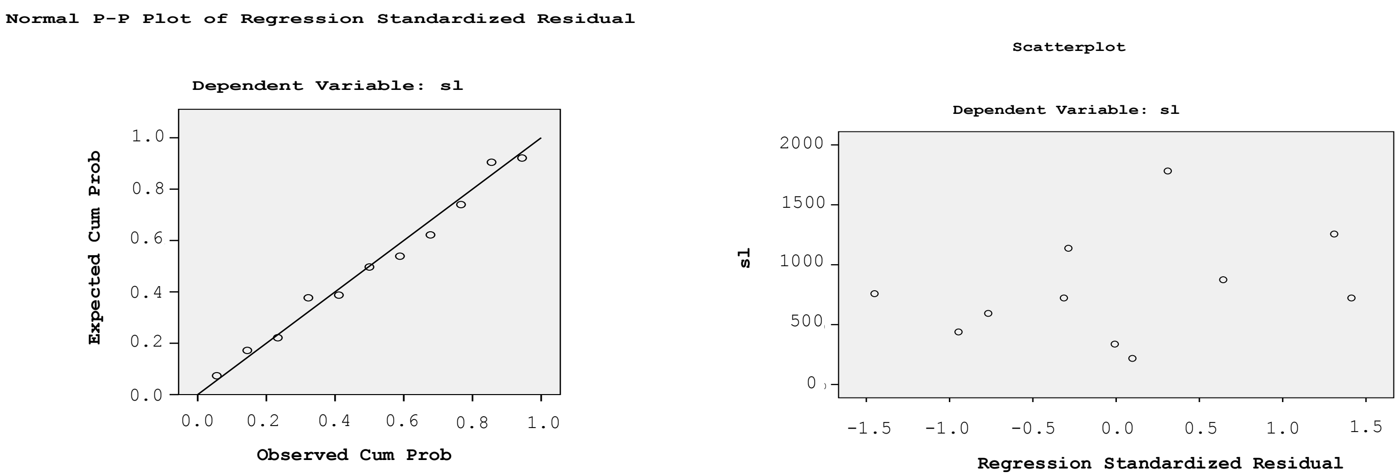

Figure 3. Graphically views of residual analyses of soil loss models.

families (Table 2). Differences in physical and chemical properties of soils affect soil erosion differently (Akalan, 1974; Taysun, 1989). It is considered that, soils have no resistance to erosion, when dispersion and erosion ratios are higher than 15 and 10%, respectively (Akalan 1974; Taysun 1989). However, aggregate stabilities were found to be very low in experimental soils. If the clay content is lower than 20% and silt content is lower than 12%, soils could be become powder (Taysun, 1989). For this condition, aggregate stabilities of soil samples were found very low especially in Typic Xeropsamment soils. Also, scelation materials on soil surfaces reduce soil erosion by water (Taysun, 1986), but no scelation materials on soils were found in this experiment. From Table 2, it can be understood that all of the soil samples in used this experiment have no resistance to erosion.

Runoff

Soil samples in used the experiment have different physical and chemical properties and these properties also varied in the wide ranges (Table 2). Therefore, soils affected runoff at different levels. For example, soil no: 3 (Typic Xerefluvent) has highest C.E.C and silt content. As it is known, highest C.E.C in soils increases dispertion of soils and also increases soil erosion (Wuddivira et al., 2010). In addition, aggregate stabilities in soils were found very low levels, therefore, runoff were increased (Akalan, 1974). The absence of scelation materials on soil surfaces increased runoff (Taysun, 1986). According to correlation analyses, soluable salt (%) in water, cation exchangeable capacity (me 100 g^{-1}), silt (%), clay (%), field capacity (%), suspension (%), and dispersion (%) were positively correlated with runoff, whereas, sand (%), clay ratio (%), and erosion ratio (%) were negatively correlated with runoff, respectively (Table 4). Kolmogorov-Smirnov and Shapiro-Wilk tests results showed that, total runoff and total soil loss were normally distributed, but crust strengths were not (Table 5), therefore, total runoff and total soil loss variations can be used to regression analyses without crust strength. 53% of runoff were explained by C.E.C, clay (%), and suspension (%); and 47% of runoff were explained by other factors (Klic and Zartl, 2001; Wuddivira et al., 2010). By running stepwise multiple regression method, two models of runoff were obtained in the experiment. Similar findings were found by Sheridan et al. (2000).

Soil loss

The lowest soil loss was obtained from soil no: 5 (Typic Xerefluvent) and the highest soil loss was obtained from soil no: 3 (Typic Xerefluvent). Similarly to runoff, soil no:3 (Typic Xerefluvent) has highest C.E.C and silt (%). As it is known, highest C.E.C in soils increases dispersion of soils and also increases erosion (Wuddivira et al., 2010). In addition, aggregate stability decrases soil loss. According to Table 3, soil no: 3 and 5 (Typic Xerefluvent) have the highest and the lowest aggregate stabilities, respectively. Whereas, the lowest soil loss was obtained from soil no:3 (Typic Xerefluvent) (Moldenhauer and Long, 1964; Sheridan et al., 2000). Soil loss were varried in wide ranges, it might be that soil samples have different physico-chemical properties in both of same and different soil groups (Altınbaş et al., 1990; Yönter, 2010). In this study, it was found that soluable salt (%), cation exchangable capacity (C.E.C: me 100 g^{-1}), silt (%), clay (%), field capacity (FC: (%)), and runoff (R: mm h^{-1}) were positively correlated with soil loss significantly, whereas sand (%), clay ratio (%) and erosion ratio (%) were negatively correlated with soil loss. Similar findings were explained by some researchs (Moldenhauer and Long, 1964; Taysun, 1986; Sheridan et al., 2000; Brandao et al., 2006). Runoff explained at 76 % of soil loss. In other words, runoff was found effective on soil loss at the highest ratios. 23% of soil loss were explained by other factors. Secondly, clay content (%) of soils explained 66% of soil loss (Wuddivira et al., 2010). Aggregate stabilities in soil samples were found very low, therefore, aggregate stabilities did’nt affect soil loss (Fufa et al., 2002). In the equation no: 4, runoff explained 80% of soil loss differently than equation no: 9 and 3 (76%) (Yönter, 2006). In other words, soil loss was explained by runoff at 76–80% percents. In equation no: 5, soil loss were explained by runoff and soluble salt at 90% percent. 10% of soil loss were explained by other factors. Similarly, some researchers determined multiple regression models of soil erosion based on soil properties (Felix and Johannes, 1995; Sheridan et al., 2000).

Crust strengths

In the experiment, the lowest crust strengths were measured in soil no: 2 and 6 (Typic Xerefluvent, and Aquic Xerefluvent), whereas the highest crust strength was measured in soil 7 (Aquic Xerefluvent). Some researchers explained that crust strengths were effected by soil properties (Erpul and Çanga, 1999; Yönter, 2006). On contrary, no significant relationships soil properties to crust strengths (Table 4). It might be that soil samples have similar physico-chemical properties (Altınbaş et al., 1990; Yönter, 2010). In this study, it was found that crust strengths were not normally distrubuted and were not correlated with soil properties, runoff and soil loss; however, no regression equations of crust strengths were formed. It might be that, the experimental soils have aggregate stabilities and clay content at lower levels (Klik and Zartl, 2001). Singer and Shainberg (2004) emphasized that the tendency of a soil to form a seal and crust depended to some degree on the time-dependent property of soil structural stability, which tends to increase with increasing clay content.

Conclusions

Our results indicate that the physical and chemical properties of soils affects runoff and soil loss significantly. In addition, crust forming on the surface of the soil after heavy rainfall negatively affects plant production in terms of agriculture systems. For this reason, farmers often have to tillage soils to break the crust layers. As a result of this situations, additional labor and costs are increasing. Both of bilateral and multiple relationships of soil characteristics can be used effective on runoff and soil loss significantly. For estimating of runoff and soil loss, it should be determine to soil pysical and chemical properties. According to this results, runoff and soil loss can be estimated easly under the determined rainfall conditions by using soil parameters.

ACKNOWLEDGEMENTS

The authors would like to thank the Ege University Scientific Research Found for providing financial supporting for project number 2005-ZRF-056.

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