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Effects of Erosion on Crop Yields, Soil Properties and Nutrients in the Semi-arid Region of the Turkey

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Abstract: This research was carried out in Kazova which has a high agricultural potential in Tokat province. Tokat region is located in the northern Turkey, having a microclimate. The region has an important level of erosion problem and with this research erosion and fertility relationship and the effect of erosion on soil properties, is studied. The quantitative soil erosion amount was determined by USLE method for agricultural lands having less than 10% slope. The bilateral relations between the amount of the soil loss calculated by USLE equation in the lands of Bağlar, Güzeldere, Gülpınar, Çerçi and Söngüt villages having two different landscape (toeslope, backslope and footslope). The statistical evaluations showed that there is an inverse relationship between the soil loss and productivity of the crops. A positive correlation between the soil loss amount and the sand and $CaCO_3$ and a negative correlation between clay, pH, salt and Cu content were determined. No statistical relationship was detected among the variables which are the soil loss amount, silt, CEC, P, K, organic matter, B, Fe, Zn and Mn.

Key words: Crop yield, soil erosion, soil properties, USLE

INTRODUCTION

The erosion realized in agricultural lands has negative effects on the productivity of the soil. This destructive effect of the soil erosion is caused by the decreasing water holding capacity of the soil and loss of nutrients from the soil, as well as the negative changes taken place in various soil properties. Together, these changes decrease the soil fertility and diminish bio-production capability (Evans, 1981).

Some differences occurred depending on the levels of the soil loss, according to the changes in the soil properties, there is a tendency of decreasing productivity in years in proportion to the soil loss.

Soil erosion event is very effective to change soil properties and crop yields. This effect should be researched for different climate and soil conditions.

The objective of this study was to determine erosion-fertility relationships by comparing estimated erosion rates with temporal changes in soil properties. This research is carried out in Tokat-Kazova where soil erosion is experienced, to determine the relationship between the soil loss amount and the productivity of sugar beet and wheat and to compare the physical and chemical properties of the land with different soil loss ratio.

MATERIALS AND METHODS

A study was conducted in 2001 and 2002 for 121 farm fields located in Kazova Plain in Tokat province. Kazova has a high agricultural potential and has semi arid climatic conditions. The annual average precipitation is about 430 mm (Anonymous, 2005). The study area elevation is 600 m from sea level. Soil moisture regime was defined as the ustic. The study area soils are composed of entisols and kuaterner geologic age.

Field studies were conducted at Bağlar, Güzeldere, Gülpınar, Çerçi and Songüt villages. All samples were taken from the slope where less than 10% in the sugar beet-wheat crop rotation.

Soil texture was measured by hydrometer method (Day, 1965). Organic matter was determined by modified Walkley-Black (1934) method. The pH was estimated using a saturation paste (Tüzüner, 1990). Available phosphorus (P) was determined by the Olsen *et al.*, (1954) method. Available potassium (K) was determined by the ammonium acetate extraction method (Tüzüner, 1990). Lime ($CaCO_3$) was determined by Scheibler calsimeter method (Tüzüner, 1990). Total salt content was determined in a soil saturation paste (Tüzüner, 1990). Boron (B) was determined spectrophometric method (Kacar, 1994). Exchangeable copper (Cu), zinc (Zn) and iron (Fe) were determined

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by atomic adsorption spectrophotometric method (Kacar, 1994).

Sugar beet yield in 2001 and wheat yield in 2002 were estimated by clipping the plants at ground level from one m^2 quadrats adjacent to the soil core sampling sites.

The soil losses of the research field were identified according to the Universal Soil Loss Equation (USLE) (Wischmeier *et al.*, 1971; Wischmeier and Smith, 1975). L and S factors were determined by making measurement in the fields. C factor was determined depending on the schedule of crops, with USLE method (Oğuz, 1997; Oğuz and Noyan, 2000). Soil erodibility (K Factor) was determined with the nomograph from clay, silt, very fine sand and organic matter contents (Wischmeier and Smith, 1978). At this time the application of USLE method, stone cover, profile permeability and topsoil aggregation were taken into account. R factor was used in the equation according to the research results (Oğuz, 1997). P factor was used as one, because contour tillage was not done.

In order to use USLE factor values in the equation, soil loss values are identified for each field as ton ha^{-1} (Wischmeier and Smith, 1975).

Soil specifications of the work area are identified by chemical analysis. Crop productivity is identified by the collected plant samples. The soil loss of the work area is calculated with the help of USLE. Soil specifications, crop productivity and soil losses were taken into considereration altogether to identify the effect of erosion on soil specifications, crop productivity and nutritian specifications.

Statistical analysis and several comparisons were made among the soil loss, crop productivity and soil properties. Regression and correlation analysis between soil losses, crop yields and soil properties were used (Minitab Inc., 2000).

RESULTS AND DISCUSSION

Some correlation coefficients between soil losses and soil properties and some statistical analysis are given in Table 1 and 2, respectively.

Soil loss: Calculated soil losses were determined between 0.296-10.016 ton ha^{-1} (Table 2). The study area was grouped in two erosion classes. Slightly erosion class has 0-3 ton ha^{-1} and moderate erosion class has 3 < ton ha^{-1} soil losses.

All soil samples collected from the slopes varied between 0.6-10%. Slopes were grouped in two erosion classes (Table 3). Average slopes were determined as 0.84 and 4.83% in slightly and moderately erosion classes, respectively.

Effects of erosion on crop yields: Sugar beet yields varied from 21.92 to 138.86 ton ha^{-1} and significantly correlated with soil losses ($R = -0.247$). Wheat yields

Table 1: Correlation coefficients between soil losses and soil properties

Soil properties	Correlation coefficient
Sand	0.348**
Clay	-0.279**
Silt	-0.051ns
Ca CO_3	0.188*
P_2O_5	0.099ns
K_2O	-0.080ns
B	-0.037ns
PH	-0.361**
Salt	-0.193*
Organic matter	-0.041ns
CEC	-0.130ns
Fe	0.095ns
Cu	-0.193*
Mn	0.174ns
Zn	0.127ns
Cd	0.083ns

NS: Non-significant, *, **significant and highly significant, respectively

Table 2: Minimum, maximum, median, mean and standard deviation values of soil properties, crop yields and soil loss

Variable	N	Minimum	Maximum	Median	Mean	SD
Sand (%)	121	6.760	69.410	29.720	30.870	12.300
Clay (%)	121	4.080	65.480	33.250	34.980	13.840
Silt (%)	121	16.890	70.060	34.560	34.144	8.100
$CaCO_3$ (%)	121	6.800	43.600	13.100	14.133	5.508
P (ppm)	121	2.390	103.360	14.000	18.280	14.120
K (ppm)	121	56.400	643.900	215.700	248.800	123.500
B (ppm)	121	0.090	27.000	0.270	0.550	2.430
pH	121	7.430	8.490	7.840	7.886	0.184
Salt (%)	121	0.010	0.076	0.027	0.029	0.013
Organic matter	121	0.290	2.610	1.270	1.295	0.477
CEC (me100 g^{-1})	121	10.000	42.520	23.210	23.803	6.996
Fe (ppm)	121	4.800	52.740	12.980	14.454	7.578
Cu (ppm)	121	0.660	7.400	3.680	3.715	1.220
Mn (ppm)	121	4.420	39.320	18.080	18.307	6.483
Zn (ppm)	121	0.070	3.220	0.300	0.394	0.376
Cd(ppm)	121	0.000	0.040	0.020	0.021	0.009
Sugar beet yield (ton ha^{-1})	121	21.920	138.860	94.320	92.510	23.720
Wheat yield (ton ha^{-1})	121	0.960	5.700	3.110	3.119	1.003
Soil loss (ton ha^{-1})	121	0.296	10.016	0.962	1.585	1.651

Table 3: Slope for slightly and moderately eroded sites

	Slope(%)		
Erosion level	Mean	Range	SD
Slight	0.84	0.6-5.0	0.82
Moderate	4.83	3.0-10	2.04

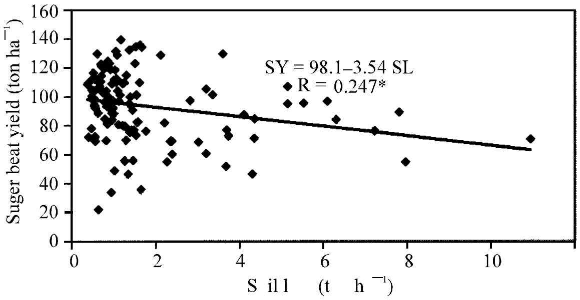

Fig. 1: Relationships between sugar beat yield and soil loss

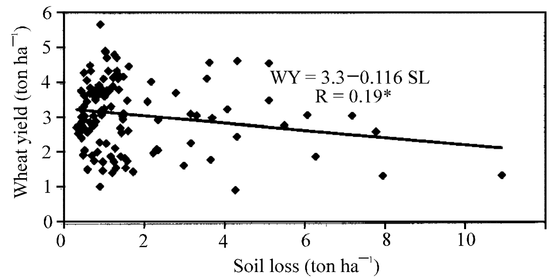

Fig. 2: Relationships between wheat yield and soil loss

varied from 0.96 to 5.70 ton ha^{-1} and significantly correlated with soil losses (R = −0.190) (Table 4, 5, Fig. 1 and 2).

Increased soil loss depending on the decrease in surface soil amount, soil nutrition element and negative changes in the soil properties caused decrease in the productivity.

Table 4: Soil loss, sugar beat yield and wheat yield on 121 farm fields

Field No.	Soil loss (ton ha^{-1})	Sugar beat yield (ton ha^{-1})	Wheat yield (ton ha^{-1})	Field No.	Soil loss (ton ha^{-1})	Sugar beat yield (ton ha^{-1})	Wheat yield (ton ha^{-1})	Field No.	Soil loss (ton ha^{-1})	Sugar beat yield, (ton ha^{-1})	Wheat yield (tonha^{-1})
1	0.296	107.85	2.76	42	0.778	122.52	3.78	83	1.345	122.34	3.08
2	0.328	71.44	2.59	43	0.798	91.31	3.97	84	1.350	134.00	2.99
3	0.384	110.58	2.66	44	0.806	118.22	3.91	85	1.358	72.51	4.21
4	0.393	77.56	2.89	45	0.814	90.27	2.33	86	1.371	100.27	3.16
5	0.398	99.46	3.81	46	0.825	33.45	1.08	87	1.391	81.34	1.88
6	0.399	97.57	3.05	47	0.834	87.69	5.70	88	1.410	81.82	1.60
7	0.403	104.00	2.46	48	0.835	108.16	3.19	89	1.441	108.82	3.53
8	0.426	102.71	3.33	49	0.842	94.69	3.73	90	1.449	127.79	3.50
9	0.426	115.85	3.25	50	0.845	83.14	3.88	91	1.469	35.67	2.67
10	0.441	112.03	1.97	51	0.860	96.48	3.25	92	1.490	134.99	1.80
11	0.447	98.12	2.98	52	0.861	91.19	3.11	93	1.583	75.51	1.50
12	0.452	93.57	3.36	53	0.882	87.40	3.21	94	1.909	133.69	4.52
13	0.460	111.60	4.32	54	0.889	111.09	1.53	95	1.992	81.20	4.06
14	0.462	92.78	3.67	55	0.890	48.39	1.77	96	2.040	54.35	2.02
15	0.467	103.56	2.74	56	0.906	117.91	4.15	97	2.116	68.65	2.13
16	0.467	92.60	4.33	57	0.923	130.84	3.30	98	2.147	68.57	2.11
17	0.468	71.69	2.09	58	0.926	109.17	3.64	99	2.154	59.58	2.97
18	0.469	91.11	3.08	59	0.942	111.67	4.95	100	2.551	96.36	3.74
19	0.475	68.49	2.11	60	0.952	128.07	4.91	101	2.735	67.96	1.68
20	0.521	129.05	4.11	61	0.962	103.33	2.30	102	2.902	59.89	2.30
21	0.523	110.02	3.49	62	0.984	79.57	4.75	103	2.902	104.58	3.14
22	0.539	21.92	1.56	63	0.987	96.17	3.82	104	3.040	100.49	3.09
23	0.540	87.86	2.62	64	1.016	100.29	4.38	105	3.265	129.11	4.15
24	0.574	106.62	2.67	65	1.033	138.86	3.80	106	3.330	51.35	4.61
25	0.592	109.78	2.90	66	1.068	108.38	1.92	107	3.353	76.01	1.83
26	0.592	104.33	3.73	67	1.075	79.03	3.36	108	3.392	72.05	3.02
27	0.599	121.75	4.54	68	1.104	109.00	1.46	109	3.729	86.71	3.27
28	0.605	113.84	3.89	69	1.119	54.98	3.94	110	3.911	45.83	0.96
29	0.619	120.01	4.38	70	1.123	78.51	4.18	111	3.959	70.60	2.48
30	0.635	102.09	1.96	71	1.142	69.20	1.77	112	3.964	83.84	4.66
31	0.680	95.51	3.09	72	1.150	114.17	4.85	113	4.692	94.32	4.60
32	0.681	83.71	2.82	73	1.166	77.46	2.16	114	4.693	106.49	3.52
33	0.685	118.90	1.81	74	1.189	45.89	1.60	15	5.049	94.74	2.81
34	0.713	103.29	3.82	75	1.213	94.00	4.75	116	5.568	96.06	3.11
35	0.715	69.21	3.64	76	1.216	131.75	4.39	117	5.762	83.14	1.91
36	0.719	122.96	3.6	77	1.221	74.67	4.30	118	6.603	75.31	3.08
37	0.726	92.20	3.55	78	1.238	99.03	4.15	119	7.145	88.26	2.62
38	0.731	80.22	2.93	79	1.259	76.00	3.84	120	7.301	54.10	1.37
39	0.741	123.98	3.68	80	1.290	89.70	2.74	121	10.016	69.83	1.36
40	0.745	99.38	3.70	81	1.299	55.25	1.93				
41	0.764	93.97	2.05	82	1.313	75.91	2.60				

Table 5: Regression equations of sugar beet and wheat yields

Dependent variable	Regression equation	R
Sugar beet yield (SY)	SY = 98.1-3.54 SL	0.247**
Wheat yield (WY)	WY = 3.3-0.12 SL	0.190*

SL: Soil Loss, *, **significant and highly significant, respectively

Table 6: Mean, range and SD of crop yields on slightly and moderately eroded sites

	Crop Yield, (ton ha^{-1})							
	Sugar beet				Wheat			
Erosion level	N	Mean	Range	SD	N	Mean	Range	SD
Slight	103	94.33	21.92-138.86	23.84	103	3.15	1.08-5.70	0.98
Moderate	18	82.12	45.83-129.11	20.61	18	2.91	0.96-4.66	1.14

SD: Standard Deviation

Table 7: Mean, range and SD of topsoil textures on slightly and moderately eroded sites

	Sand (%)			Silt (%)			Clay (%)			
Erosion level	Mean	Range	SD	Mean	Range	SD	Mean	Range	SD	Texture class
Slight	29.63	6.76-69.41	12.19	34.61	16.89-70.06	8.33	35.76	4.12-65.48	14.04	CL
Moderate	37.98	23.35-59.18	10.63	31.50	22.45-43.30	6.15	30.52	4.08-49.10	12.08	CL

SD: Standard Deviation

Sugar beet and wheat yields according to erosion class are given in Table 6. There were significant differences between two erosion classes. The slightly eroded sites had the highest yield compared to the moderate erosion class. At the moderate eroded site, sugar beet and wheat yield decreased to 12.9 and 7.6%, respectively compared to the slight erosion class. Meanwhile, Mokma and Sietz (1992) stated that; on the corn crop in Michigan, the severely eroded plots, produced 21% less grain than the slightly eroded plots. Besides, the impact of erosion on soil productivity was assessed for a Typic Hapludox on the Eastern Plains of Colombia for an upland rice crop (*Oryza sativa*). The results demonstrate that the influence of erosion on crop productivity is complex and simple relationships with changes in soil quality variables and with crop yields may often be confounded by other factors (Obando and Stocking, 2001).

Effects of erosion on soil properties: In the texture of soil samples, sand content changed between 6.76-69.41%, silt content changed between 16.89-70.06% and clay content changed between 4.08-65.48% (Table 1).

The correlations between soil loss and soil texture were investigated. Positive correlation between the soil loss and sand, negative correlation between soil loss and clay and no correlation between soil loss and silt were detected. Because there is not sufficient structural development in the research fields in which, small clay fractions were carried with soil erosion away from the environment. Larger sand particles were carried away less than clay particles, because sand was increased proportionally in the places where erosion was high.

Fullen and Brandsma (1995) indicated that, sand content has been increased, where silt and clays contents have been decreased in the study areas which received in total 46.2 ton ha^{-1} rainfall for six years in England. In another research carried out in West Ohio, clay content increased while silt content decreased when the soil erosion levels increased (Ebeid *et al*., 1995).

There were significant differences between two erosion classes (Table 7). The moderate eroded sites had the high sand content, low silt and clay content as compared to the slightly erosion class. At the moderate eroded site, sand content increased by 28.18%, silt and clay content decreased 8.98 and 14.65%, respectively compared to the slightly erosion class. Depending on the intensity of the erosion, the sand content of the upper soil layer was increasing while silt and clay contents were decreasing with the decreasing amount of water. Despite the textural changes texture classes remained unchanged in both of the erosion classes.

The $CaCO_3$ content varied between 6.8-43.6%, $CaCO_3$ content was significantly correlated with soil losses (R = 0.188). The positive correlation between the soil loss and the $CaCO_3$ content is caused by the $CaCO_3$ accumulation because the $CaCO_3$ layer came closer to the surface with the help of the surface erosion which caused increase in the lime content. The accumulation of the lime, removed from the main lime material with capillarity, close to the surface area increases this effect. On the other hand increase in the lime content could have effected the structure stability. The decrease in structure stability depending on the lime can cause an increase in the soil erodibility. According to Castro and Logan (1991), liming increased soil erodibility because of structural degradation in the short term.

At the moderately eroded site, $CaCO_3$ content increased by 21.1%, compared to the slight erosion class (Table 8).

The pH value varied between 7.43-8.49. pH content was significantly correlated with soil losses (R = −0.361). In the fields highly subjected to soil loss, a positive correlation among the clay content, adsorbed hydrogen

Table 8: Mean, range and SD of lime, pH, salt and CEC on slightly and moderately eroded sites

	Slight			Moderate		
Soil	Mean	Range	SD	Mean	Range	SD
$CaCO_3$ (%)	13.700	6.8-43.6	5.53	16.600	11.9-27.8	4.78
pH	7.920	7.56-8.49	0.18	7.710	7.43-7.86	0.12
Salt (%)	0.030	0.011-0.076	0.01	0.026	0.010-0.055	0.01
CEC (cmol kg^{-1})	23.950	10.00-42.52	6.96	22.970	14.87-36.66	7.33

Table 9: Mean, range and SD of P_2O_5, K_2O, organic matter, B, Cu, Fe, Zn and Mn on slightly and moderately eroded sites

	Slight			Moderate		
Soil	Mean	Range	SD	Mean	Range	SD
P (ppm)	17.92	2.39-103.36	13.00	20.38	3.81-90.76	19.72
K (ppm)	248.60	56.40-643.90	128.70	250.20	116.20-461.30	90.60
OM (%)	1.29	0.29-2.57	0.48	1.32	0.88-2.61	0.47
B (ppm)	0.59	0.09-27.00	2.63	0.30	0.18-1.10	0.21
Cu (ppm)	3.78	0.66-7.40	1.25	3.32	2.26-5.72	0.98
Fe (ppm)	14.05	4.80-37.42	6.63	16.78	5.16-52.74	11.61
Zn (ppm)	0.36	0.07-2.08	0.29	0.56	0.20-3.22	0.68
Mn (ppm)	17.57	4.42-31.98	6.18	22.53	15.26-39.32	6.74

*Organic matter, SD: Standard Deviation

ions and pH were found. In the fields which were subject to slight soil loss, higher clay amount and adsorbed hydrogen ions increased the pH value. Increased clay ontent increase the adsorbed hydrogen ions (Sezen, 1991). On the other hand, the changes in the pH values depending on
the clay amount were investigated and very important positive correlation was found. In a research carried out in England, in fields having artificial erosion, it was observed that the pH value decreased from 5.55 to 5.05 (Fullen and Brandsma, 1995).

At the moderate eroded site, pH value decreased, compared to the slight erosion class (Table 8). This result is caused because there is more clay contained in slight erosion compared to moderate erosion class (Table 7). Higher clay content increased adsorbed hydrogen ions and decreased pH.

The salt content of the research fields varied between 0.010-0.076%. Salt content was significantly correlated with soil losses (R = −0.193). The salt contents decreased with soil loss, with the help of the surface flow in addition to erosion the salt dissolved and accumulated in less erodible areas. In the research area increased soil loss was calculated with increasing slope. For this reason, salt movement was higher where there was higher slope and higher soil loss, with increasing surface flow, thus the salt content increased.

At the moderate eroded site, salt content increased 13.3%, compared to the slightly erosion class (Table 8).

The CEC content of the research fields changed between 10.00-42.52 cmol kg^{-1}. There was not a significant relation between soil loss and CEC. According to a research carried out in West Ohio, the cation exchange capacity of the soil increased as the erosion increased (Ebeid *et al.*, 1995).

At the moderately eroded site, CEC decreased 4%, compared to the slight erosion class (Table 8). The decrease observed in CEC observed, In the moderately eroded site where there was higher soil loss, compared to slightly eroded site, was caused by the decrease in the clay content because of the soil loss.

Effects of erosion on nutrients: The Cu contents of the research area varied between 0.66-7.40 ppm (Table 9). The Cu contents was significantly correlated with soil losses (R = −0.193). The decrease in the Cu content of the surface soil as the soil loss increases was considered as the soil loss secondary effect depending on the decrease on clay content of the soil with erosion.

The P contents of the research area changed between 2.39-103.36 ppm (Table 9). There was not a significant relation between soil loss and P contents. Phosphorus contents decreased 34, 28 and 38% for the Corvin, Miami and Morley soils, respectively, as soil erosion phase increased from slight to severe (Schertz *et al.*, 1985).

The K contents of the research area varied between 56.4-643.9 ppm (Table 9). There was not a significant relation between soil loss and K contents. In the work area field there were no K fertilization. The different K values in the soil were caused by main material specifications. In the fields where different soil losses were observed K values were different depending on the main material. For this reason no statistical relation was established between the K values and soil loss.

The organic matter contents of the research area changed between 0.29 and 2.61% (Table 9). There was no significant relation between soil loss and organic matter contents. Organic matter contents decreased significantly with increase of erosion for each of the Corwin, Miami and Morley soil series (Schertz *et al.*, 1985). In two different study carried out, one in West Ohio in USA and one in GAP region in Turkey, no significant relation was found between the organic material contents of the soil and the erosion amount (Ebeid *et al*., 1995; Taysun and Dağdeviren, 1991).

The B, Fe, Zn and Mn contents of the research area varied between 0.09-27 ppm, 4.8-52.74 ppm, 0.07-3.22 ppm and 4.42-39.32 ppm, respectively (Table 9). No statistical relation was found between B, Fe, Zn and Mn contents. In the work area field there were no B, Fe, Zn and Mn fertilization. The different B, Fe, Zn and Mn values in the soil were caused by main material specifications.

In this research, it was observed that, with the increase of the soil loss, sugar beet and wheat yields were decreased.

There were positive correlation between soil loss and sand and $CaCO_3$ contents of the soils. Moreover, negative correlation was found between soil loss and clay, pH, salt and Cu contents of the soils.

No relation was found between soil loss and silt, CEC, P, K, organic matter, B, Fe, Zn and Mn content of the soil.

The decreasing effects of erosion on the crop productivity might be caused by the negative changes in physical and chemical properties in soils. In two different erosion classes, the productivity loss observed was 7.6% for wheat and 12.9% for sugar beet.

If cultural precautions will not be taken in Kazova which has a very high agricultural potential, the decrease in the agricultural productivity will continue. Taking into consideration the factors effecting the productivity, precautions to develop the physical and chemical properties of the soil should be taken.

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