African Journal of Agricultural Research Vol. 5(10), pp. 1127-1137, 18 May, 2010
Available online at http://www.academicjournals.org/AJAR
ISSN 1991-637X © 2010 Academic Journals

Full Length Research Paper

Spatial analysis of some physical soil properties in a saline and alkaline grassland soil of Kayseri, Turkey

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Accepted 20 April, 2010

In this study, geostatistical analysis of electrical conductivity (EC) and soil pH values, soil clay (C), silt (Si), and sand (S) content, permanent wilting point (PWP), organic matter (OM), field capacity (FC) and water stable aggregates (WSA) were investigated in 1500 ha degraded grassland of Kayseri, Turkey. Coefficients of variations (CVs) of EC (125 -103 dS m^{-1}) were higher than the other soil properties while the lowest CV was found for pH (5 - 5) in 0 - 30 (D1) and 30 - 60 cm (D2) depths. To summarize the relationships among examined soil properties, Pearson Correlation analysis was performed and significant correlations were found between LnEC-LnpH and selected physical soil properties for D1 and D2 ($p<0.01$ and $p<0.05$). Independent sample t-test indicated that the means of EC and organic matter content of soil (OM) were statistically different while there were no differences for the others ($p<0.05$). In geostatistical analysis, exponential model was fitted to experimental variograms for LnEC, LnC, SqSi, and LnS of D1 and LnEC of D2, while spherical model was used for LnpH, SqOM, PWP, SqFC, and SqWSA of D1 and LnpH, LnC, SqSi, LnS, SqOM, PWP, FC, and SqWSA of D2. Selected soil variables showed different degree of spatial correlation. Kriging maps showed environmentally risky areas of the study site.

Key words: Salinity, alkalinity, geostatistics, spatial variation, kriging.

INTRODUCTION

Land use change is a significant problem in wetland ecosystems of Turkey. Several wetlands were dried out to gain cropland and grassland and to avoid malaria. Approximately, there are 200.000 ha dried wetlands in Turkey, but most of the dried wetlands didn't become fertile as expected and territory became infertile because of salinity and wind erosion (Timur, 2008). Prathapar and Qureshi (1999) and Ali et al. (2000) investigated and discussed in detail the effects of quality of irrigation water, irrigation strategy, soil type, ground water quality and depth on salinisation of soils. High soil salinity and alkalinity restricts crop growth by reducing the osmotic potential, decreasing nutrient availability and soil physical quality parameters.

According to Richards et al. (1956) soluble salts affect productivity of soils in two principal ways: changing the osmotic potential of soil solution and increasing the content of exchangeable sodium. Alkaline soils are characterized by exchangeable sodium contents and sodium attached to clay surfaces can increase clay dispersion. Dispersion of clay particles can restrict air and water transport in soil profile and could promote soil erosion and total loss of soil (Quirk and Schofield, 1955; Dougherty and Anderson, 2001; Inakwu et al., 2008).

Reclamation of saline, alkaline, and saline-alkaline soils require two measurements: leaching soluble salts with quality water and removing exchangeable sodium via gypsum application. But salinity and alkalinity can show very complex spatial variability in a site where different application of water and gypsum are required. Therefore, spatial variation of salinity and alkalinity can be determined using geostatistical methods and also results

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Abbreviations: EC, Electrical conductivity; **C,** soil clay; **Si,** silt; **S,** sand content; **PWP,** permanent wilting point; **OM,** organic matter; **FC,** field capacity; **WSA,** water stable aggregates; **CVs,** coefficients of variations; **GPS,** geographical position system.

of management practices can be monitored. The effective management of saline-alkaline soils requires understanding of not only the salinity sodicity continuum, but also of its spatial variation (Inakwu et al., 2008). Soil properties show spatial variation with intrinsic and extrinsic soil forming factors (Heuvelink and Webster, 2001). Soil scientists focused on predicting spatial variability of soil properties using geostatistics and different kriging methods over small to large spatial scale (Yost et al., 1982; Trangmar et al., 1987; Miller et al., 1988; Voltz and Webster, 1990; Chien et al., 1997; Tsegaye and Hill, 1998; Lark, 2002; Bo et al., 2003).

Samra et al. (1988) investigated spatial variability in sodic soils. Cemek et al. (2007) investigated spatial variability of some soil properties as related to salinity and alkalinity. They inferred that the strong spatial dependency of soil properties may have resulted from extrinsic factors such as ground water level, drainage and irrigation systems. Dhillion et al. (1994) used pH as an indicator of soil fertility in strategies based on spatial analysis of plant nutrients. Sultan Marsh is one of the largest and most important wetlands in Turkey, Middle East and Europe, embodying saline and fresh water ecosystems together and provides a shelter for 426 bird species. It was taken under protection by the International Ramsar Treaty (ÇEVKO, 1998). Saraycık Grassland is located 20 km northwest of Sultan Marhs. Drainage canals were excavated in Sultan Marsh to avoid malaria and to gain cropland or grassland after 1940 (Karadeniz, 1995). Similar drainage cannels were also excavated in Saraycak Grassland and the area was opened to grazing. Objectives of this study were to investigate and interpret spatial relationships and spatial variation of EC, soil pH, soil organic matter content, soil clay, silt, and sand content, permanent wilting point, field capacity and water stable aggregates in saline and alkaline grassland soil of Kayseri, Turkey.

MATERIALS AND METHODS

Study area

The study area is located in Saraycık Grassland, covering an area of 28 km^2, approximately 15 km southeast of Kayseri and 20 km northwest of Sultan Marsh, Turkey. Sultan Marsh is one of the largest and most important wetlands in Turkey, Middle East and Europe, embodying saline and fresh water ecosystems, providing a shelter for 426 bird species, and was taken under protection by the International Ramsar Treaty (ÇEVKO, 1998). Saraycik grassland is located in saline water ecosystems of Sultan Marsh. There is a Salt lake in the south part of the grassland. The average temperature and annual precipitation of the region are 10.4°C and 397 mm. The elevations of the study area vary from 1026 to 1036 m above sea level. (Figure 1) Dry grass yield of the study area changes between 10 - 50 kg da^{-1}.

Soil sampling and analysis

A total of 160 soil samples were collected in grassland in March 2008 with irregular intervals from 0 - 30 and 30 - 60 cm soil depths. Mean sampling distance was 592 m. The soil color variation, field water table condition and vegetation density were taken into account in selecting the sampling sites. Geographical Positioning System (GPS) was used to determine coordinates of the sampling locations.

Soil clay (C), silt (Si), and sand (S) contents were analyzed in accordance with Soil Survey Staff (1996). The method of Nelson and Sommers (1982) was used to determine soil organic matter (OM). Soil pH and EC were determined in 1: 2, 5 soil-water suspensions. Permanent wilting point (PWP) and field capacity (FC) were determined according to Cassel and Nielsen (1986). Saturated hydraulic conductivity was performed according to Klute and Dirksen (1986). Soil samples were analyzed for aggregate stability with wet sieving apparatus, and the percent of water-stable aggregates (WSA) in 1.00 - 2.00 mm size was calculated by:

$$WSA = \frac{\left(M_{(a+s)} - M_s\right)}{\left(M_t - M_s\right)} x100 \qquad (1)$$

Where $M_{(a+s)}$, M_s and M_t are the mass of the resistant aggregates plus sand (g), the sand fraction alone (g), and the sieved oven-dried soil (g), respectively.

Statistical analysis

The mean, standard deviation (SD), minimum-maximum values, coefficient of variation (CV), skewness, and kurtosis were calculated for considered variables. The Kolmogorov-Smirnov test (K-S test) and the Pearson correlation analysis were, respectively, conducted for the conformance to a normal distribution of data and for the examination of relationships between the selected soil properties (SPSS - 10) was used for statistical analysis.

Geostatistical analysis

Experimental semivariogram for the separation distance (lag) h were calculated for the investigated soil properties (Matheron, 1965; Journal and Huijbregts, 1978; Burgess and Webster, 1986ab; Trangmar et al., 1985):

$$\gamma^*(h) = \frac{1}{2N(h)} \sum_{i=1}^{N(h)} \left[z(x_i) - z(x_i + h)\right]^2 \qquad (2)$$

Where $z(x_i)$ was the value of the measured soil properties at spatial location x_i and $N(h)$ was the number of pairs with a distance of (lag) h. The spherical and exponential models were fitted to the experimental semivariograms. All geo-statistical computations were conducted by the software package GS +5.1.

RESULTS AND DISCUSSION

Descriptive statistics of soil properties

Descriptive statistics of some physical and chemical soil properties such as minimum, maximum, mean, SD, CV, skewness, kurtosis and K-S coefficient were given in Tables 1 and 2 for D1 and D2. Large differences were

Table 1. Descriptive statistics for 0-30 cm soil depth (n = 80).

Soil properties	Min.	Max.	Mean	S.D.	C.V	Skewness	Kurtosis	K-S
C	3.45	66.38	30.29	18.24	60	-0.04	-1.33	0.05
Si	1.43	75.48	35.21	18.32	52	0.66	-0.83	0.006
S	10.85	94.09	34.49	13.41	39	1.77	4.72	0.03
pH	7.95	9.67	8.69	0.43	5	0.288	-0.78	0.05
EC	0.13	58.60	9.96	12.49	125	2.00	4.14	0.001
OM	0.03	13.25	3.44	2.58	75	1.36	1.69	0.002
PWP	4.20	50.15	29.85	9.20	31	-0.28	0.14	0.94
FC	7.56	115.90	51.75	19.71	38	1.15	2.29	0.03
WSA	0.27	45.71	10.80	10.57	98	1.38	1.48	0.006

C: Clay (%), Si: Silt (%), S: Sand (%), EC: Electrical conductivity (dS), OM: Organic matter (%), PWP: Permanent willing point (%), FC: Field capacity (%), WSA: Water stable aggregates (%), S.D.: Standard deviation, C.V.: Coefficient of variation, K-S: Coefficient of Kolmogorav-Smirnow

Table 2. Descriptive statistics for 31- 60 cm soil depth (n = 80)

Soil properties	Min.	Max.	Mean	S.D.	C.V	Skewness	Kurtosis	K-S
C	3.15	67.0	27.7	19.5	70	0.29	-1.28	0.02
Si	0.62	73.4	37.5	19.1	51	0.34	-1.24	0.01
S	17.2	93.4	34.6	12.5	36	1.65	4.96	0.05
pH	7.9	10.0	8.7	0.44	5	1.02	0.86	0.03
EC	0.24	63.1	14.8	15.3	103	1.56	1.90	0.003
OM	0.02	7.76	2.6	1.5	58	1.19	2.06	0.05
PWP	2.65	44.0	28.1	7.7	27	-0.43	0.68	0.83
FC	5.39	93.2	52.8	15.1	29	0.21	0.77	0.62
WSA	0.27	46.2	12.3	11.3	92	1.22	0.89	0.04

C: Clay (%), Si: Silt (%), S: Sand (%), EC: Electrical conductivity (dS), OM: Organic matter (%), PWP: Permanent willing point (%), FC: Field capacity (%), WSA: Water stable aggregates (%), S.D.: Standard deviation, C.V.: Coefficient of variation, K-S: Coefficient of Kolmogorav-Smirnow

found between minimum and maximum values of the investigated soil properties both of D1 and D2. While EC had the highest CVs (125 and 103), the smallest CVs were obtained at pH (5 and 5) in both soil depths. Cemek et al. (2007) indicated similar CVs for EC (57 for topsoil and 85 for subsoil) and pH (5 - 4.7). Especially, CVs of EC and OM were higher than the other soil properties for each soil depth. These large differences were attributed to spatial variation of the soil texture, micro topography and ground water level of the research area. The Kolmogorov-Smirnov test (K-S test) was performed to test the normality of data for soil properties. Results showed that C, Si, S, pH, EC, OM, FC, and WSA for D1 and C, Si, S, pH, EC, OM, and WSA for D2 were not normally distributed ($p<0.001$ and $p<0.05$). Not-normal distribution requires transformations to increase applicability of the statistical techniques based on the normality assumption. Logarithmic or Square Root Transformation was performed for not-normally disturbed variables. Transformed variables were tested again with K-S test whether they are normally distributed or not. Second K-S test showed that transformations were valid for each variable. These transformed values were used for all statistical and geostatistical analysis.

Relationships between soil properties

To summarize the relationships between examined soil properties, Pearson Correlation analysis were performed for D1 and D2 (Tables 3 and 4). Elevation had significant correlation with SqSi, LnEC, and SqOM (r = -0.341, -0.443, and -0.286). Water erosion transport and deposition processes may have increased Si content of soil in the lower sections. Beside this, micro topographic differences and ground water table may have also affected variation of EC and OM content. While significant negative relationships were found between LnS and PWP - SqFC (r = - 0.563 and - 0.428) for D1 and PWP - FC (r = -0.590 and -0.419) for D2, SqOM of both soil depths had positive correlations with PWP of D1, PWP of D2, SqFC of D1 and FC of D2 (r = 0.399, 0.223, 0.408, and 0.443, respectively).

SqWSA had positive correlation with LnS of D1 and D2

Table 3. Pearson correlation coefficients between selected soil properties for 0-30 cm soil depth (n=80).

Soil properties	H	LnC	SqSi	LnS	LnpH	LnEC	SqOM	PWP	SqFC
LnC	0.272*								
SqSi	- 0.341**	- 0.664**							
LnS	0.055	- 0.268*	- 0.371**						
LnpH	0.247*	0.524**	- 0.452**	- 0.025					
LnEC	- 0.443**	- 0.306**	0.622**	- 0.296**	- 0.214				
SqOM	- 0.286*	- 0.375**	0.433**	- 0.052	- 0.513**	0.355**			
PWP	- 0.444**	0.017	0.463**	- 0.563**	- 0.244*	0.562**	0.399**		
SqFC	- 0.432**	- 0.042	0.502**	- 0.428**	- 0.247*	0.601**	0.408**	0.741**	
SqWSA	- 0.199	- 0.299**	0.235*	0.074	- 0.441**	0.125	0.501**	0.265*	0.369**

**: p<0.01, *: p<0.05, LnC: Logarithmic transformed clay, SqSi: Square root transformed silt, LnS: Logarithmic transformed sand, LnpH: Logarithmic transformed pH, LnEC: Logarithmic transformed electrical conductivity, SqOM: Square root transformed organic matter, PWP: Permanent willing point, SqFC: Square root transformed field capacity, SqWSA: Square root transformed water stable aggregates, h: Elevation

Table 4. Pearson correlation coefficients between selected soil properties for 30-60 cm soil depth (n=80).

Soil properties	H	LnC	SqSi	LnS	LnpH	LnEC	SqOM	PWP	FC
LnC	0.296*								
SqSi	- 0.320**	- 0.744**							
LnS	0.059	- 0.265*	- 0.269*						
LnpH	0.158	0.454**	- 0.410**	0.036					
LnEC	- 0.330**	- 0.410**	0.551**	- 0.181	- 0.158				
SqOM	- 0.350**	- 0.182	0.341**	- 0.281*	- 0.314**	0.359**			
PWP	- 0.103	0.186	0.206	- 0.590**	- 0.056	0.313**	0.223*		
FC	- 0.408**	- 0.135	0.492**	- 0.419**	- 0.215	0.493**	0.443**	0.581**	
SqWSA	- 0.054	- 0.476**	0.265*	0.342**	- 0.336**	0.077	0.134	0.195	0.087

LnC: Logarithmic transformed clay, SqSi: Square root transformed silt, LnS: Logarithmic transformed sand, LnpH: Logarithmic transformed pH, LnEC: Logarithmic transformed electrical conductivity, SqOM: Square root transformed organic matter, PWP: Permanent willing point, FC: Field capacity, SqWSA: Square root transformed water stable aggregates, h: Elevation

(r = 0.074 and 0.342), while relationship between SqWSA and LnC was significantly negative for each soil depth (r = -0.299 and -0.476). These relationships between LnC and SqWSA can be related to high salinity or high exchangeable sodium percentage of the soil profile which could lead to dispersion of the clay fractions in the research area. Dispersion of alkaline and saline soils, restriction of root penetration, water and air movement were discussed in detail by Sumner (1993); Quirk and Schofield (1955) and Dougherty and Anderson (2001).

Differences between two soil layers

Table 5 shows t-test results of the soil properties. Equal variance assumed was used for each soil properties with t values to compare two different soil layers. According to t-test results, D1 and D2 had statistically different means for EC and OM. EC of D2 (14.8 dS m^{-1}) was statistically higher than EC of D1 (9.96 dS m^{-1}), while OM of D1 (3.46%) was found to be significantly lower than OM of D2 (2.6%) at significance levels of $p<0.01$ and $p<0.05$, respectively. However, there were no significant differences between two soil layers for the other soil properties.

Geostatistical analysis

Table 6 shows variogram models, parameters of the selected soil properties and elevation of the research area. The directional semivariograms calculated at the angles of 0° (N - S), 45° (NE - SW), 90° (E - W), and 135° (SE - NW) for the measured variables indicated no severe anisotropy. Therefore, omni-directional semi-variograms were obtained using the best fitting model by the cross-validation method, and the data were modeled with isotropic functions to determine the spatially dependent variance within the research area.

The values for each property at observation points were used for estimating the values at unknown points by the ordinary block kriging using parameters of the semi-variograms generated. Exponential model was fitted to experimental semivariograms for LnEC, LnC, SqSi, LnS,

Table 5. Differences between 0-30 cm and 30-60 cm for selected soil properties (n = 80).

Soil properties	Levene's test for equality of variance		*t*-test for equality of means	
	F	Significance	*t*	Significance (two tailed)
LnC	1.89	0.171	1.09	0.274
SqSi	0.88	0.349	-0.71	0.475
LnS	0.001	0.975	-0.239	0.811
LnpH	1.00	0.319	-0.327	0.744
LnEC	3.11	0.080	-2.86	0.005*
SqOM	7.03	0.009	2.02	0.045**
PWP	1.03	0.311	1.02	0.305
SqFC	0.912	0.341	-0.390	0.697
SqWSA	0.098	0.755	-0.796	0.427

LnpH: Logarithmic transformed pH, LnEC: Logarithmic transformed electrical conductivity, LnC: Logarithmic transformed clay, SqSi: Square root transformed silt, LnS: Logarithmic transformed sand, LnpH: Logarithmic transformed pH, LnEC: Logarithmic transformed electrical conductivity, SqOM: Square root transformed organic matter, PWP: Permanent willing point, SqFC: Square root transformed field capacity, SqWSA: Square root transformed water stable aggregates.

Table 6. Variogram model and parameters of two different soil depths (n = 80).

Variables	Soil depth	Model	Nugget effect (Co)	Sill (C+Co)	Co/ C+Co (%)	Range (m)	R^2
LnC	D1	Exponential	0.16	0.92	17	1320	0.831
LnC	D2	Spherical	0.32	1.15	28	4680	0.923
SqSi	D1	Exponential	0.59	2.56	23	680	0.642
SqSi	D2	Spherical	1.54	3.17	49	4260	0.879
LnS	D1	Exponential	0.11	0.21	52	21100	0.071
LnS	D2	Spherical	0.083	0.19	43	16400	0.587
LnpH	D1	Spherical	0.0011	0.0028	39	2000	0.332
LnpH	D2	Spherical	0.0011	0.0029	39	2800	0.624
LnEC	D1	Exponential	0.91	3.62	25	2640	0.891
LnEC	D2	Exponential	0.70	3.96	18	6060	0.946
SqOM	D1	Spherical	0.12	0.53	23	2600	0.539
SqOM	D2	Spherical	0.10	0.27	37	3000	0.858
PWP	D1	Spherical	29	86	34	1800	0.669
PWP	D2	Spherical	20	61	33	1300	0.475
SqFC	D1	Spherical	0.59	2.09	28	3070	0.731
FC	D2	Spherical	93	255	36	2900	0.813
SqWSA	D1	Spherical	0.80	2.61	31	3110	0.937
SqWSA	D2	Spherical	1.06	2.86	37	2580	0.888
h		Spherical	6.82	15.8	43	3680	0.862

LnpH: Logarithmic transformed pH, LnEC: Logarithmic transformed electrical conductivity, LnC: Logarithmic transformed clay, SqSi: Square root transformed silt, LnS: Logarithmic transformed sand, LnpH: Logarithmic transformed pH, LnEC: Logarithmic transformed electrical conductivity, SqOM: Square root transformed organic matter, PWP: Permanent willing point, SqFC: Square root transformed field capacity, FC: Field capacity, SqWSA: Square root transformed water stable aggregates, h: Elevation, D1: 0 - 30 cm soil depth, D2: 30-60 cm soil depth.

of D1 and LnEC of D2, while spherical model was provided the best fit for LnpH, SqOM, PWP, SqFC, and SqWSA of D1 and LnpH, LnC, SqSi, LnS, SqOM, PWP, FC, and SqWSA of D2. Elevation was also modeled with spherical. Because of short range variation of variables and measurement errors, some nugget effects occurred for each variable.

Because of intrinsic and extrinsic soil forming factors, different spatial relationships were determined for investigated variables. Trangmar et al. (1985) and Goovaerts (1997) indicated that sampling intervals influence the semivariogram range. In this study, the spatial correlations of LnC and SqSi of D1 (1320 and 680 m, respectively) were much lower than spatial correlation of LnC and SqSi of D2 (4680 and 4260 m, respectively). Transportation and deposition processes because of

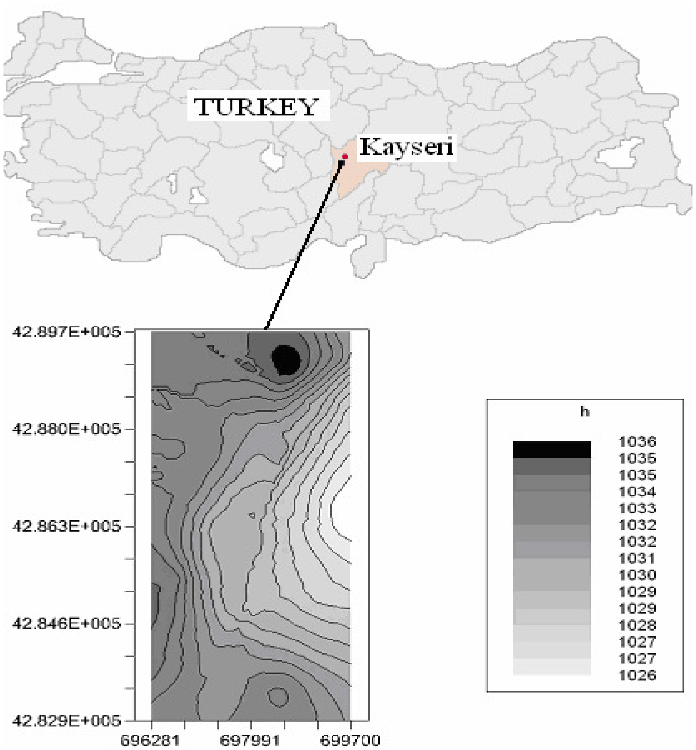

Figure 1. Study area and variation of elevation.

water and wind erosion interaction in the research area could have decreased the spatial correlation of SqSi and LnC of D1. Spatial correlation of SqOM of D1 and D2 were 2600 and 3000 m. The range of SqOM for surface soil layer could be related to spatial variation of vegetation density while the spatial correlation of SqOM could be effected from decomposition conditions of D2. The spatial correlations of LnpH and LnEC of D1 (2000 and 2640 m, respectively) were much lower than spatial correlation of LnpH and LnEC of D2 (2800, and 6060 m, respectively). Micro topographic differences, temporal variation of ground water table and quality and variation of soil characteristics could lead to short range spatial relationships of LnpH and LnEC of D1. Pozdnyakova and Zhang (1999) found spatial range of 700 m in 3375 ha with 200 x 200 m grid sampling distance for EC. Kilic and Kilic (2007) obtained 169 -150 m spatial correlations for EC and 210 -177 m for pH in 0 - 30 and 31 - 60 cm soil layers with 10 x 10 m grid sampling of 5000 m^2 area. Spatial correlation of PWP and SqFC of D1 (1800, 3070 m) were found to be slightly higher than PWP and FC of D2 (1300 and 2900 m) which could be related to cross dependence of C, S, EC and OM in the research area. Gajem et al. (1981) investigated spatial correlation of soil water contents at -0.10 and -1.50 Mpa. They found a geostatistical range of 0.6 m for -1.50 MPa with 20 cm sampling interval and of 15 m with 20 m sampling interval. They also found similar increase in spatial correlation at -0.10 MPa. According to Vauclin et al. (1983) spatial range at -0.033 MPa was 26.0 m in a 70 x 40 m field. Ersahin and Brohi (2006) calculated approximately 350 and 480 m spatial relationships at -0.033, -0.10, and -1.50 MPa in topsoil and subsoil with 25 m sampling intervals.

Geostatistical range of SqWSA of D1 and SqWSA of D2 were 3110 and 2580 m. Spatial correlation of topsoil was higher than the subsoil. That was due to higher particulate organic matter content of the topsoil than subsoil because of recently accumulated organic debris in the research area. It was already stated that particulate organic matter content could promote macro aggregate stability of the study area. Basaran et al. (2008) stated that WSA had spatial range of 175 m for grassland and of 375 m for woodland. They also reported that woodland had significantly higher particulate organic matter content than grassland for surface soil layer. According to the classification of Chien et al. (1997) by the nugget-to-sill ratio (C_0/ (C_0+C), LnC, SqSi, LnEC, and SqOM of D1 (17, 23, 25, and 23% respectively) had strong and LnS, LnpH, PWP, SqFC, and SqWSA of D1 (52, 39, 34, 28, and 31%, respectively) had medium spatial dependencies. Spatial dependencies of D2 was strong only for LnEC with 18% while medium spatial were determined for LnC, SqSi, LnS, LnpH, SqOM, PWP, FC, and SqWSA for D2 (28,49, 43, 39, 37, 33, 36, and 37%, respectively).

Spatial pattern of soil properties

Spatial pattern of salinity and alkalinity

Spatial variation of EC and pH indicated that the study area was very complex with respect to salinity and alkalinity (Figure 2). There were significantly different spatial patterns of EC (Figures 2a and b) and pH (Figures 2c and d) for two soil depths, but each soil properties showed similar spatial variation with soil depth. While the west part had higher values of EC, higher pH was determined at the southeast part of the study area for both soil depths.

These indicate that the west part of the research area could have higher soluble sodium content and lower ESP, while the southeast part could have higher ESP and lower soluble sodium content. Tables 7 and 8 show CEC, ESP, pH, and EC values of selected soils in the study area. Minimum and maximum values of ESP had large differences (0.85 - 57.7 and 2.03 - 97.1 for D1 and D2, respectively). Mean ESP values also indicated that the research area affected not only by salinity but also by alkalinity.

There were relationships between micro topography and EC-pH in the kriging maps. Higher values of EC were found on the lower area, while the higher areas had higher pH values. Especially, significant negative correlation was found between h and EC, and statistically positive correlation was determined between h and pH for D1 (Table 3). This could be due to high water table and

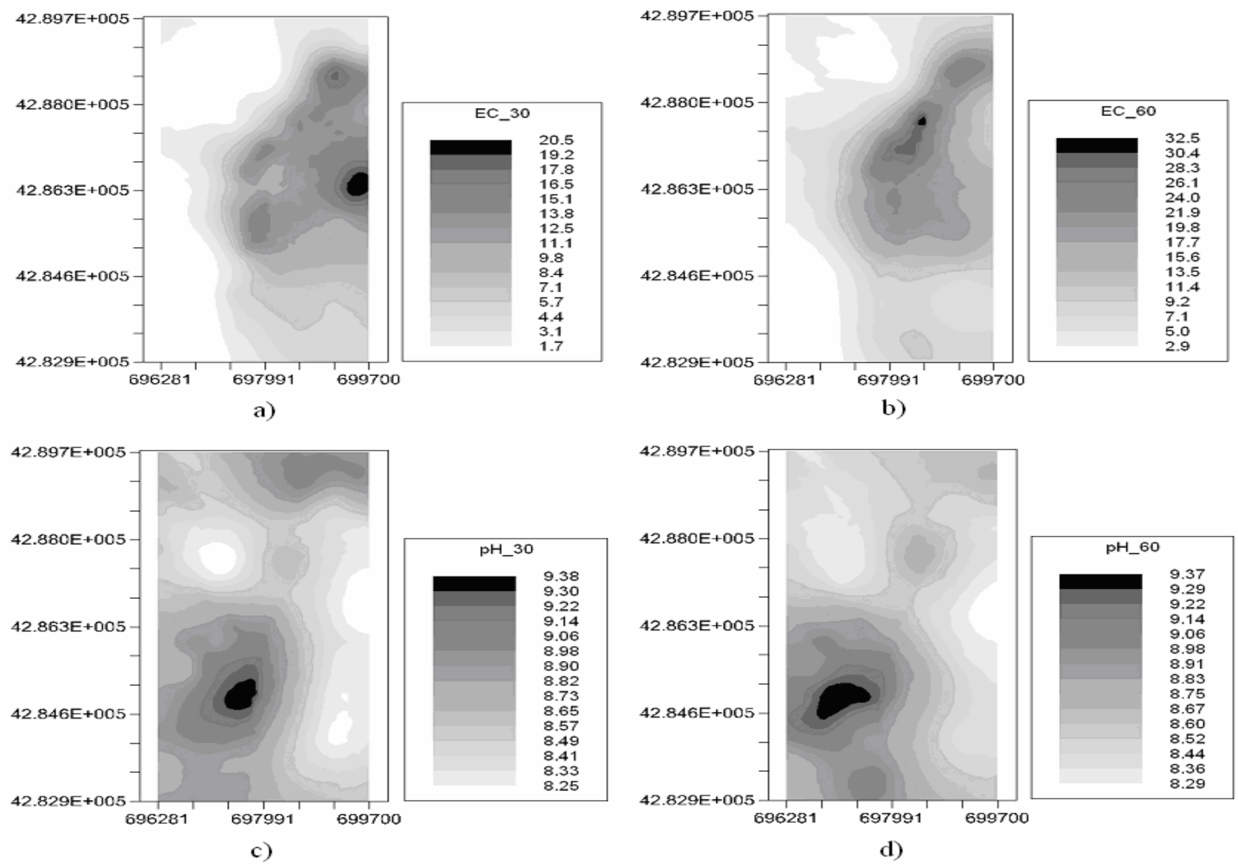

Figure 2. Spatial patterns of EC and pH for both soil depths.

Table 7. Descriptive statistics of some soil properties for 0 -30 cm soil depth (n = 7)

Soil properties	Min.	Max.	Mean	S.D.
CEC	13,43	44,51	29,22	9,80
ESP	0,85	57,7	34,27	20,63
pH	8,13	9,55	8,74	0,45
EC	0,25	20,60	9,91	8,1

CEC; Cation exchange capacity (me $100g^{-1}$), ESP; exchangeable sodium percentage (%); EC; Electrical conductivity (dS m^{-1}).

Table 8. Descriptive statistics of some soil properties for 31- 60 cm soil depth (n =7)

Soil properties	Min.	Max.	Mean	S.D.
CEC	11,66	40,51	23,45	9,14
ESP	2,03	97,1	46,16	33,02
pH	8,45	9,63	8,80	0,40
EC	0,38	54,50	21,80	18,47

CEC; Cation exchange capacity (me $100g^{-1}$), ESP; exchangeable sodium percentage (%); EC; Electrical conductivity (dS m^{-1}).

poor ground water quality of the study area. Douaik et al. (2006) reported that elevation was a major concern in soil salinization. The other factors may be groundwater depth and chemical composition.

Soil erosion risk and soil organic matter

As mentioned above, because of degradation of the vegetation and soil, there is serious wind and water erosion in the grassland. Water stable aggregates rate could show soil erosion risk in the study area. Spatial patterns of WSA and OM were similar for both soil depths (Figure 3). In east part of the study area, WSA were patterned with lower values similar to OM for each soil depth. In southwest part, higher OM content could have increased water stable aggregates rate, therefore significant positive correlation was found between WSA and OM for D1 ($r = 0.501$). Kavdir et al. (2004), Aoyamata et al. (1999) Six et al. (2000) Puget et al. (2000) Basaran et al. (2008) stateed that soil organic carbon content promote soil aggregation and recently accumulated organic matter have increasing effect on macro and micro aggregates. Literature also suggested positive correlations between C content and WSA (Tisdall and Oades, 1982; Oades and Waters, 1991), and WSA has negative

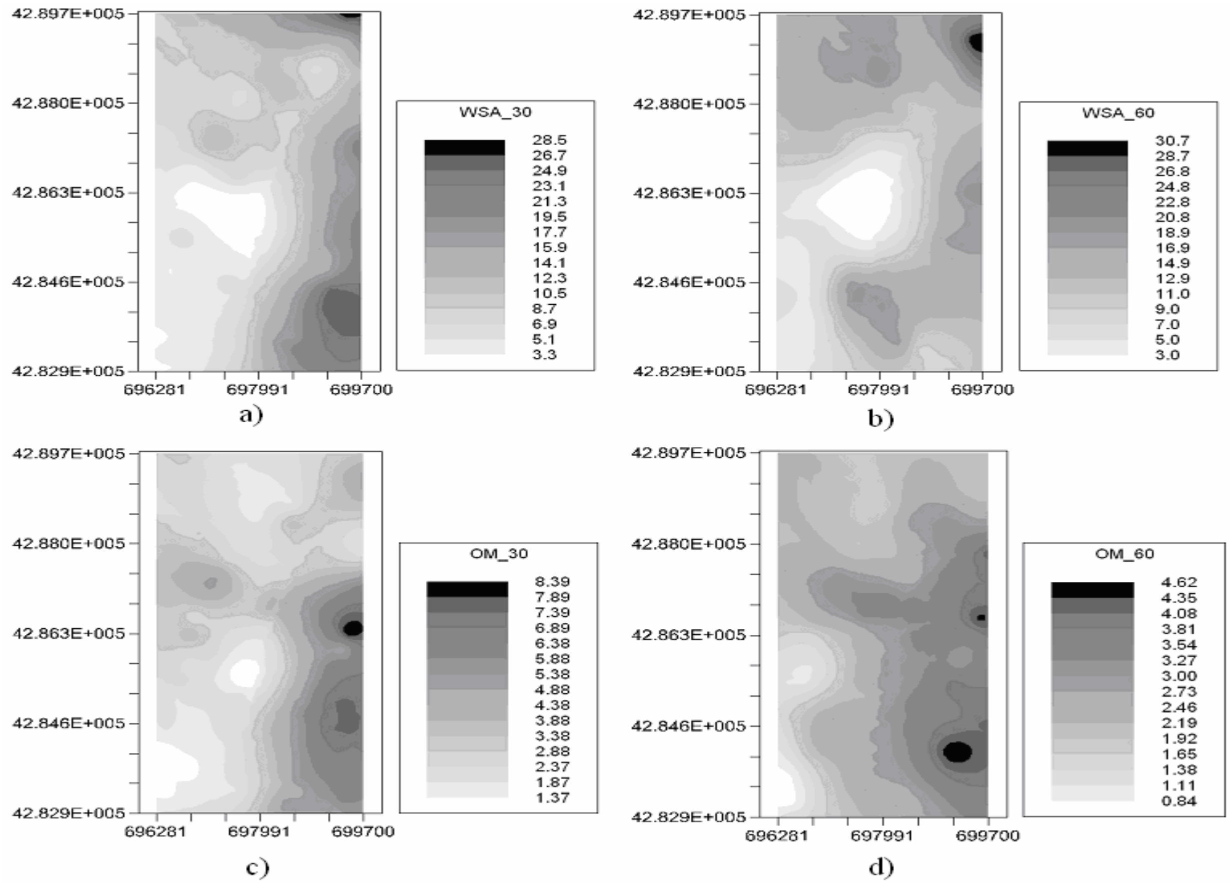

Figure 3. Spatial patterns of WSA and OM for both soil depths.

correlation with sand content (Basaran et al., 2008), but, in this study, significant negative correlation was found for C and positive correlation was determined for S of D1. These contrast relationships could be related to dispersion effect of ESP on clay particles. Negative correlations between WSA and pH of two soil depths indicated that increasing rate of ESP values had decreasing effect of aggregate stability. Shainberg and Letey (1984), Sumner (1993), Rengasamy and Sumner (1998) documented the effect of large ESP on soil dispersion. Dispersion of alkaline and saline soils, restriction of root penetration, water and air movement was discussed in detail by Quirk and Schofield (1955) and Dougherty and Anderson (2001).

Kriging maps show that there were some differences in OM of D1 and D2. Map of OM of D2 had smother variation than map of D1. The higher salinity concentration, closer ground water table, and lower oxidation conditions could provide protection of the soil organic matter of the subsoil and could lead to smooth variation. The study area was originally a wetland. After the reclamation project on wetlands with the drainage canals, water table level was decreased and the area was converted into grassland. Decreasing water table and overgrazing could have changed biodiversity and vegetation density of the study area that might decrease soil organic matter content and could affect spatial pattern of OM for D1.

Soil texture

Figure 4 shows spatial variation of C, Si, and S for both soil depths. There was no spatially different variation of C (Figures 4a and b), Si (Figures 4c andd), and S (Figures 4e and f) with respect to soil depth. Micro topography map indicated that western part of the study area had lower elevation where Si was patterned with higher values while C and S was patterned with lower values. Although there is a small slope in the research area, water erosion and deposition processes could lead to siltation at lower elevation areas (Figures 4b and c).

Low hydraulic conductivity, dispersion of the aggregates and lower vegetation density could have caused water and wind erosion. Wind data of local meteorological station indicate that erosive winds blow from the southwest and the southeast. Because of the saltation processes of sand particles from the southwest and the southeast, S could be accumulated on the northern part of the grassland (Figure 4e).

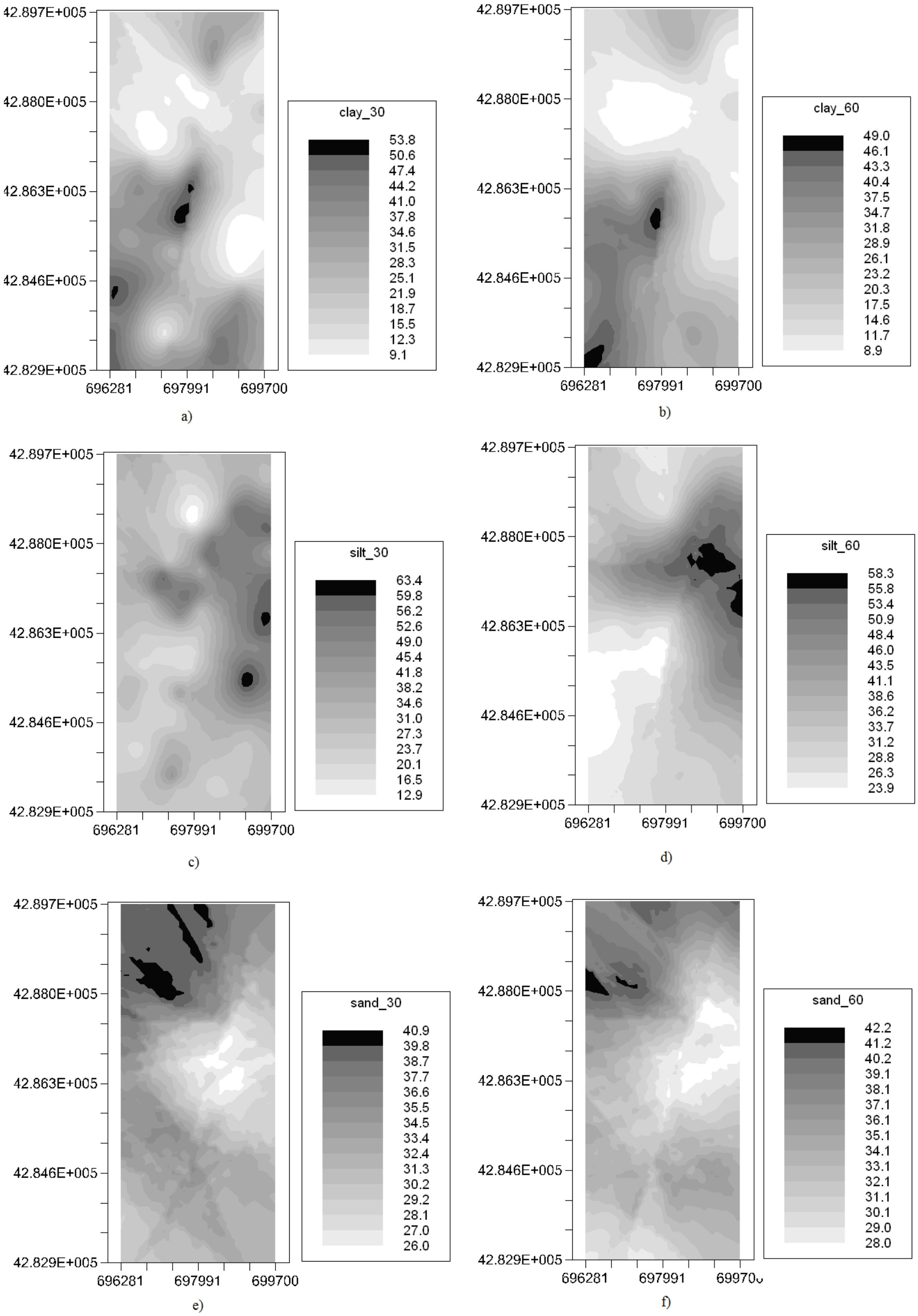

Figure 4. Spatial patterns of C, Si, S ofr both soil depths

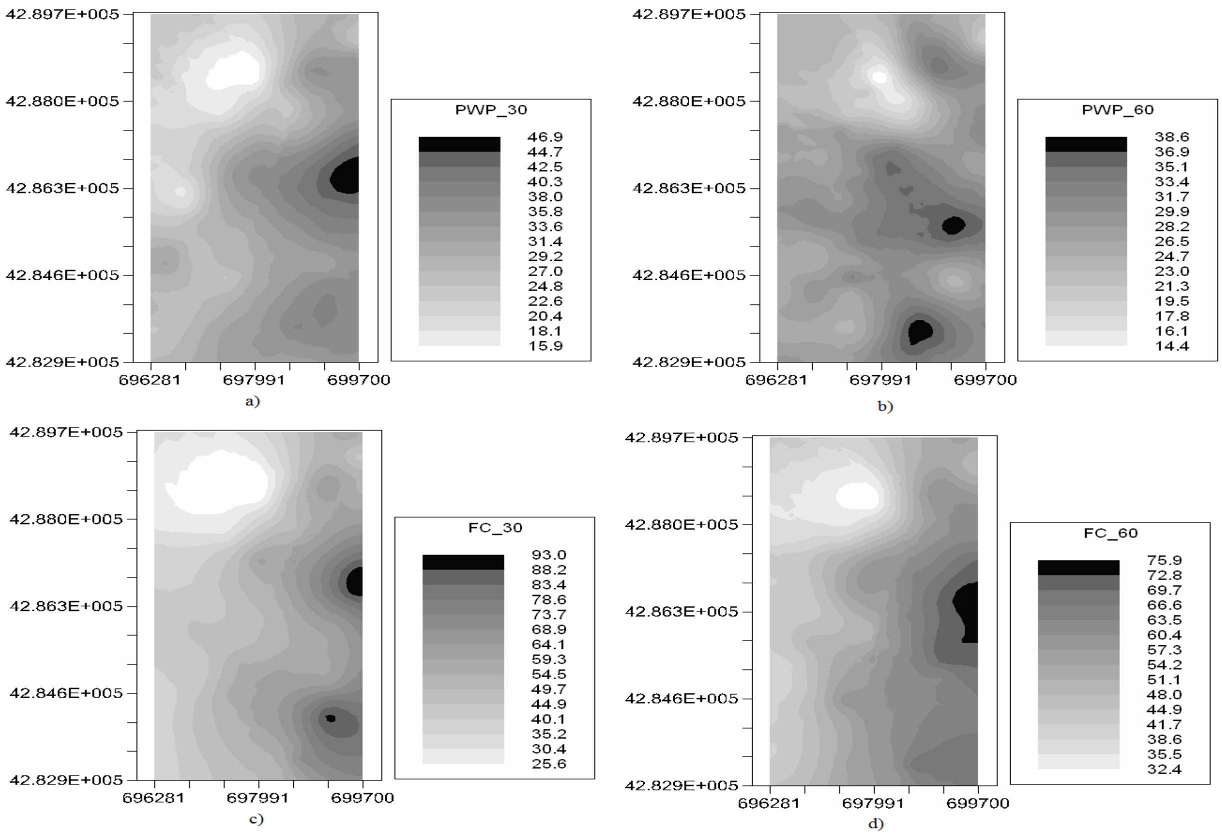

Figure 5. Spatial patterns of PWP and FC for both soil depths.

Soil water content

Spatial variations of PWP and FC were given in Figure 5. Similar spatial patterns were determined for PWP and FC for both soil depths. While the north part of the study area had lower PWP and FC values, PWP and FC varied with the higher values on southwest part. As stated above, higher values of S varied with lower values of OM on the north part, and higher values of OM patterned with lower values of S on the southwest. This could affect the spatial variation of soil water potentials in the research area. Person correlation analysis showed that not only S and OM but also EC had significant correlation with FC and PWP in both soil depths. This suggested that S, OM, and EC could be cross depended with soil water contents. Ersahin and Brohi (2006) reported that soil water contents at -0.033, -0.10, and -1.50 were cross depended with S and Si content in a Typic Ustifluvent.

Conclusion

In this study, some physical soil properties were investigated with classical and geostatistical methods in a salinity and alkalinity affected grassland of Kayseri, Turkey. The study area is a good sample to explain the degradation effect of land use change in wetland ecosystems. According to the study results, land use change can cause serious degradation of soil quality parameters in wetland ecosystems because of salinity and alkalinity. Over grazing after conversion of wetland into grassland and decrease in plant cover intensity have increased the impacts of water and wind erosion pressure. Although soils of research site have high organic material content, low levels of aggregation was mostly due to dispersion effect of exchangeable sodium. Different degrees of spatial relationships were determined for selected physical soil properties. Differences in the range of variograms for each property and in each depth were attributed to degradation of the study area soils. Kriging maps of the soil properties can be used to determine environmentally risky areas and may also be used for management and monitoring of the soil quality parameters.

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