

Similarity analysis of soils formed on limestone/marl-alluvial parent material and different topography using some physical and chemical properties via cluster and multidimensional scaling methods

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Abstract The aim of this study is to analyze the similarity of soils formed on limestone/marl alluvial parent material and different topography using some physical and chemical properties via cluster analysis (CA) and multidimensional scaling analysis (MDSA). Physical and chemical soil properties included in this study are texture, CaCO₃, organic matter, pH, electrical conductivity, cation exchange capacity, and available water content. The study was carried out in Çetinkaya region located on Bafra Deltaic Plain. The study area has two main physiographic units. The first one is the flat or gently slope alluvial lands (0–2 %), and the other one involves hills with slopes ranging from middle to steep (3–20 %). The soil in the study area is mainly classified as entisol, inceptisol and vertisol. According to the CA results, while C horizons of the soils formed on alluvial deposits (typic ustifluent and typic ustipsamment) bear similarity, Ap horizons of the soils formed on lime/marl parent material (vertic usthorient, vertic calciustept, and calci haplustert) appear in the same group. Additionally, in order to support CA, MDSA was performed. Significant correlations were observed between the results of both analyses.

Keywords Cluster analysis · Multidimensional scaling analysis · Soil classification · Different topographical units · Soil physical and chemical properties

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Introduction

Soil is a biologically active and complex mixture of weathered minerals, organic matter (OM), organisms, air, and water that provide the foundation for life in terrestrial ecosystems. Soil, however, is not merely the sum of the minerals, OM, water, and air but a product of their interactions (Juma 1999). Soil is an important natural resource that meets the basic needs of people. Also, it makes physical, chemical, and biological contributions to the exchange of nutrient, water, and air which is required for plant growth, allowing continuation of life by creating a living environment for many small and large organisms, and influences the growth of plants directly or indirectly. Because of the fact that the physical, chemical, and biological properties of soil are changeable and that it develops from particles of different sizes (sand, clay, and silt), OM, and living organism species over a very long timescale, soil can be considered as a non-renewable natural resource (Sağlam 2008). In addition, soil provides a filter that allows the absorption of wastes in the natural change cycle, a genetic reservoir for organisms, a depot for water and mine storage, a spatial foundation for socio-economic activities, and a basic element respecting historical and cultural heritage (Sarioğlu and Dengiz 2012).

The issue to be addressed initially for the long-term sustainable use of the land is to identify the characteristics and the quality of the land and terrains. Terrain characteristic is a simple quality of a terrain that can be measured and observed in any case. As well as terrain characteristics, quality of the soil provides a significant

contribution to land use types and suitability assessment processes because the physical, chemical, biological, and mineralogical properties of the soil are the factors that directly affect the growth and development of the plants. Nowadays, rapid advancement in computer and space technologies provide significant benefits to the evaluation of land and soil characteristics. The use of facilities provided by the technology enables access to “adequate, reliable, and rapid” information from data related to the desired geographical area. Therefore, in the evaluation of data related to land and soil characteristics, spatial analysis such as geographic information systems (GIS), remote sensing (RS) and geostatistical analysis, and multivariate statistical methods such as principal components analysis (PCA), cluster analysis (CA), and multidimensional scaling analysis (MDSA) are used frequently as well.

CA is one of the multivariate statistical methods commonly used for classification of grouped data according to their similarity. The primary objective in CA is to group the individuals or objects by taking their basic features into consideration, in other words, to provide information for the researcher by grouping the grouped data according to their similarity. CA calculates the values of individuals or objects observed in the study on all variables measured, and it focuses on emergent clusters or groups. Similarity measures of distance measures, correlation measures, or quality data are used to determine the similarities between individuals or objects. Intra-cluster homogeneity and inter-cluster heterogeneity of the clusters obtained as a result of the analysis are very high. In a sense, while individuals/objects which form a cluster are similar to each other, others are not similar to individuals or objects of other clusters. Ultimately, if the classification is successful, the objects in the cluster will be geometrically close to each other; otherwise, they will not be (Uçar 2010).

MDSA is a statistical method used for identification of the relationships between objects, making use of distances, in cases where inter-object relation is unknown but the distances between them can be calculated. The application area of MDSA is extremely widespread, and this analysis can be applied to both metric and non-metric variables. Additionally, it enables the best arrangement of various objects according to similarities and differences. The overall objective of the analysis is to introduce the structure of the objects (using distance values) close to the original with minimum dimensions. By virtue of this technique, complex

relationships between objects or individuals in multi-dimensional data matrix can be understood and explained more easily. MDSA is a method frequently used in many different branches to introduce the differences and similarities as well (İşler 2010).

The key difference between MDSA and CA is that MDSA provides a spatial visualization of the proximities, whereas CA simulates proximities as tree-like. When hierarchical CAs are analyzed, it is observed that small clusters adapt to each other and constitute meaningful groups; it is possible to say that large cluster exceeding trees are insignificant. Therefore, in CA, small similarity can be interpreted, but great similarity is difficult to interpret. However, contrary to CA, MDSA can evaluate or interpret great dissimilarity (Uçar 2010). Another difference is that all the objects in MDSA are considered independent of each other and evaluated separately in the solution process. This is not possible in CA (İşler 2010).

This study aims to analyze the similarities and dissimilarities of soils formed on steep slope and alluvial lands in different taxonomic groups in Çetinkaya district on Bafra Deltaic Plain, a major agricultural region in Samsun and the Black Sea region, in terms of some physical and chemical properties related to genetic horizons via CA and MDSA. Although there are many geo-chemical studies on genetic horizon formations in Turkey and in the world, any study using these methods to identify the similarities and differences in genetic horizon formation of different soils is hardly available. Therefore, the study aims to develop such methods as an alternative to classical methods to bring the soils with similar characteristics together in terms of management requirements and to obtain information to ensure long-term sustainability of lands and soils.

Materials and methods

Description of the study area

The study area is Dedeli and Çetinkaya villages and their near vicinity in Bafra, a district of Samsun province (Fig. 1).

In terms of physiographic features, the study area, on the left bank of the Kızılırmak River, consists of bottomlands, which were formed on alluvial deposits carried by the Kızılırmak River at different times, and the steep slope and piedmont lands. The altitude of the bottomland above the sea

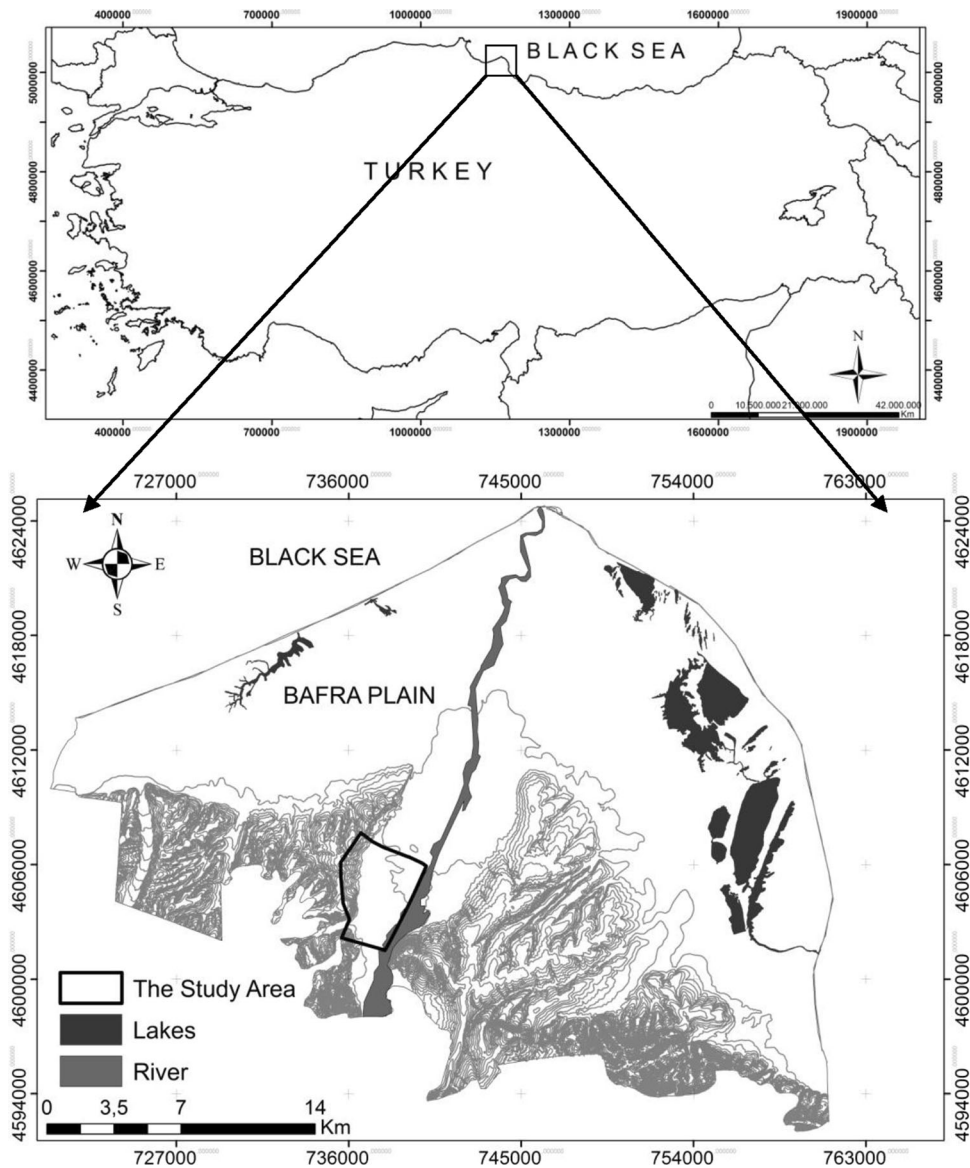


Fig. 1 Location map of the study area

level ranges from 5 to 10 m in general, but the terrains in the north and north-west reaches an altitude of 150 m. While soils on **piedmont lands** are composed of very thin colluvial materials, the bottomlands are composed of old and new alluvial deposits carried by the Kızılırmak River. While the soils which were examined in terms of similarities using physical and chemical soil properties and which were classified as **calci haplustert** (foot slope), **typic ustipsamment** (terrace), and **typic ustifluent** (flood plain) according to Soil Survey Staff (1999) formed on alluvial parent material, the

soils classified as **vertic ustorhent** (shoulder) and **vertic calciustept** (back slope) formed on limestone marl parent material. Moreover, while **vertic ustorhent** soil formed on marl parent material and **vertic calciustept** formed on argillaceous limestone marl parent material locate on terrains with steep slope (12–20 %), **typic ustifluent** formed on fine and coarse alluvial deposit mixture, **typic ustipsamment** formed on fine sand and silty alluvial parent material, and **calci haplustert** formed on fine colluvial deposit distributed on almost flat lands with slopes ranging from 0 to 2 % (Fig. 2). There

are also longitudinally arranged materials carried by the Kızılırmak River in flood times in different forms such as river banks and river terraces, scattered throughout the field. The general slope of the bottomland is in north–south direction.

The average annual temperature and rainfall of the region are 13.6 °C and 764.3 mm, respectively. The region receives most rainfall in winter and spring. Therefore, ground water level is high from January to June in the plain. Climate type of the region was assessed according to the method of Thorntwaite (1948). Based on the assessments, humidity index was calculated as 16.94 Im, and depending on this value, the climate type of Bafra district was classified as semi-humid climate (C2). According to the amount of the annual potential evapotranspiration (726.7 mm), the climate type was in mesothermal (medium hot climates) B2 class. The temperature regime was b4 class, which is close to marine climate. According to these results, Bafra district was in a semi-moist humid climate zone indicated by “C2B2'sb4” symbols, referring to mesothermal climate, moderate water deficit in summer, close to maritime climate. In addition, according to Soil Survey Staff (1999), moisture regime is ustic and temperature regime is mesic (Sarioğlu and Dengiz 2012).

Sampling and laboratory analysis

Geological landform and vegetation cover were combined with geological data, and soils formed on different

parent materials/rocks and different physiographies have been identified. In order to determine different soils and their limitations, besides the information about soil profile, data obtained from changes in cropping pattern and drainage property, terracing pattern, and textural changes resulting from test drilling and observations were used due to the fact that a large part of the study area consists of alluvial plains, where differences in bedrock/parent material or topography are not noticeable.

The places of soil profile which were determined by preparatory field studies were found using global positioning system (GPS), and soil profile pits were dug. Morphological descriptions (Soil Survey Staff 1993; 1999) were done on the basis of genetic horizon principle, and soil samples were obtained. Then, texture (Gee and Bauder 1986), CEC (Rhoades 1986), CaCO₃ (Allison and Moodie 1965), OM (Jackson 1958), pH (Hendershot et al. 1993), and EC (Rhoades 1982) analyses were performed. Available water content (AWC) was calculated from the difference between field capacity (Klute 1986) and permanent wilting point (Klute 1986) of soil samples.

Statistical analysis

In this study, hierarchical CA and MDSA were performed to classify the horizons and some physical and chemical properties of soils on different physiography and parent materials in Dedeli and Cetinkaya villages and in the immediate vicinity of these villages.

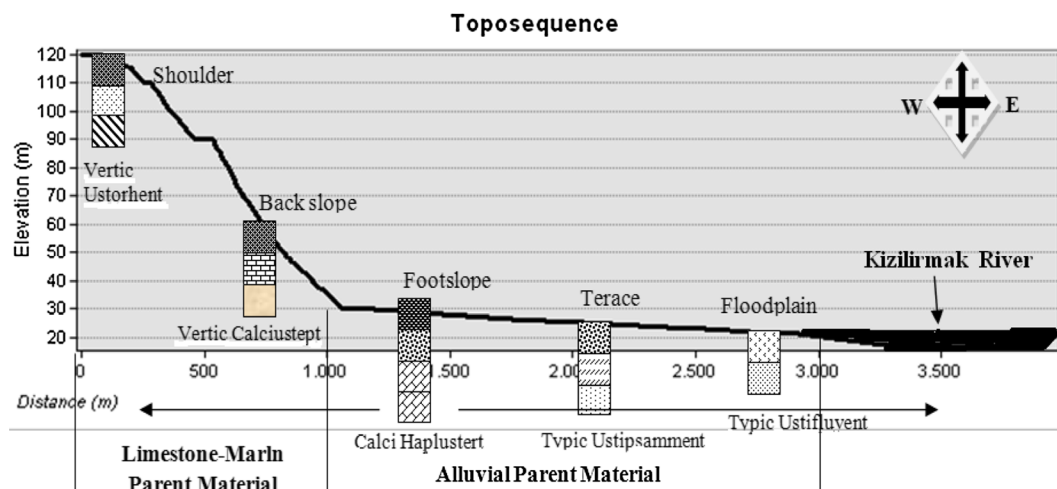


Fig. 2 Toposequence (east–west) and classification of different soils formed on limestone/marl-alluvial parent material

CA is one of the multivariate statistical methods commonly applied to multidimensional data sets in order to study the similarities of objects (e.g., soil samples) in the variables' space (e.g., parameters) or similarities of variables in the objects' space (Zolotajkin et al. 2014). CA is characterized by the similarity measure used and the way the resulting sub-clusters are linked. Euclidean squared distance matrix used as the most popular similarity measure in CA is calculated using the whole of the semivariogram to maximize the information going into the clustering algorithm (Wagener et al. 2007). Also, the methods of ward linkage, single linkage, complete linkage, average linkage, Mcquitty linkage, median linkage, and centroid linkage can be used as the linkage method. In CA, which was used to classify physical and chemical soil properties and horizons in terms of their similarity, Pearson's distance, which is a weighted type of Euclidean distance, as a measure of similarity and single linkage method based on the shortest distance principle as linkage method, was performed separately.

MDSA enables identification of inter-object relations by displaying the objects that can be displayed in k -dimensional space in a conceptual space with fewer dimensions (two, three) in a format very close to the original position. The overall objective of the analysis is to determine the structure of the objects (using distance values) very close to the original shape with the fewest dimensions possible. In MDSA, stress value, an indicator of difference between multi-dimensional (p -dimension) actual figure and the figure estimated in k -dimensional space, is calculated. MDSA provides opportunity to make an evaluation by displaying the compatibility of observational distances and configuration distances in a graph called Sheppard diagram. In Sheppard diagram, a scatter table is created by placing the observed distances in the Y axis and the value of differences in the X axis (Şahin and Miran 2007). All statistical analyses were done using a Statistical Package for Social Science (SPSS) 16.0 package program.

Results and discussion

In this study, both the similarity of the horizons of five different soil profiles identified from bottomland, piedmont land, and steep slope land formed on limestone

marl parent material and alluvial parent material and the similarity of physical and chemical soil properties of these horizons were analyzed. Descriptive statistics concerning physical and chemical properties of the soil horizons are presented in Table 1, and the analysis results of the horizons are given in Table 3.

When physical and chemical soil properties of all the horizons were analyzed with respect to coefficient of variation (CV), it was seen that the variability of soil properties was predominantly high (Table 1). While clay, sand, OM, CEC, CaCO_3 , and EC showed high variability, silt and pH showed medium and low variability, respectively. According to Wilding et al. (1994) and Mulla and McBratney (2000), variation is considered as low when coefficient of variation is lower than 15 %, medium when it ranges from 15 to 35 %, and high when it is higher than 35 %. Wilding et al. (1994) reported that static soil properties such as soil texture, mineralogy, soil thickness, and color have lower degree of variability in comparison with dynamic soil properties such as water content, hydraulic conductivity, redox state, biological activity, exchangeable cations, and OM content. Again, Tsegaye and Hill (1998), Yost et al. (1982), and Aimrun et al. (2007) reported that pH has low variability compared to other chemical soil properties. The pH values are a log scale of proton concentrations in the soil solution, and there would be much higher variability if soil acidity was expressed in terms of proton concentrations directly (Sun et al. 2003). The result of this study is consistent with the above-mentioned results.

The highest positive correlation among physical and chemical soil properties was observed between clay and CEC (0.94, $p < 0.01$), whereas the highest negative correlation was between clay and sand (-0.96 , $p < 0.01$). The lowest positive and negative correlations were observed between CaCO_3 and pH (0.53, $p < 0.05$) and silt and clay (-0.46 , $p < 0.05$), respectively (Table 2).

Physical and chemical analysis results related to the horizons of soil series are shown in Table 3. While almost all horizons of vertic ustorthent, vertic calciustept, and calci haplustert soils had clay texture, the texture classes of horizons of typic ustifluent and typic ustipsamment soils were in loam and sandy loam class. Loamy texture was observed on the upper horizons, whereas sandy loam texture was observed on the lower horizons (Table 3). All the horizons of typic ustifluent and typic ustipsamment soils were in medium calcareous soils in terms of CaCO_3 content (Ülgen and

Table 1 Descriptive statistics concerning physical and chemical soil properties

Variables	Unit	Mean	Min.	Max.	SD	CV, %	Skewness	Kurtosis	Number, <i>n</i>
Clay	%	39.45	8.0	72.00	20.45	51.8	-0.41	-1.18	20
Silt	%	32.20	21.0	44.00	6.08	18.9	0.15	-0.36	20
Sand	%	28.35	6.00	66.00	18.47	65.1	0.84	-0.45	20
OM	%	1.31	0.10	3.10	0.99	75.6	0.56	-0.75	14
CEC	cmol (+) kg ⁻¹	36.67	9.20	55.90	15.81	43.1	-0.79	-0.74	20
AWC	%	15.17	8.40	26.60	4.94	32.6	0.66	-0.05	20
CaCO ₃	%	11.92	1.60	42.90	9.70	81.4	1.89	4.71	20
pH		8.28	8.00	8.80	0.18	2.2	1.01	2.68	20
EC	dS m ⁻¹	0.31	0.10	0.50	0.11	35.5	0.16	-0.67	20

OM organic matter, CEC cation exchange capacity, AWC available water content, EC electrical conductivity, SD standard deviation, CV coefficient of variation

Yurtsever 1974), but all horizons of vertic calcistep soils, except for Bk horizon, were in calcareous soil class. On the other hand, while Ap horizon of vertic ustorthent soils was classified as calcareous in terms of CaCO₃ content, horizons of sub-soils were classified as high calcareous and very high calcareous soils. Bkss2 horizon of calci haplustert soils was classified as high calcareous, whereas other horizons were classified as medium calcareous. While OM content of soils were of medium level (2–2.7 %) in vertic ustorthent, calci haplustert and vertic calcistep soils, typic ustifluent soils were low (1.1 %), and typic ustipsamment soils were in high class (3.1 %). Except for Bss1 horizon of calci haplustert soils, B and C horizons of all soils had either very low or no OM content at all (Table 3). CEC values of soils showed parallelism with texture class of horizons and clay contents, and it had high values in horizons with clayey texture. While CEC values were very high in all horizons of calci haplustert and vertic

calciustep soils (Metson 1961), high and very high levels were observed in the horizons of vertic ustorthent soils. CEC values were high in A horizons of typic ustipsamment soils, but medium in A horizon of typic ustifluent soils. CEC values were low in C horizons of both soils. According to pH results, all horizons of other soils except for C horizon of calci haplustert soils showed moderately alkaline reaction (Bruce and Rayment 1982). On the other hand, C horizon of calci haplustert soils showed strongly alkaline reaction.

In an attempt to classify the horizons and physical and chemical properties of the soils representing Çetinkaya and Dedeli villages and near vicinity with respect to similarity, hierarchical CA was used in the study. Because the soil horizons and physical and chemical properties will be classified according to their similarities, Pearson Euclidean distance as a similarity measure and single linkage method based on the shortest distance principle as a linkage method were used

Table 2 The correlation relationships between physical and chemical soil properties

	Clay	Silt	Sand	OM	CEC	AWC	CaCO ₃	pH
Silt	-0.46*							
Sand	-0.96**	0.18						
OM	0.19	0.20	-0.28					
CEC	0.94**	-0.32	-0.94**	0.43				
AWC	0.69**	-0.52*	-0.59**	-0.09	0.59**			
CaCO ₃	-0.37	0.34	0.29	-0.53*	-0.40	-0.25		
pH	0.09	-0.28	-0.01	-0.60**	-0.11	0.18	0.53*	
EC	0.86**	-0.53*	-0.77**	0.04	0.72**	0.65**	-0.48*	-0.02

** $p < 0.01$; * $p < 0.05$

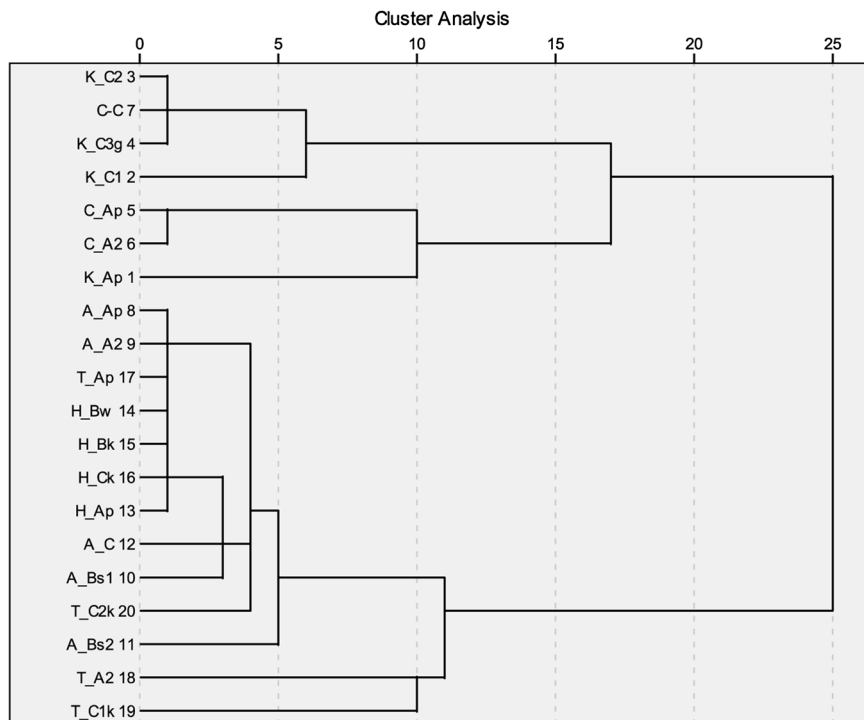
Table 3 Analysis results concerning soil horizons

Horizon	Depth, cm	Texture classes	Clay	Silt	Sand	CaCO ₃	OM	CEC	AWC	pH	EC
Typic ustifluent											
Ap	0–24	Loam	25	44	31	13.9	1.1	23.8	15.5	8.2	0.3
C1	24–57	Loam	9	43	48	14.2	–	11.2	11.4	8.4	0.1
C2	57–88	Sandy loam	8	31	61	14.3	–	9.8	8.7	8.4	0.2
C3g	88+	Sandy loam	8	26	66	13.4	–	9.2	8.4	8.4	0.2
Typic ustipsamment											
Ap	0–17	Loam	23	35	42	6.5	3.1	34.3	13.6	8.1	0.2
A2	17–48	Loam	21	37	42	7.0	1.4	30.8	13.1	8.0	0.2
C	48+	Sandy loam	9	32	59	14.9	–	10	11.1	8.3	0.2
Calci haplustert											
Ap	0–19	Clay	49	34	17	6.3	2.3	52	13	8.2	0.3
A2	19–44	Clay	49	36	15	7.4	1.5	50.7	8.7	8.2	0.3
Bss1	44–69	Clay	61	30	9	11.4	1.6	55.9	17.9	8.2	0.4
Bkss2	69–111	Clay	56	38	6	18.7	0.6	43.6	13.8	8.4	0.4
C	111+	Clay	72	21	7	8.5	0.7	54	22.9	8.8	0.4
Vertic calciustept											
Ap	0–19	Clay	52	26	22	1.6	2	44.1	18.6	8.0	0.4
Bw	19–48	Clay	57	26	17	3.3	0.5	45.8	19.4	8.2	0.4
Bk	48–78	Clay	60	24	16	9.4	0.3	46.9	19.8	8.2	0.5
Ck	78+	Clay	55	29	16	4.1	0.1	44.1	20.7	8.3	0.5
Vertic ustorhent											
Ap	0–20	Clay	47	36	17	2.4	2.7	48.2	13	8.1	0.3
A2	20–59	Clay	42	33	25	27.0	0.5	38.6	13.5	8.3	0.3
C1k	59–100	Clay loam	36	35	29	42.9	–	33.1	13.6	8.4	0.2
C2k	100+	Clay	50	28	22	16.3	–	47.2	26.6	8.4	0.3

separately to calculate the distances. Dendrogram generated as a result of the hierarchical CA applied for 20 different horizons of five different soil profiles is presented in Fig. 3.

When the dendrogram is analyzed, it can be seen that soil horizons appeared in two groups. When groups are analyzed, it can be seen that soil horizons of typic ustifluent and typic ustipsamment soils constitute the first group, and those of calci haplustert, vertic ustorhent, and vertic calciustept soils constitute the second group. Both main groups are divided into sub-clusters themselves (Fig. 3). When sub-clusters in the first group are analyzed, it can be seen that A and C horizons constitute two different distinct clusters. Typic ustifluent and typic ustipsamment soils in the group are similar in terms of the horizons where parent material is defined. When lower sub-groups

are analyzed, it can be seen that C horizon of typic ustipsamment soils and C2 and C3g horizons of typic ustifluent soils are in the same group, whereas C1 horizon of typic ustifluent soils is in a different group. The possible reason for the difference between alluvial parent materials may be because sediments with different fractions carried by the Kızılırmak River overflowed its banks at different times. While the Kızılırmak River caused accumulation of the C horizon of typic ustipsamment soils away from the river bank and the C2 and C3g horizons of typic ustifluent soils respectively closer to the river bank because of a great flood along the river, it caused the accumulation of the sediments defined as the C1 horizon of typic ustifluent soils because of minor floods that may have occurred later on. Despite the fact that A horizons of typic ustipsamment and typic



K typic ustifluent, *C* typic ustipsamment, *A* calci haplustert, *H* vertic calciustept, *T* vertic ustorhent

Fig. 3 Similarity dendrogram of soil horizons. *K* typic ustifluent, *C* typic ustipsamment, *A* calci haplustert, *H* vertic calciustept, *T* vertic ustorhent

ustifluent soils showed similarity in sub-cluster, they were different in lower sub-group (Fig. 3).

The second group, where calci haplustert, vertic calciustept, and vertic ustorhent soils were considered similar, was divided into three sub-groups. All horizons of vertic calciustept soils, Ap and A2 horizons of calci haplustert soils, and Ap horizons of vertic ustorhent soils appear in the same group in the lowest sub-cluster. In the upper cluster, the aforementioned horizons and other horizons of calci haplustert soils and C2k horizon of vertic ustorhent soils constitute the second group. The third group consists of A2 and C1k horizon of vertic ustorhent soils (Fig. 3). The main reason for these similarities between the soils is the effect of parent material (marl parent material) in depths, but on the surface, this similarity results from a similar texture.

The similarities of soil horizons and physical and chemical soil properties were evaluated two-dimensionally via MDSA. In two-dimensional display of MDSA related to soil horizons, the stress value calculated according to Kruskal's formula was 0.060, and R^2 was 0.989. Kruskal's stress value is calculated by

taking the square root of the ratio of the differences between configuration distances and estimated configuration distances to estimated configuration distances, and it expresses the conformity between the data distances and configuration distances (İşler 2010). According to the analysis results, the value of stress explained the data with a rate of 0.989 for two-dimension, and also good compatibility was observed between data distances and configuration distances (Şahin et al. 2008). Also, the observational distances and the disparities showed a linear relationship. Because the aim in MDSA is to measure the similarity of estimated distances determined according to disparities matrix obtained from distance matrix to the distance matrix obtained from direct data, having a direct relation explains the fact that estimated distances are accordant with the actual values (İşler 2010).

According to the two-dimensional MDSA, the coordinates of horizons of soil series determined by physical and chemical properties are shown in Table 4. In the table, C1, C2, and C3g horizons of typic ustifluent soils and C horizon of typic ustipsamment soils were

positively charged in primary dimension with values above 1. It was also of primary importance whether these horizons are perceived as similar in terms of the physical and chemical soil properties selected. Because the alluvial sediments carried by the Kızılırmak River serve as parent material in soil formation in soil series in this group, parent material horizons were perceived to be remarkably similar with their higher values in comparison with other horizons.

Except for this group, A2 and Ap horizons of typic ustipsamment soils, Ap horizon of typic ustifluent soils, and C1k horizon of vertic usthorhent soils with positive values ranging from 0 to 1 were perceived as similar to each other. In this group, A2 and Ap horizons of typic ustipsamment soils and Ap horizon of typic ustifluent soils with positive values close to 1 were more similar to each other, whereas C1k horizon of vertic usthorhent soils was perceived as the least similar horizon to these horizons due to the fact that it takes a positive value close to zero (Table 4). Soil horizons which showed similarity in MDSA were also similar in CA and fell into the same group. In this study, which investigates the similarity of soil horizons with respect to some physical and chemical soil properties selected by using two different analysis methods, both methods produced similar results. This result also showed that similarity classification carried out with respect to physical and chemical soil properties was successful. Soil horizons which took negative values in primary dimension in Table 4 were not similar to those horizons with positive values. While no soil horizons with positive values higher than 1 in the secondary dimension was found, positive values remained between 0 and 1, and soil horizons were perceived to have less similarity. Soil horizons taking negative values were found to have insignificant similarity in secondary dimension.

Disparities matrix results of MDSA, in which similarity of soil horizons was analyzed with respect to physical and chemical properties, are shown in Table 5.

While soil horizons with values close to 0 in disparities matrix were perceived as similar, those with values higher than 1 were considered to be different or dissimilar (İşler 2010). According to the disparities matrix results, C horizon of typic ustipsamment soils and C2 horizon of typic ustifluent soils with values of 0.00 were the most similar horizons, and this result was also similar to the result obtained from CA. Disparities matrix results showed that the aforementioned parent materials from typic ustipsamment soils and typic ustifluent soils are the

Table 4 Stimulus coordinates of soil horizons

Name of Stimulus	Dimension of stimulus coordination	
	1	2
<i>K</i> -Ap	0.81	-0.30
<i>K</i> -C1	1.97	-0.11
<i>K</i> -C2	2.31	0.15
<i>K</i> -C3g	2.46	0.32
<i>C</i> -Ap	0.84	0.34
<i>C</i> -A2	0.98	0.28
<i>C</i> -C	2.22	0.09
<i>A</i> -Ap	-0.89	0.17
<i>A</i> -A2	-0.90	0.08
<i>A</i> -Bss1	-1.52	-0.09
<i>A</i> -Bkss2	-1.13	-0.58
<i>A</i> -C	-1.94	0.10
<i>H</i> -Ap	-0.73	0.43
<i>H</i> -Bw	-1.03	0.32
<i>H</i> -Bk	-1.18	0.35
<i>H</i> -Ck	-0.95	0.21
<i>T</i> -Ap	-0.76	0.32
<i>T</i> -A2	-0.13	-0.58
<i>T</i> -C1k	0.32	-1.28
<i>T</i> -C2k	-0.74	-0.22

K typic ustifluent, *C* typic ustipsamment, *A* calci haplustert, *H* vertic calciustept, *T* vertic usthorhent

sediments accumulated in the same period after a great flood along the Kızılırmak River, which show similar characteristics. Again, according to the disparities matrix results, while Bw and Bk horizons of vertic calciustept soils (0.02), Bw and Ck horizons of vertic calciustept soils (0.05), Ap and A2 horizons of typic ustipsamment soils (0.06), Ap and A2 horizons of calci haplustert soils (0.09), Ap horizon of calci haplustert soils and Ap horizon of Vertic Usthorhent soils (0.12), C2 and C3g horizons of typic ustifluent soils (0.17), Bw and Ap horizons of vertic calciustept soils (0.19), Bk and Ck horizons of vertic calciustept soils (0.20), Ck and Ap horizons of vertic calciustept soils (0.23), C horizon of typic ustipsamment soils, and C3g horizon of typic ustifluent soils (0.29) were the most similar soil horizons, in terms of the values they took, with respect to physical and chemical soil properties selected, C horizon of calci haplustert soils and C3g horizon of typic ustifluent soils (4.36), C horizon of calci haplustert soils and C2 horizon of typic ustifluent soils (4.23), C horizon of calci haplustert soils and C horizon of

Table 5 Disparities matrix for soil horizons

	K- Ap	K- C1	K- C2	K- C3g	C- Ap	C- A2	C-C	A- Ap	A- A2	A- Bss1	A- Bkss2	A-C	H- Ap	H- Bw	H- Bk	H- Ck	T- Ap	T- A2	T- C1k	
K-C1	1.07																			
K-C2	1.66	0.66																		
K-C3g	1.93	0.98	0.17																	
C-Ap	0.73	1.21	1.48	1.66																
C-A2	0.61	1.01	1.34	1.54	0.06															
C-C	1.54	0.55	0.00	0.29	1.40	1.25														
A-Ap	1.74	2.85	3.22	3.38	1.67	1.81	3.13													
A-A2	1.72	2.84	3.23	3.41	1.72	1.84	3.15	0.09												
A-Bss1	2.34	3.50	3.84	4.00	2.36	2.50	3.75	0.62	0.69											
A- Bks- s2	1.90	3.08	3.26	3.73	2.18	2.26	3.43	0.77	0.68	0.66										
A-C	2.83	3.95	4.23	4.36	2.83	2.97	4.14	1.21	1.30	0.55	1.16									
H-Ap	1.72	2.76	3.03	3.17	1.59	1.73	2.95	0.51	0.67	0.86	1.07	1.14								
H-Bw	1.95	3.04	3.34	3.47	1.90	2.03	3.24	0.52	0.66	0.59	0.90	0.81	0.19							
H-Bk	2.12	3.20	3.48	3.61	2.06	2.20	3.39	0.64	0.78	0.54	0.95	0.66	0.34	0.02						
H-Ck	1.81	2.93	3.26	3.41	1.82	1.95	3.16	0.47	0.61	0.60	0.78	0.91	0.23	0.05	0.20					
T-Ap	1.59	2.71	3.10	3.28	1.55	1.68	3.01	0.12	0.19	0.82	0.86	1.37	0.48	0.56	0.72	0.49				
T-A2	1.16	2.18	2.52	2.71	1.35	1.42	2.42	1.07	1.06	1.41	1.03	1.90	1.18	1.27	1.39	1.16	1.13			
T-C1k	1.38	2.10	2.42	2.61	1.70	1.72	2.32	1.89	1.86	2.15	1.68	2.60	2.00	2.09	2.19	1.97	1.95	0.68		
T-C2k	1.68	2.76	3.07	3.21	1.67	1.81	2.96	0.72	0.89	0.83	0.93	1.19	0.63	0.63	0.71	0.54	0.84	0.82	1.53	

typic ustipsamment soils (4.14), Bss1 horizon of calci haplustert soils and C3g horizon of typic ustifluent soils (4.00) were the least similar horizons in terms of the values they took (Table 5). These results obtained from disparities matrix and CA dendrogram results showed similarity with a rate of 100 %. While soil horizons, which were found similar in disparities matrix, were perceived as similar because they were in the same cluster in the dendrogram which shows the CA results, the horizons which were different were perceived as dissimilar since they took part in two different main groups in dendrogram (Table 5; Fig. 3).

According to MDSA results carried out to create disparities matrix for physical and chemical properties, Kruskal’s stress value was 0.054, and R² was 0.989. According to the two-dimensional MDSA results, as clay and CEC take positive values higher than 1, and silt takes positive values close to 1, they became physical and chemical soil properties of primary importance in terms of whether they were perceived as similar to primary dimension (Table 6). It was seen that physical and chemical soil properties which took negative values

did not have primary importance in primary dimension. These results suggested that clay, CEC and silt were the most important physical and chemical soil properties exhibiting the similarities between horizons in primary dimension. In secondary dimension, sand took positive

Table 6 Stimulus coordinates of physical and chemical soil properties

Name of stimulus	Dimension of stimulus coordination	
	1	2
Clay	2.05	-0.72
Silt	0.86	0.71
Sand	0.08	1.72
OM	-1.40	-0.45
CEC	1.71	-0.44
AWC	-0.25	-0.25
CaCO ₃	-0.76	0.09
pH	-0.85	-0.21
EC	-1.45	-0.46

Table 7 Disparities matrix for physical and chemical soil properties

	Clay	Silt	Sand	OM	CEC	AWC	CaCO ₃	pH
Silt	1.91							
Sand	3.12	1.41						
OM	3.47	2.52	2.62					
CEC	0.56	1.45	2.70	3.09				
AWC	2.34	1.50	1.96	1.15	1.98			
CaCO ₃	2.91	1.76	1.96	1.13	2.54	0.88		
pH	2.95	1.93	2.12	0.52	2.56	0.60	0.73	
EC	3.51	2.57	2.65	0.00	3.15	1.19	1.14	0.56

value higher than 1 and became the most important soil property in the determination of horizon similarity. The silt which took a positive value close to 1 in secondary dimension became another important soil property.

When the disparities matrix results of physical and chemical soil properties were analyzed, while clay and EC with a value of 3.51 were perceived as the most dissimilar soil properties, EC and OM with a value of 0.00 appeared to be the closest soil properties which could be used interchangeably (Table 7). In addition, because the silt and sand content took values higher than 1 in their relations with all the physical and chemical soil properties, they were regarded as different from other soil properties examined. Observational distances related to soil properties and disparities showed a linear relationship. The linear relationship observed revealed that estimated distances created to measure the similarity of the physical and chemical soil properties were compatible with the actual values.

Conclusions

The topographic condition strongly affects the physical, chemical, mineralogical, and morphological properties of soil either directly or indirectly in the region (Dengiz et al. 2013). In order to identify similarity of genetic soil horizons with respect to some physical and chemical soil properties, CA and MDSA were done in the study. The analysis results related to 20 different genetic soil horizons from bottomland, piedmont land, and steep slope land in Çetinkaya region and nine different physical and chemical soil properties belonging to these genetic horizons were used as data set. According to the results of CA, soils in the study area were classified in two main groups as typic ustifluent and typic ustipsamment soils and vertic ustifluent, vertic

ustorhent, and calcic calciustept soils. In the group of typic ustifluent and typic ustipsamment soils, while C horizons in the lowest cluster of the dendrogram were perceived as similar, in the group of vertic ustorhent, vertic calciustept, and calci haplustert soils, Ap horizons in the lowest cluster were perceived as similar. Similar perceptions were obtained via MDSA results. The results of MDSA suggested that the clay content, CEC, and silt content of soils have primary importance in primary dimension in determining the similarity between the soil horizons, whereas sand and silt contents of soils have primary importance in the secondary dimension. Again, the results of MDSA revealed that, in the classification of horizon similarities, EC and OM properties are most similar soil properties that can be used interchangeably. On the other hand, these results showed that clay content and EC properties are most dissimilar soil properties.

Classifications of the variables examined are described in detail via CA and MDSA. Thanks to the grouped clusters, the data sets can be made less crowded and less complicated in order to make them easier to analyze and examine. Eliminating the complex data sets is necessary, especially in soil studies. Grouping performed with the help of CA is more effective in both obtaining the results and organizing the information. In this study, CA and MDSA, which simplify the data and provide opportunity to work on more efficient variables, were examined, and their application on soil classification was discussed. The result of the study suggest that the methods used in this study, which can be used successfully in order to determine different soils and their capabilities, can be an alternative to time-consuming and troublesome classical methods. In addition, it is possible to make the soil resources sustainable for a long period of time by using the results obtained through these methods which help to find out the soils of

similar characteristics and decide about similar management practices, thus allowing the decision makers to make effective plans rapidly.

References

- Aimrun, W., Amin, M. S. M., Ahmad, D., Hanafi, M. M., & Chan, C. S. (2007). Spatial variability of bulk soil electrical conductivity in a Malaysian paddy field: key to soil management. *Paddy and Water Environment*, 5, 113–121.
- Allison, L. E., & Moodie, C. D. (1965). Volumetric calsimeter method. In C. A. Black (Ed.), *Methods of soil analysis. Part II: Chemical and microbiological properties* (pp. 1389–1392). Madison: ASA Agronomy Monograph.
- Bruce, R. C., & Rayment, G. E. (1982). Analytical methods and interpretations used by the agricultural chemistry branch for soil and land use surveys. Indooroopilly, Queensland: Queensland Department of Primary Industries, Bulletin QB8 (2004).
- Dengiz, O., Sağlam, M., Özyaytekin, H. H., & Başkan, O. (2013). Weathering rates and some physico-chemical characteristics of soils developed on a calcic toposequences. *Carpathian Journal of Earth and Environmental Sciences*, 8(2), 13–24.
- Gee, G. W., & Bauder, J. W. (1986). Particle-size analysis. In A. Klute (Ed.), *Methods of Soil Analysis. Part I: Physical and mineralogical methods* (2nd ed., pp. 388–409). Madison: ASA and SSSA Agronomy Monograph.
- Hendershot, W. H., Laareae, H., & Duquette, M. (1993). Soil reaction and exchangeable acidity. In M. R. Carter (Ed.), *Soil sampling and methods of analysis* (pp. 141–145). Boca Raton: Lewis.
- İşler, D. B. (2010). Multidimensional scaling analysis. In Ş. Kalaycı (Ed.), *Multivariate statistical techniques SPSS applied* (pp. 379–386). Ankara: Asil Publication Distribution Limited Company.
- Jackson, M. L. (1958). *Soil chemical analysis*. New Jersey: Prentice Hall, Inc., Englewood Cliffs.
- Juma, N. G. (1999). What is soil? Major components of soil. In: The pedosphere and its dynamics. *A systems approach to soil science*. <http://www.Pedosphere.com>.
- Klute, A. (1986). Water retention: Laboratory methods. In A. Klute (Ed.), *Methods of soil analysis. Part I: Physical and mineralogical methods* (2nd ed., pp. 635–662). Madison: ASA and SSSA Agronomy Monograph.
- Metson, A. J. (1961). *Methods of chemical analysis for soil survey samples. Soil Bureau Bulletin No 12, New Zealand Department of Scientific and Industrial Research* (pp. 168–175). Wellington: Government Printer.
- Mulla, D. J., & McBratney, A. B. (2000). Soil spatial variability. In M. E. Summer (Ed.), *Handbook of soil science* (pp. A-321–A-351). Boca Raton: CRS.
- Rhoades, J. D. (1982). Soluble salts. In A. L. Page, R. H. Miller, & D. R. Keeney (Eds.), *Methods of soil analysis. Part II: Chemical and microbiological properties* (2nd ed., pp. 167–178). Madison: ASA and SSSA Agronomy Monograph.
- Rhoades, J. D. (1986). Cation exchange capacity. In C. A. Francis (Ed.), *Methods of soil analysis. Part II: Chemical and microbiological properties* (2nd ed., pp. 149–158). Madison: ASA and SSSA Agronomy Monograph.
- Sağlam, M. (2008). Analyses of spatial variability in some soil quality indices at widely distributed soil series of Gökhöyük State Farm using geostatistical methods. Ph.D. thesis. University of Ankara, Science Institute, Department of Soil Science and Plant Nutrition, Ankara, Turkey.
- Sarıoğlu, F.E., & Dengiz, O. (2012). Soil survey and mapping of soils formed on two different physiographic units and their classification. Proceedings, 8th International Soil Science Congress on “Land Degradation and Challenges in Sustainable Soil Management”, May 15–17, Çeşme, İzmir.
- Soil Survey Staff. (1993). *Soil soil survey manual*. Washington, DC: USDA Handbook, No 18.
- Soil Survey Staff. (1999). *Soil taxonomy. A basic of soil classification for making and interpreting soil survey*. Washington, DC: USDA Handbook, No 436.
- Sun, B., Zhou, S., & Zhao, Q. (2003). Evaluation of spatial and temporal changes of soil quality based on geostatistical analysis in the hill region of subtropical China. *Geoderma*, 115, 85–99.
- Şahin, A., & Miran, B. (2007). Farmer based risk map for crops: the case of Bayındır district. *The Journal of Ege University Faculty of Agriculture*, 44(3), 59–74.
- Şahin, A., Atış, E., & Miran, B. (2008). Identifying homogeneous locations for more efficient agricultural and environmental policies: the case of Ege region. *Journal of Ecology*, 17(67), 15–23.
- Thorntwaite, C. W. (1948). An approach to a rational classification of climate. *Geographic Review*, 38, 55–94.
- Tsegaye, T., & Hill, R. L. (1998). Intensive tillage effects on spatial variability of soil test, plant growth and nutrient uptake measurement. *Soil Science*, 163, 155–165.
- Uçar, N. (2010). Cluster analysis. In Ş. Kalaycı (Ed.), *Multivariate statistical techniques SPSS applied* (pp. 350–369). Ankara: Asil Publication Distribution Limited Company.
- Ülgen, N., & Yurtsever, N. (1974). The fertilizer and fertilization guide of Turkey. *Ankara: Technical Publication of Soil and Fertilizer Research Institute, No, 28*.
- Wagener, T., Sivapalan, M., Troch, P., & Woods, R. (2007). Catchment classification and hydrologic similarity. *Geography Compass*. doi:10.1111/j.1749-8198.2007.00039.x.
- Wilding, L. P., Bouma, J., & Goss, D. W. (1994). Impact of spatial variability on interpretative modelling. In R. B. Bryant & R. W. Arnold (Eds.), *Quantitative modelling of soil forming processes*. Madison: SSSA Special Publication 39.
- Yost, R. S., Uehara, G., & Fox, R. L. (1982). Geostatistical analysis of soil chemical properties of large land areas. *I. Semi-variograms*. *Soil Science Society of America Journal*, 46, 1028–1032.
- Zolotajkin, M., Smolinski, A., Ciba, J., Kluczka, J., & Skwira, M. (2014). Comparison of the chemical properties of forest soil from the Silesian Beskid. *Poland. Journal of Chemistry*. doi: 10.1155/2014/748236.