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Spatial variability of some soil properties: a case study of the Lower Seyhan river basin in Turkey

Tülay TUNÇAY[1], İlhami BAYRAMIN[2], Abdullah ERHAN TERCAN[3], İlhami ÜNVER[2]

[1]Ankara University, Earth Sciences Application and Research Center
Ankara, Turkey
E-mail: tuncay@agri.ankara.edu.tr

[2]Ankara University, Department of Soil Science and Plant Nutrition
Ankara, Turkey

[3]Hacettepe University, Department of Mining Engineering
06800 Ankara, Turkey

Abstract

The aim of this study was to evaluate the performance of a closed drainage system in one area of the Lower Seyhan river basin in Çukurova, Turkey by measuring spatial variations in soil characteristics. Seven parallel transects which had a 150 m length were selected at 5 m intervals within the study area, and 104 soil samples were collected and analysed for soil pH, electrical conductivity (EC), exchangeable sodium (Na) content and exchangeable sodium percentages (ESP). Results were subjected to inverse distance weighting (IDW) interpolation. EC, pH and ESP estimates obtained from IDW interpolation were compatible with the results of soil analysis. Cross validation was performed to determine the accuracy of the interpolation technique. Interpolation of EC values showed a high mean error in 120–150 cm depth (9.010%), which was attributed to poor drainage conditions. Minimum sample number, maximum sample number, maximum radius and power were found to have an influence on the accuracy of IDW interpolation. ESP, exchangeable Na, EC values were generally low for shallow soil horizons, with values increasing with increases in depth. Data sets were analyzed with two-way *ANOVA* (the factors were six pipe regions (1–6) and five soil depths (30, 60, 90, 120, 150 cm)) and means compared with Duncan's multiple range test. It was found that the efficiency of drainage pipe, in regions 1, 2, 3 and 4 can diminish rather than the other pipe regions.

Key words: closed drainage system, Çukurova (Turkey), inverse distance weighting, spatial variability.

Introduction

Site-specific management (SSM) has received considerable attention based on its potential to increase input efficiency, improve economic margins of crop production and reduce environmental risks (Redulla et al., 1996). The analysis and interpretation of spatial variability of soils is a key element in site-specific farming.

Geostatistical methods can provide reliable estimates at unsampled locations (Kerry, Oliver, 2004). Two of the most commonly used interpolation methods for SSM are IDW and kriging (Kravchenko, Bullock, 1999). IDW has been used primarily because it is simple and quick, whereas kriging, although more complex and time-consuming, is considered to provide the best unbiased linear estimates. The literature contains numerous mathematical descriptions of both these methods (Weber, Englund, 1992; Hosseini et al., 1994; Gotway et al., 1996; Nalder, Wein, 1998; Kollias et al., 1999; Kravchenko, Bullock, 1999; Schloeder et al., 2001; Kravchenko, 2003; Panagopoulos et al., 2006; Lu, Wong, 2008; Wenjio et al., 2009.

There have been many conflicting reports concerning the use of interpolation methods and their parameters. Whereas some studies have found the performance of kriging to be, in general, better than that of IDW (HHosseini et al., 1994; Kravchenko, Bullock, 1999), others have reported IDW to be more accurate than kriging (Weber, Englund, 1992; Nalder, Wein, 1998).

Cross validation is a common practice used to validate the accuracy of an interpolation (Voltz, Webster, 1990) and also is excellent scheme for solving the inconvenience of redundant data collection (Olea, 1999; Webster, Oliver, 2001). Cross validation is obtained by eliminating one observation from the data set, estimating the value at that location with the remaining data, and then computing the difference between the actual and observed values for the data location (Robinson, Metternicht, 2005). This study conducted cross validation using the *Pronet* software program.

In view of the conflicting results reported by previous studies, this study aimed to identify the spatial variability of various soil parameters in the study area and to evaluate the accuracy of IDW interpolation in determining the values for these parameters due to poor sample points around study area. This would enable the identification of areas where remediation is required to improve crop growth, and land management process.

Materials and methods

Study area. This study was carried out in the Lower Seyhan river basin, an alluvial plain located in southern Turkey. The study area was comprised of 104 ha of irrigated agriculture land within a multi-directional drainage system (WGS84; 679312–681014 E, 4079399–4081100 N) (Fig. 1). The climate of the study area is Mediterranean, with a mean average annual temperature of 19° and a total annual precipitation of 583 mm, according to the Turkish State Meteorological Service. Based on data from 1975–2008, the study area was classified according to Thornthwaite (1948) as a semi-arid, mesothermal (B′3) marine climate with a large winter water surplus, a xeric soil-moisture regime and a mesic temperature regime.

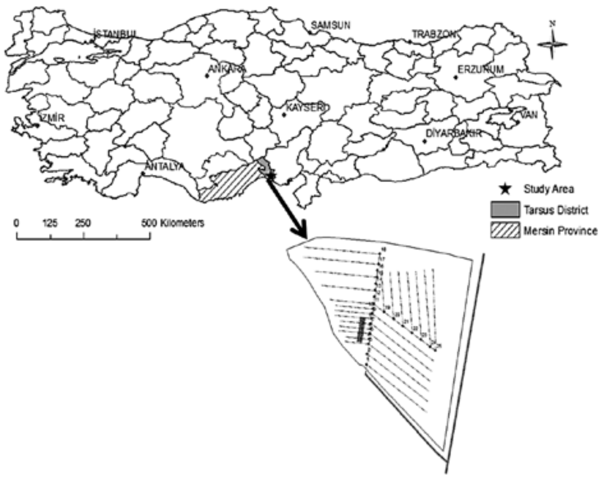

Figure 1. The research area

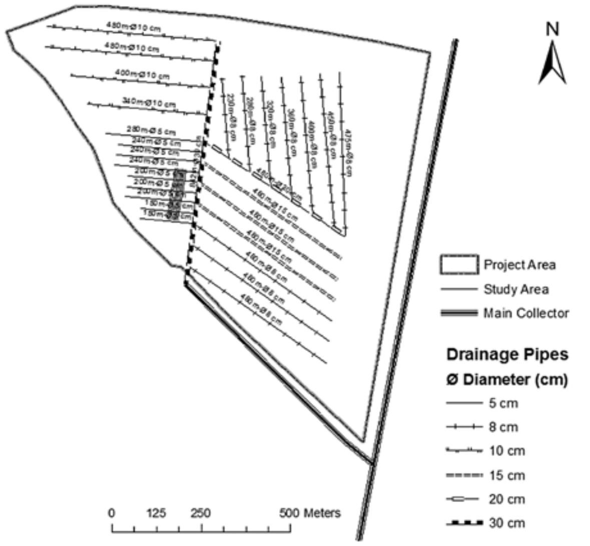

Figure 2. Drainage pattern of the study area

Soil in the Lower Seyhan river basin is formed from sediment conveyed from the Toros mountains to Tarsus by the Seyhan river, resulting in heavily stratified sedimentation. The upper layer of soil in the study area was formed from alluvial material in the Quaternary age and consists mainly of clay, with some sand and silt. Despite poor slope and drainage characteristics, following the completion of a drainage system and land remediation in the early 1960s, a satisfactory level of plant cultivation was established (Kumova, Yarpuzlu, 1987).

In the project area, drainage studies were started in 1963 and completed in 1988. The project area occupies 104 ha agricultural land. Four different drainage patterns were established in the project area. Drainage pipe diameters and pipe installation intervals were 5 cm – 30 m, 8 cm – 60 m, 10 cm – 80 m and 15 cm – 60 m, respectively. These drainage patterns were shown in Figure 2. Drainage pipes consist of polyvinyl chloride (PVC), and are surrounded by a gravel envelope with design depth of 1.4 m. All of the drainage pipes were connected to main collector, which was established from north to south, and drainage waters were conveyed to major open drainage channel using this collector. During drainage system construction, twenty-five observation wells were established (Fig. 2). During field observation in rainy seasons (November and December) some poundings and drainage problems were determined especially in the 5 cm – 30 m drainage pipe interval pattern. The drainage system is also used as an irrigation system by the residents of Alifakı village, who graze their animals in the area (Tunçay, 2010).

Seven parallel transects of 150 m in length were designated at 5 m intervals within the study area. In total, 104 soil samples were collected at different soil horizons from 24 different points (0, 50, 100 and 150 m in the 1st, 3rd, 5th and 7th transects; at 25, 75 and 125 m in the 2nd and 6th transects; and at 50 and 100 m in the 4th transect). The coordinates of each sampling location were recorded using a differential global position system (DGPS).

Sampling design. The study area is located on the alluvial plain, and it is very well known that spatial variability of the soil properties change in short distance on alluvial soils. To determine spatial variability of the soil parameters (such as pH, EC, ESP, exchangeable Na content, etc.) and drainage efficiency, vertical and horizontal experimental design was selected for soil sampling (Fig. 2). Soil pH, EC, exchangeable Na, ESP are important soil properties which have a devastating effect on soil productivity. Soil samples were analyzed for pH, EC and exchangeable Na content. These results were evaluated by inverse distance weighting (IDW) using the *GemcomSurpac 3D* software program. For each sample point, soil samples were taken to depth of 150 cm and used to produce five different soil layers depth (from 30 to 150 cm) maps for each property and parameter *p* (*p*; 2). The precision and performance of IDW are affected by the number of known samples used for estimation. In this study, the number of close sample locations was fixed at 24, and each soil sample point was evaluated at 4–5 soil horizons, depending upon soil classification. A total of 104 soil samples were collected at 24 soil samplings from each soil horizon at the study area.

Soil samples were gathered individually and packed into boxes, air dried, crushed and sieved (2 mm). Mixtures of 1:2 soil to pure water were prepared, and pH and EC were measured using a pH electrode. Exchangeable sodium percentages (ESP) analysis is a measure of exchangeable charges per unit of soil as expressed using NH_4OAc and a pH of 7.0 (Thomas, 1982). In this study, ESP was calculated using exchangeable Na values.

Spatial prediction methods. Interpolation techniques. IDW is commonly used to map soil properties in agricultural areas (Weber, Englund, 1992; Franzen, Peck, 1995; Gotway et al., 1996), and the interpolation procedures are clearly explained in the literature (Laslett et al., 1987; Kravchenko, Bullock, 1999). IDW is one of a number of local deterministic methods of interpolation that operates directly on the assumption that the value of an attribute at an unsampled location is that of a weighted average of the known data points within a local neighborhood surrounding the unsampled location (Burrough, McDonnell, 1998). Estimated values are interpolated based on the data from surrounding locations using the formula:

$$Z\times(xo) = \sum_{i=1}^{n} wi\,Z(xi) \qquad (1),$$

where wi is the weight assigned to the value at each location $Z(\chi_i)$, n – the number of close neighboring sampled data points used for estimation.

Weights are established using the formula:

$$wi = \frac{1/d_i^p}{\sum_{i=1}^{n} 1/d_i^p} \qquad (2),$$

where d_i is the distance between the estimated point and the sample point, p – an exponent parameter.

The choice of exponent value is known to significantly affect estimation quality (Isaaks, Srivastava, 1989; Weber, Englund, 1994). Weighting is highly dependent upon p, with an increase in distance resulting in an exponential decrease in weighting. This study used a power of 2 and a skewness value of <1 in IDW (Agris, 1998).

The process of determination drainage efficiency using statistical analysis. The Kolmogorov-Simirnov and Levene's statistic tests were applied to test normality and homogeneity of variance, respectively. Data sets were analyzed with two-way *ANOVA* (the factors were six pipe regions (1, 2, 3, 4, 5, 6) and five soil depths (30, 60, 90, 120, 150 cm)) and means compared with Duncan's multiple range test. Variables were displayed as mean ± standard error of the mean (SEM). *ANOVA* was performed using *Minitab 15* software and means were compared using the *MSTAT* package program for Duncan tests. The alpha level was set at 1%.

Results and discussion

Descriptive statistics result of the soil properties. The findings of soil analysis for the parameters pH, EC, exchangeable Na and ESP are summarized in Table 1. Soil analysis showed the pH value of the study area ranged mainly from 7.62 to 9.33, with the pH increasing with increasing depth. EC values ranged from 0.17 to 3.49 dS m^{-1}. Mean values of soil parameters varied by interval, with EC ranging from 0.17 to 3.49 dS m^{-1} and ESP from 0.61% to 44.31%.

Table 1. Descriptive statistics for selected soil properties

Variable	Min	Max	Mean	Median	Skewness	Kurtosis	SD	CV %
pH	7.62	9.33	8.57	8.53	0.11	0.04	0.34	3.97
EC dS m^{-1}	0.17	3.49	0.86	0.65	1.23	1.20	0.70	81.08
Exchangeable Na meq 100 g^{-1}	0.25	18.08	5.46	5.140	0.99	0.73	3.71	68.12
ESP %	0.61	44.31	15.79	15.16	0.64	−0.30	10.40	65.84

EC – electrical conductivity, ESP – exchangeable sodium percentages, Min – minimum, Max – maximum, SD – standard deviation, CV – coefficient of variation

Inverse distance weighting process, result maps and cross validation results for the selected soil parameters. EC values showed the greatest variability of the different soil parameters analysed, with a 57.40% coefficient of variation. This finding was attributed to poor drainage conditions and high clay content, especially in the subsurface horizons, which restricted downward movement of water. The mean overall clay content was 61.83%, with clay content ranging from a minimum of 41.15% to a maximum of 84.42%. Table 2 shows descriptive statistics of selected soil properties using IDW method.

Table 2. Descriptive statistics of selected soil properties using inverse distance weighting (IDW) method

Variable	Min	Max	Mean	Median	Skewness	Kurtosis	SD	CV %
pH	7.900	9.240	8.557	8.545	0.39	0.20	0.211	2.47
EC dS m^{-1}	0.236	2.809	0.867	0.777	0.72	−0.25	0.497	57.40
Exchangeable Na meq 100 g^{-1}	1.565	13.580	5.407	4.902	0.63	−0.40	2.428	44.90
ESP %	4.090	34.505	15.732	14.815	0.37	−0.83	6.914	43.95

Explanations under Table 1

IDW was conducted with a minimum of 3 samples, a maximum of 24 samples and a maximum radius of 30 m. These parameters were chosen based on the size of the study area and the positions of sampling locations. Table 3 shows the weighted average values of the soil parameters among the increasing depth. All parameters values tended to increase with increasing soil depth.

Soil pH. Figure 3 shows the spatial distribution of soil pH values in the study area. In the first two soil horizon layers (0–30 and 30–60 cm), pH generally varied between 8.2–8.5. In the third soil layer (60–90 cm) of the soil pH values generally varied between 8.2–8.8. In the last two soil horizon layers (90–120 and 120–150 cm), pH values in some places were as high as 8.8–9.3, especially in the northern section of the study area (Fig. 3). But generally, the last two soil layers (90–120 and 120–150 cm) of the pH values had mostly variation range between 8.5 and 8.8.

Table 3. The weighted average values of the soil parameters among the increasing depth

Depth cm	pH	EC dS m^{-1}	Exchangeable Na meq 100 g^{-1}	ESP %
0–30	8.312	0.331	2.729	7.436
30–60	8.449	0.494	3.709	10.850
60–90	8.618	0.812	4.961	15.541
90–120	8.707	1.199	6.859	20.537
120–150	8.700	1.500	8.778	24.297

Explanations under Table 1

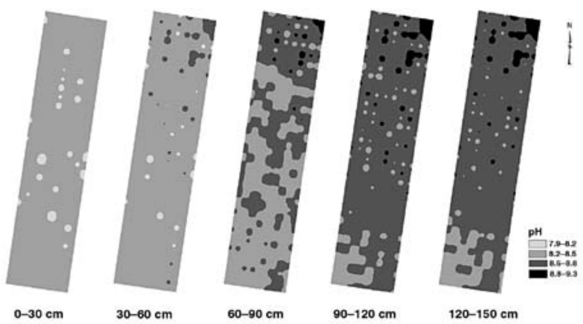

Figure 3. Soil layer mapping of estimated soil pH values

Soil analysis and interpolated values for pH showed good correlation, particularly for up to 60 cm, suggesting that IDW is an appropriate method for the estimation of soil pH as well as other soil properties. At soil depths of 90–120 and 120–150 cm, pH values tended to range between 8.5–8.8, although they were higher in the northern part of the study area, reaching 8.8–9.3. At depths closer to 120 cm, pH values tended to exceed 8.5 due to high groundwater levels and clay content, with the greatest problems found in the north. These results are in line with the findings for EC, exchangeable Na and ESP. Moreover, they indicate that the closed drainage network in the study area is inadequate, and that as a result, the water level has a tendency to rise above the root zone, particularly after precipitation and irrigation. Robinson and Metternicht (2005) compared the accuracy of ordinary kriging, lognormal ordinary kriging, IDW and splines for interpolating seasonally stable soil properties (pH, EC and organic matter). The researchers indicated that IDW interpolated subsoil pH with the greatest accuracy and ordinary kriging performed best for the topsoil pH in their experimental design. It was shown that IDW interpolated both topsoil and subsoil with the greatest accuracy in this research. Also Weber and Englund (1992) found that IDW produced better results than kriging.

Electrical conductivity (EC). EC values in the two soil layers (0–30 and 30–60 cm) ranged from 0.23–1.00 dS m^{-1}, whereas EC values in the last two soil layers (90–120 and 120–150 cm) generally ranged from 1–2 dS m^{-1} (Fig. 4). The increase in EC values with increasing depth can be attributed to drainage problems and improper irrigation.

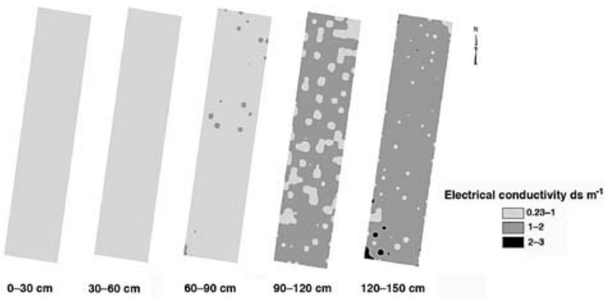

Figure 4. Soil layer mapping of estimated electrical conductivity (EC) values

Exchangeable sodium (Na). In general, exchangeable Na levels increased with increasing depth (Fig. 5). According to obtained data, the critical depth of sodium is 30 cm for plant growth. This situation is critical in terms of soil remediation, especially in the root zone, and has implications for land use planning and management. The last two soil layers (90–120 and 120–150 cm) had very high exchangeable Na values especially in the northern section of the study area.

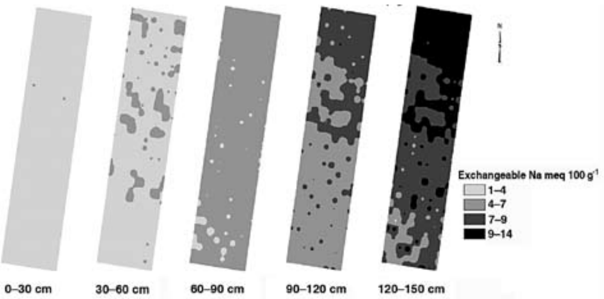

Figure 5. Soil layer mapping of estimated exchangeable sodium (Na) values

Exchangeable sodium percentages (ESP). ESP values increased with increases in soil layer depths, especially in the northern part of the study area (Fig. 6). ESP variations were observed to parallel those of exchangeable Na. This suggests that rather than calculating cation exchange capacity (CEC) to determine ESP values, exchangeable Na can be used as a parameter in IDW. It is apparent that values of all soil parameters of pH, EC, ESP and exchangeable Na are mainly higher in the north part of the study area. This could be explained by decreasing of the drainage efficiency in drainage pipe regions 1, 2, 3 and 4. Although drainage system is under operation at the study area, drainage pipes and pattern of the research area must be controlled for soil management practices (Halliwell et al., 2001). A new drainage pipe could be installed and designed in the study area for encountering drainage problem.

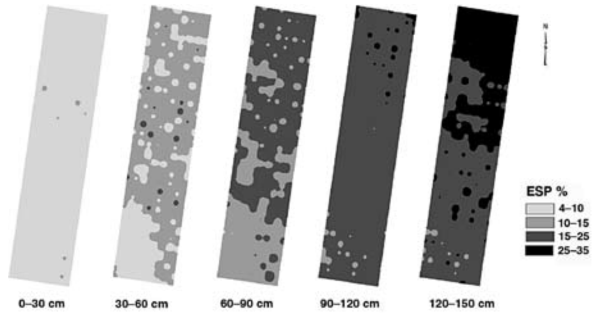

Figure 6. Soil layer mapping of estimated exchangeable sodium percentage (ESP) values

Cross validation was performed for all variables to determine the accuracy of IDW interpolation in a different depth in Table 4. In general, the results of interpolation were compatible with those of soil analysis for EC, pH, exchangeable Na and ESP. Of the different parameters examined, EC had the highest mean error in 120–150 cm depth (9.010%), which was attributed to the variability of EC values obtained from laboratory analysis of soil samples. Exchangeable Na values had also high mean error especially 90–150 cm depth (8.963). Soil pH, mean errors ranging between 0.007–0.421%, had the lowest mean error values.

According to IDW soil layer maps and cross validation results, the subsurface drainage systems in the study area cannot control the watertable, limit salinization through capillary rise, and facilitate the leaching of salts. IDW interpolation is more effective when the values of points with similar depths are used in interpolation. In this study, ESP, exchangeable Na and EC values were generally low for shallow soil layer, with values increasing with increases in depth. For the first soil layer (0–30 cm), interpolated values were higher than measured values. This finding can be attributed to an increase in mean error caused by the excessive ESP in soil horizons beyond 30 cm. A similar situation was observed between measured and interpolated values for EC and exchangeable Na values. It is likely that IDW interpolation would have been more accurate if a greater number of sample points could have been used.

The process of drainage efficiency determination. Results of the IDW data were used to evaluate drainage efficiency of the drainage pipes. Six drainage pipes were determined in the study area. The study area was divided into 6 subregions according to their effectiveness (Fig. 7).

Table 4. Cross-validation results for four soil properties

Exchangeable Na meq 100 g^{-1}	MEV	MEP %	EC dS m^{-1}	MEV	MEP %
0–30 cm	0.034	1.257	0–30 cm	0.007	2.136
30–60 cm	0.180	4.418	30–60 cm	0.011	2.100
60–90 cm	0.134	2.478	60–90 cm	0.004	0.547
90–120 cm	0.070	8.963	90–120 cm	0.006	0.508
120–150 cm	0.845	8.963	120–150 cm	0.150	9.010
ESP %	MEV	MEP %	pH	MEV	MEP %
0–30 cm	1.076	3.870	0–30 cm	0.002	0.034
30–60 cm	2.610	8.554	30–60 cm	0.003	0.044
60–90 cm	0.325	1.713	60–90 cm	0.006	0.007
90–120 cm	0.022	0.107	90–120 cm	0.002	0.026
120–150 cm	0.599	2.905	120–150 cm	0.036	0.421

ESP – exchangeable sodium percentages, MEV – mean error value, MEP – mean error percent, EC – electrical conductivity

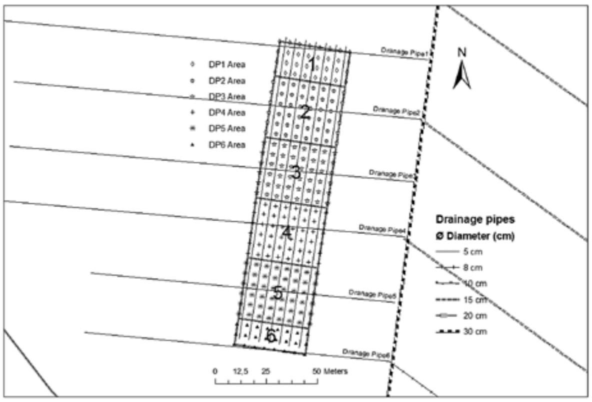

Figure 7. Drainage pipe regions of the study area

Results of analysis of variance. There were significant interactions between regions × depths for independent variables such as exchangeable Na, ESP and pH. Accordingly, the Duncan test results are given in Tables 5, 6 and 7. Exchangeable Na and ESP values increased with increasing depth in all pipe regions, this rising was found significant ($p < 0.001$). Variable Na values for the pipe regions detected in the order of 2, 3, 1 and 4, respectively at a depth of 0–30 cm pointed out that these regions were more important than other pipe regions. Similarly, at a depth of 60–90 cm, the increase in the values for the regions in order of 1, 3 and 2 was higher compared to that for the other regions. The rise in variable Na values, especially for the 1st pipe region at a depth of 120–150 cm, was higher than the rise in values for the other regions at the same depth (Table 5). In the investigation area, the condition of higher exchangeable Na values for the pipe regions 1, 2, 3 and 4 compared to the values for other regions is an indication of more severe drainage problem for these regions.

Similar situation can be indicated by the results of two-way *ANOVA* for ESP values as shown in Table 6. When all the pipe regions are concerned, the increase in ESP values for the regions in order of 1, 2, 3 and 4 at depths more than 60 cm layer of soil with a p value lower than 0.001 was found to be more important.

Table 5. Descriptive statistics and Duncan test results for exchangeable sodium (Na) values (meq 100 g^{-1}) in five soil depths × six drainage pipe regions

Depth cm	Pipe 1 region	Pipe 2 region	Pipe 3 region
0–30	2.78 ± 0.098 Ea	2.86 ± 0.080 Ea	2.84 ± 0.077 Ea
30–60	3.81 ± 0.164 Dab	3.79 ± 0.126 Dab	3.95 ± 0.139 Da
60–90	5.42 ± 0.148 Ca	5.16 ± 0.130 Ca	5.19 ± 0.133 Ca
90–120	7.77 ± 0.116 Ba	7.32 ± 0.140 Bab	7.04 ± 0.151 Bbc
120–150	10.71 ± 0.20 Aa	9.53 ± 0.161 Ab	9.10 ± 0.190 Ab
Depth cm	Pipe 4 region	Pipe 5 region	Pipe 6 region
0–30	2.76 ± 0.048 Ea	2.55 ± 0.052 Ea	2.47 ± 0.092 Ea
30–60	3.85 ± 0.122 Dab	3.37 ± 0.082 Dab	3.30 ± 0.080 Db
60–90	4.92 ± 0.107 Cab	4.51 ± 0.093 Cb	4.50 ± 0.104 Cb
90–120	6.59 ± 0.091 Bcd	6.23 ± 0.139 Bd	6.14 ± 0.183 Bd
120–150	8.32 ± 0.154 Ac	7.55 ± 0.270 Ad	7.42 ± 0.370 Ad

Note. Vertically, different capital letters indicate statistically significant differences among depth of measurements according to the Duncan test at the 0.01 level; horizontally, different small letters indicate statistically significant differences between the groups of pipe regions according to the Duncan test at the 0.01 level.

Table 6. Descriptive statistics and Duncan test results for exchangeable sodium percentage (ESP %) values through in five soil depths × six drainage pipe regions

Depth cm	Pipe 1 region	Pipe 2 region	Pipe 3 region
0–30	7.47 ± 0.265 Ea	7.70 ± 0. 225 Ea	7.74 ± 0.225 Ea
30–60	11.11 ± 0.484 Dab	11.07 ± 0.383 Dab	11.69 ± 0.449 Da
60–90	17.23 ± 0.484 Ca	16.40 ± 0.434 Cab	16.38 ± 0.414 Cab
90–120	23.58 ± 0.417 Ba	22.14 ± 0.451 Bab	21.29 ± 0.413 Bbc
120–150	29.82 ± 0.423 Aa	26.61 ± 0.460 Ab	25.41 ± 0.465 Ab
Depth cm	Pipe 4 region	Pipe 5 region	Pipe 6 region
0–30	7.55 ± 0.144 Ea	7.00 ± 0.148 Ea	6.88 ± 0.257 Ea
30–60	11.24 ± 0.339 Dab	9.80 ± 0.241 Db	9.70 ± 0.268 Db
60–90	15.53 ± 0.328 Cb	13.77 ± 0.312 Cc	13.43 ± 0.384 Cc
90–120	20.08 ± 0.255 Bc	18.20 ± 0.428 Bd	17.38 ± 0.546 Bd
120–150	23.23 ± 0.397 Ac	20.62 ± 0.669 Ad	19.55 ± 0.904 Ad

Explanations under Table 5

Table 7. Descriptive statistics and Duncan test results for pH values in five soil depths × six drainage pipe regions

Depth cm	Pipe 1 region	Pipe 2 region	Pipe 3 region
0–30	8.36 ± 0.013 Ca	8.30 ± 0.013 Da	8.29 ± 0.013 Da
30–60	8.51 ± 0.032 Ba	8.45 ± 0.020 Cab	8.44 ± 0.016 Cab
60–90	8.74 ± 0.041 Aa	8.65 ± 0.027 Bb	8.62 ± 0.021 Bbc
90–120	8.82 ± 0.041 Aa	8.74 ± 0.027 Aab	8.72 ± 0.022 Abc
120–150	8.83 ± 0.039 Aa	8.75 ± 0.023 Aab	8.71 ± 0.019 Ab
Depth cm	Pipe 4 region	Pipe 5 region	Pipe 6 region
0–30	8.30 ± 0.016 Da	8.32 ± 0.013 Da	8.33 ± 0.013 Ca
30–60	8.43 ± 0.015 Cb	8.43 ± 0.011 Cb	8.45 ± 0.012 Bab
60–90	8.59 ± 0.018 Bbc	8.56 ± 0.013 Bc	8.56 ± 0.015 Ac
90–120	8.70 ± 0.017 Abcd	8.64 ± 0.015 Acd	8.62 ± 0.019 Ad
120–150	8.69 ± 0.015 Abc	8.62 ± 0.016 ABcd	8.59 ± 0.020 Ad

Explanations under Table 5

According to results of analysis of variance, there were non-significant interactions between regions × depths for independent variable electrical conductivity and it was found that the main factors were significant (Table 8).

Table 8. Descriptive statistics for electrical conductivity (EC) values (dS m^{-1}) in five depths × six drainage pipe regions

Pipe region	mean ± SEM	Depth cm	mean ± SEM
1	0.86 ± 0.036 B	0–30	0.33 ± 0.027 **E**
2	0.88 ± 0.030 B	30–60	0.49 ± 0.008 **D**
3	0.87 ± 0.032 B	60–90	0.81 ± 0.012 **C**
4	0.83 ± 0.031 B	90–120	1.20 ± 0.018 **B**
5	0.85 ± 0.033 B	120–150	1.50 ± 0.025 **A**
6	0.96 ± 0.054 A		

Note. Capital letters indicate statistically significant differences among different pipe region and bold capital letters indicate statistically significant different depth measurements according to the Duncan test at the 0.01 level, SEM – standard error of the mean.

Considering EC, the factors of pipe region and depth were found to be important statistically ($p < 0.001$). Duncan test results performed accordingly are presented in Table 8. The 6th pipe region at a depth of 120–150 cm showed higher EC compared to other regions.

Conclusions

1. Factors that impact the relative performance of inverse distance weighting (IDW) such as minimum sample number, maximum sample number, maximum radius and size of the study area are important for site-specific management (SSM). Some studies have found the performance of IDW to vary with changes in grid size (0.09 ≤ grid size ≤ 4.0 ha) (Hosseini et al., 1994; Weisz, 1995; Mueller et al., 2001). However, the most significant effect on IDW performance and accuracy is the proximity in location and depth of the known soil parameters such as exchangeable sodium percentages (ESP), exchangeable sodium (Na), pH and electrical conductivity (EC) values used in interpolation. Our study area is 4500 m^2 (150 × 30) and there was a good relationship between known soil parameters' (such as pH, EC, ESP, exchangeable Na) depth and interpolation results.

2. This study found the majority of data with low skewness values to provide the best results with a power of 2. In general, the exchangeable Na of the soil samples in this study was greatest at depths of 45–50 cm as a result of poor drainage and high clay content (approx. 45%). Measured and estimated values for other soil properties – pH, EC, ESP, and cation exchange capacity (CEC) – were also found to increase with increasing depth.

Overall, the data obtained from our study can be used for SSM, such as testing the performance of irrigation and drainage systems and evaluating land-use practices.

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Dirvožemio savybių erdvinis kitimas: atvejo studija Seyhan žemupio baseine Turkijoje

T. Tunçay[1], İ. Bayramin[2], A. Erhan Tercan[3], İ. Ünver[2]

[1]Ankaros universiteto Žemės mokslų ir taikomųjų tyrimų centras, Turkija
[2]Ankaros universiteto Dirvožemio mokslo ir augalų mitybos skyrius, Turkija
[3]Ankaros Hacettepe universiteto Kalnakasybos inžinerijos skyrius, Turkija

Santrauka

Tyrimo tikslas – įvertinti uždaros drenažo sistemos Seyhan žemupio baseine Çukurovoje, Turkijoje, darbą, matuojant dirvožemio savybių erdvinį kitimą. Tyrimo teritorijoje buvo parinkti septyni lygiagretūs skersiniai 150 m ilgio pjūviai su 5 m intervalais ir paimti 104 dirvožemio mėginiai, kurių nustatytas pH, elektrinis laidumas, mainų natrio (Na) kiekis ir procentas. Rezultatai apdoroti naudojant atvirkštinę atstumų svorio interpoliaciją. Elektrinio laidumo, pH ir mainų Na procento vertės, gautos atlikus atvirkštinę atstumų svorio interpoliaciją, atitiko dirvožemio analizių rezultatus. Siekiant nustatyti interpoliacijos metodo tikslumą, atliktas patikimumo tyrimas. Elektrinio laidumo verčių interpoliacija 120–150 cm gylyje parodė didelę vidutinę paklaidą (9,010 %), kurios priežastimi laikytos prastos drenažo sąlygos. Nustatyta, kad atvirkštinės atstumų svorio interpoliacijos tikslumui turi įtakos mažiausias ir didžiausias mėginių skaičius, maksimalus spindulys ir galia. Dirvožemio sekliuose horizontuose mainų Na procento, mainų Na, elektrinio laidumo vertės buvo mažos, didėjant dirvožemio gyliui jos didėjo. Duomenų rinkiniai buvo išanalizuoti taikant dviejų veiksnių (pirmasis – šešių uždarų drenažo sistemų regionas (1–6), antrasis – penki dirvožemio gyliai (30, 60, 90, 120, 150 cm)) *ANOVA* analizę, vidurkiai buvo palyginti pagal Dunkano kriterijų. Nustatyta, kad drenažo sistemos efektyvumas 1, 2, 3 ir 4 regionuose gali sumažėti greičiau, lyginant su kitais regionais.

Reikšminiai žodžiai: atvirkštinis atstumų svoris, Çukurova (Turkija), erdvinis kitimas, uždara drenažo sistema.