Anadolu Tarım Bilimleri Dergisi
Anadolu Journal of Agricultural Sciences
http://dergipark.gov.tr/omuanajas

Araştırma/Research

Anadolu Tarım Bilim. Derg./Anadolu J Agr Sci, 36 (2021)
ISSN: 1308-8750 (Print) 1308-8769 (Online)
doi: 10.7161/omuanajas.799510

Evaluation of soil hydropedological properties by factor analysis in gypsic ustorthent and typic ustifluent

Gülay Karahan[a,*]

[a]*Çankırı Karatekin Üniversitesi, Orman Fakültesi, Peyzaj Mimarlığı Bölümü, Çankırı, Turkey*

*Sorumlu yazar/corresponding author: gkarahan03@gmail.com

Geliş/Received 24/09/2020 Kabul/Accepted 13/01/2021

ABSTRACT
This study was conducted to evaluate soil morphological and hydrologic variables by factor analysis in a paddy field (Gypsic Ustorthent) and grassland (Typic Ustifluvents) in Kızılırmak county of Çankırı province in central Anatolia of Turkey. Fifty undisturbed soil samples were taken from the paddy field and seventy from the grassland with plastic soil samplers. Disturbed soil samples were taken from the same points for basic soil analyses. Saturated hydraulic conductivity (K_s) was measured on soil columns using a hydraulic conductivity set with a constant-head permeameter. Following the K_s measurements, soil columns were covered to prevent evaporation. When the water flow through the columns was stopped, samplings were taken for bulk density and penetration resistance was measured. Then the soils were removed, the morphological properties were defined and quantified with the help of standard soil description charts. Soil parametric and morphological properties were evaluated by factor analysis. Five factors (Hydropedology, Silt and soil chemistry, Root, pH and mottles, Aggregation) described 80.00% of the total variation in the paddy soils and six factors (Hydropedology, Silt and soil chemistry, Root, pH and mottles, Color and soil chemistry, Aggregation) defined 84.41% of the total variation in the grassland soils. The use of soil morphological variables along with parametric variables was found promising in understanding interlinkages between pedology and hydrology.

Keywords:
Factor analysis
Hydrological properties
Hydropedology
Morphological properties
Soil mechanics

Toprak hidropedolojik özelliklerinin gypsic ustorthent ve typic ustifluent'de faktör analizi ile değerlendirilmesi

ÖZET
Bu çalışma, Orta Anadolu'nun Çankırı ili Kızılırmak ilçesinde bulunan bir çeltik tarlasında (Typic Ustifluvent) ve mera alanında (Gypsic Ustorthent) toprak morfolojik ve hidrolojik değişkenlerini faktör analizi ile değerlendirmek amacıyla yapılmıştır. Plastik toprak örnekleyicileri ile çeltik tarlasından 50, mera alanından 70 adet bozulmamış toprak örneği alınmıştır. Temel toprak analizleri için aynı noktalardan bozulmuş toprak örnekleri alınmıştır. Doymuş hidrolik iletkenlik (K_s), toprak kolonlarında sabit yük seviyeli bir hidrolik iletkenlik seti kullanılarak ölçülmüştür. K_s ölçümünü takiben, buharlaşmayı önlemek için toprak kolonlarının üstü kapatılmıştır. Kolonlardan su akışı durduğunda, hacim ağırlığı için örnekler alınmış ve penetrasyon direnci ölçülmüştür. Sonra, topraklar çıkarılmış, toprak örneklerinin morfolojik özellikleri tanımlanarak standart toprak tanımlama çizelgeleri yardımıyla nicelendirilmiştir. Çeltik tarlası ve mera topraklarında toprak parametrik ve morfolojik özellikleri faktör analizi ile değerlendirilmiştir. Çeltik topraklardaki toplam varyasyonun %80'ini beş faktör (Hidropedoloji, Kök, Silt ve toprak kimyası, Toprak kimyası, Agregasyon) ve mera topraklarındaki toplam varyasyonun %84.41'ini altı faktör (Hidropedoloji, Kök, Silt ve toprak kimyası, Toprak kimyası, Renk ve toprak kimyası, Agregasyon) tanımlamıştır. Pedoloji ve hidroloji arasındaki bağlantıların anlaşılmasında parametrik değişkenlerle birlikte toprak morfolojik değişkenlerinin kullanılması umut verici bulunmuştur.

Anahtar Sözcükler:
Faktör analizi
Hidrolojik özellikler
Hidropedoloji
Morfolojik özellikler
Toprak mekaniği

1. Introduction

Pedology focuses on topics such as soil morphology, soil formation, and soil classification. However, it lacks in explaining some processes such as water movement in soil and plant root zone, and soil morphological and physical properties. In turn, hydrology studies the properties, occurrence, and circulation of water, and the relationship between water and environment (Hornberger et al. 1998). According to Van Tol et al. (2018), hydrological processes are quite effective in occurrence of morphological properties of soils such as mottles, color, and carbonation. However, measurement and even observation of most of the hydrological processes in the field are very difficult since these processes have large temporal and spatial variation and they are dynamic in nature. But, morphological properties of soils are not dynamic in nature and they have random spatial variation. This makes soil properties the ideal tool to conceptualize the hydrological processes. Pachepsky et al. (2008) reported that dynamics is feedback between soil structure and hydrologic function were accepted while scientific information about it was lacking. Bouma (2006) explained that pedologists have better information at the user experience, expert knowledge, and about measurements and simple models on the definition of water movement at the landscape level. However, hydrologists and soil physicists have more information on complex and specialized measurements, deterministic models for entire systems, and models for certain aspects. When pedology and hydrology are combined, hydrology can use pedological properties and pedology can use hydrological flow theory. This application will be more powerful and efficient for research than by studying separately as in the past (Bouma 2006). In addition, Lin et al. (2006) reported that working together with pedology and hydrology may be a strong tool for complex environmental issues. Hydrologists cannot see water movement clearly in the unsaturated zone, whereas pedologists can see soil pedological properties quite well from clay films to hydrologic regimes.

Bouma (2006) reported that negotiations should be made with stakeholders in all research including pedologists and hydrologists. The collaborations of pedologists and hydrologists will provide the development of the combined datasets that would be useful for each other. Related with the movement of soil water, Wood (1999) noted that it should be understood clearly where, when, and how it occurs. Therefore, combining all related datasets must be demanded continuously (Pachepsky and Rawls, 2004). Briefly, hydropedology, which studies the relationship between soil and water, provides a bridge between pedology and hydrology together with other disciplines that are related to land, air, and water interfaces (Kutilek and Nielsen, 2007). Hydropedological studies emphasize that soils both control hydrological processes (through their hydraulic properties) and serve as indicators of hydrological behavior (through the interpretation of morphological properties) (Van Tol and Le Roux, 2019). Hydropedology also aims to understand the spatial and temporal variability of soil water content, which knowledge is required for implementing precision agriculture techniques in viticulture (Camara et al. 2018).

To increase the reliability of hydrologic models, pedological data must be used. Predicting and controlling the dynamics of soil structure and hydrologic function should be studied in more detailed. Moreover, image analysis of hydropedological properties of the soil may contribute more evidence for understanding the movement of water and air in the soil. These studies can give beneficial information for land use and management of gypsiferous soils (Fazeli 2017). The aim of this paper was to evaluate hydropedological properties in paddy field (Typic Ustifluvents) and grassland (Gypsic Ustorthent) by factor analysis.

2. Material and Method

2.1. Experiment Site

Soil parametric and morphologic analyses were made on 120 disturbed and undisturbed soil samples from a paddy field (Typic Ustifluvents) and grassland (Gypsic Ustorthends) in north-central Anatolia of Turkey. The size of the study area is approximately 9 ha. It is located between 40º 200' 52" North latitude and 33º 59' 12" East longitude (Anonymous 2020) (Figure 1). The climate is semi-arid, annual temperature is 11 ^{0}C, humidity is 6%, and rainfall is 418 mm. The study area is located in a region with bare highlands and plateaus with slopes ranging from 0 to 10%. The parent material of soils comprises gypsum, marl, clay, and limestone, andesite, spilite, and basalt (Anonymous 2011).

2.2. Measurement Methods

Fifty undisturbed soil samples were taken from the paddy soils and 70 undisturbed soil samples were taken from the grassland soil (Figure 1) using a polyvinyl chloride column (15 cm length and 8.0 cm diameter) within a steel core that was connected to a hydraulic apparatus mounted on the three-point system of a tractor. The soil columns were stored in vapor proof plastics to prevent water loss until analyses. For basic soil analyzes, 120 disturbed soil samples were collected from the same sampling points where soil columns were taken. In order to saturate the soil samples, the columns were placed in large beakers, and water was added slowly so as not to exceed the upper soil level. The beakers are covered to prevent evaporation and water loss during the saturation period. Undisturbed soil columns, saturated with capillarity from the bottom, were placed in the hydraulic conductivity set (constant-head permeameter) and readings were made when constant flow conditions were achieved in the column by adjusting the constant water load on the soil.

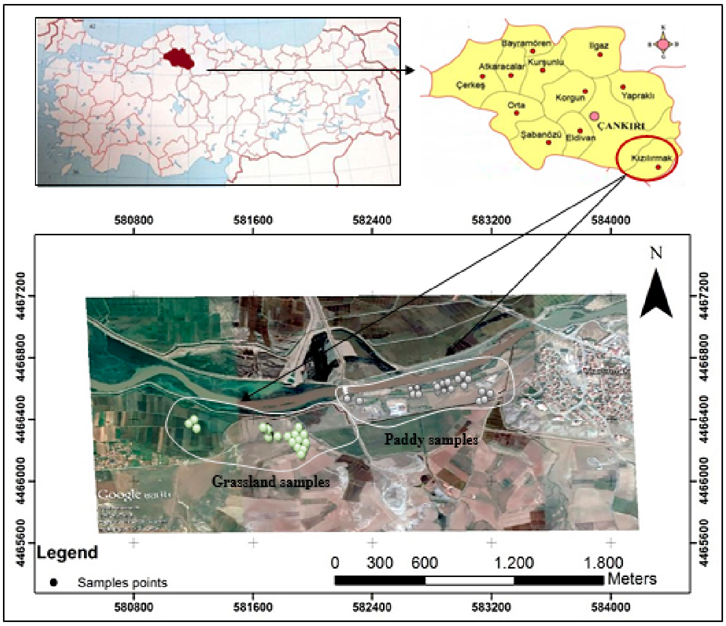

Figure 1.The study area map and sampling points (Revised from Karahan and Erşahin, 2017)
Çizelge 1. Çalışma alanı haritası ve örnekleme noktaları (Karahan and Erşahin 2017'den revize edildi)

Following saturated hydraulic conductivity measurement, a 100 cm^3 undisturbed soil sample was taken from the other end of the column that reached field capacity for measuring its bulk density (Black and Hartge, 1986). The dried soil column was standed on the floor and penetration resistance (PR) was measured with the Hand penetrometer, 30405709 (Eijkelkamp). Uniform pressure was applied to the hand grips of penetrometer, and then cone was pushed into the soil at a constant rate. Penetration resistance value was read from the under the black pointer of the manometer as Newton and noted for the appropriate depth. Following measurement of PR, soil columns were disturbed gently and morphological properties of soil color, soil structure, pores, roots, mottles, consistency, stickiness, plasticity (Schoeneberger, 2012), and coefficient of linear extensibility (COLE) (Schafer and Singer, 1976) were described by soil description charts. Soil morphological properties and soil color were converted to numerical values to facilitate their use in the correlation analysis. Greater numbers were given to properties that would match greater potential K-value (Karahan and Erşahin, 2017). In addition, particle size distribution (Gee and Bauder, 1986), aggregate stability index (4 gr soil sample between 2-1 mm sieve) (Kemper and Rosenau, 1986), pH (McLean, 1982), field capacity (FC), wilting point (WP) (Klute and Dirksen, 1986), specific surface area (SSA) (Carter et al., 1986), cation exchange capacity (CEC) (Rhoades, 1982), $CaCO_3$ content (Nelson, 1982), and soil organic matter content (OM) (Nelson and Sommers, 1982) were measured on the synchronized disturbed soil samples.

2.*3. Statistical analysis*

Data of morphologic and parametric properties of paddy and grassland soils were subjected to factor analysis separately. We selected factor analysis for two main reasons: (i) Factor analysis is a technique, which reduces a large number of interrelated variables to fewer and non-correlated variables (Sağlam 2013) and it has many uses (Gorsuch, 1983; Hair et al. 1995; Thompson 2004; Tabachnick and Fidell, 2007; Williams et al. 2010). (ii) Factor analysis aims definition of a fewer number of factors that explain the relations between variables (Johnson ve Wichern, 1992) and to have meaningful factors that are easier to interpret (Hair et al. 1998). Factor analysis, which involves many linear and sequential steps, is used in many studies of soil (Mallarino et al. 1999; Erşahin and Karaman, 2000; Shukla et al. 2006; Sağlam, 2013; Sağlam et al., 2014; Keskin and Grunwald, 2018). According to

Hair et al. (1995), it suggested that sample sizes must be equal to or greater than 100. They also reported that factors must be stopped when at least 95% of the variance is explained in the natural sciences. However, Tabachnick and Fidell (2007) and Thompson (2004) noted that explaining of scree graphs can change by researchers. These results give disagreement about the determination of the factor's number. But, Gorsuch (1983) and Pett et al. (2003) noted that when large sample sizes are used this disagreement is reduced. According to Mulaik (2009) when the eigenvalues are used greater than 1.0, a smaller number of factors will find. However, soil properties are assigned the factor with the highest eigenvalues (Shukla et al., 2006). Values greater or equal to 0.5 are accepted as significant (Hair et al., 1998). In addition, according to Velicer and Jackson (1990), cited in Costello et al. (2005), it was assumed that conserving the factors with eigenvalues greater than 1.

3. Results and Discussion

Descriptive statistics of the parametric and morphological properties of soil samples taken from the paddy field and grassland are given in Tables 1 and 2. According to Table 1, K_s has the highest (1.06%) and ASI has the smallest (0.02%) variation in the paddy field. The soils in the paddy field are heavy textured, rich in $CaCO_3$, moderate in OM, and alkaline (Table 1). Root quantity shows the largest variation (0.67%) and pH shows the smallest variation (0.03%) in grassland soils (Table 2). Our soil samples have 60% of clay textured, and they carry alluvial soil properties. Significant differences were found between mean and maximum values of K_s, sand, and silt content (0.62 and 2.26; 20.39 and 74.17; 26.79 and 65.54). These differences indicated that K_s, sand, and silt content have quite high values in some sampling points (skewness values -0.76, 0.67, and 0.64 respectively).

Table 1. Descriptive statistics of parametric and morphologic properties of the paddy soils (n=50)
Çizelge 1. Çeltik topraklarının parametrik ve morfolojik özelliklerinin tanımlayıcı istatistikleri (n = 50)

Soil Properties	Max.	Min.	Mean	SD	CV%
K_s, cm h^{-1}	2.26	0.0036	0.62	0.64	**1.06**
Clay, %	82.7	7.88	52.81	16.96	0.32
Sand, %	74.17	1.49	20.39	15.38	0.75
Silt, %	65.54	4.89	26.79	11.53	0.43
D_b, g cm^{-3}	1.62	1.06	1.23	0.09	0.07
PR, KPa	220.00	25.00	25.96	46.83	0.37
SSA, m^2 g^{-1}	284.85	96.75	21.63	44.47	0.20
CEC, Cmolc Kg^{-1}	73.85	32.46	57.93	8.21	0.14
COLE, %	9.80	4.50	8.65	1.41	0.16
FC, %	43.00	21.00	37.82	5.94	0.15
WP, %	31.00	9.00	25.55	8.27	0.53
pH	9.77	6.70	8.27	0.53	0.06
ASI	0.58	0.45	0.50	0.01	**0.02**
SOM, %	7.98	0.40	4.13	1.53	0.37
$CaCO_3$, %	24.15	11.52	17.34	2.50	0.14
Color	5.00	2.00	3.10	1.01	0.32
Structure Class	4.00	1.00	1.64	0.91	0.55
Structure Type	6.00	2.00	4.27	0.86	0.20
Structure Size	4.00	1.00	2.41	0.92	0.38
Pore Size	5.00	1.00	1.88	1.26	0.62
Pore Quantity	3.00	1.00	1.55	0.73	0.47
Consistency	6.00	1.00	4.11	1.17	0.28
Plasticity	7.00	1.00	4.87	1.56	0.32
Stickiness	7.00	1.00	4.91	1.52	0.31
Root Size	3.00	1.00	1.24	0.57	0.46
Root Quantity	4.00	1.00	1.31	0.73	0.55
Mottles	1.00	1.00	1.01	0.11	0.11

CV: Coefficient of variation (%), SD: Standard deviation, K_s: Saturated hydraulic conductivity, D_b: Bulk density, PR: Penetration resistance, SSA: Specific surface area, CEC: Cation exchange capacity, COLE: Coefficient linear expansion, FC: Field capacity, WP: Wilting point, pH: Soil reaction, ASI: Aggregate stability index, SOM: Soil organic matter, $CaCO_3$: Calcium carbonate

Table 2. Exploratory statistics of parametric and morphometric properties of the grassland soils (n=70)
Çizelge 2. Mera topraklarının parametrik ve morfolojik özelliklerinin tanımlayıcı istatistikleri (n = 70)

Soil Properties	Max.	Min.	Mean	SD	CV%
K_s, cm h^{-1}	2.71	0.0036	1.14	0.58	0.50
Clay, %	76.8	6.18	36.80	14.54	0.39
Sand, %	62.75	6.67	38.80	15.02	0.38
Silt, %	50.63	11.6	24.38	8.11	0.33
D_b, g cm^{-3}	1.51	1.08	1.26	0.09	0.07
PR, KPa	180.00	27.00	85.12	45.95	0.53
SSA, m^2 g^{-1}	253.12	82.08	181.24	39.05	0.21
CEC, Cmolc Kg^{-1}	63.63	21.80	51.64	7.36	0.14
COLE, %	9.60	4.00	7.52	1.37	0.18
FC, %	43.00	20.00	31.88	6.11	0.19
WP, %	30.00	8.00	20.02	5.58	0.27
pH	9.28	7.91	8.56	0.27	**0.03**
ASI	0.57	0.18	0.48	0.05	0.12
SOM, %	6.19	2.20	4.01	0.79	0.19
$CaCO_3$, %	23.19	5.10	11.48	4.12	0.35
Color	5.00	2.00	3.97	0.66	0.16
Structure Class	4.00	1.00	2.59	0.92	0.35
Structure Type	6.00	2.00	4.93	0.72	0.14
Structure Size	4.00	1.00	3.38	0.78	0.23
Pore Size	5.00	1.00	3.15	1.14	0.36
Pore Quantity	3.00	1.00	2.25	0.65	0.28
Consistency	6.00	1.00	2.97	1.04	0.35
Plasticity	7.00	1.00	3.22	1.41	0.43
Stickiness	7.00	1.00	3.45	1.28	0.37
Root Size	3.00	1.00	1.29	0.79	0.61
Root Quantity	4.00	1.00	1.36	0.91	**0.67**
Mottles	1.00	1.00	1.18	0.44	0.37

CV: Coefficient of variation (%), SD: Standard deviation, K_s: Saturated hydraulic conductivity, D_b: Bulk density, PR: Penetration resistance, SSA: Specific surface area, CEC: Cation exchange capacity, COLE: Coefficient linear expansion, FC: Field capacity, WP: Wilting point, pH: Soil reaction, ASI: Aggregate stability index, SOM: Soil organic matter, $CaCO_3$: Calcium carbonate

In the study area, the quantity of the roots is generally few but they are either too thin or too large. These large roots are found in soil samples were taken from the grassland field near the creek bed.

The suitability of soil morphological and parametric properties of paddy and grassland soils to factor analysis has been checked. The Kaiser–Meyer– Olkin (KMO) ratio is 0.89 (Sharma, 1996), and the Bartlett sphericity test is significant at $\alpha = 0.00$ level (Hair et al., 1998). Therefore, data of the twenty-seven soil properties were subjected to factor analysis. As a result of the factor analysis, 5 factors for paddy and 6 factors for grassland soils were determined, whose eigenvalue was>1 and each of them decreased gradually to the total variance. In addition, factor rotation was performed to decrease the number of in-kind variables loaded on different factors (Kleinbaum et al., 1988). The results of the factor analyses are given in Tables 3 and 4.

Generally, soil parametric and morphological properties described the variation in paddy and grassland soils equally. Morphological (stickiness, plasticity, pore quantity and size, COLE, structure size, consistency, structure grade and type) and parametric (clay, Ks, FC, WP, sand content, Db, PR, CEC, and SSA) properties were loaded on Factor 1. and explained 58.06% of the variance of the paddy soils. Similarly, mostly morphological (plasticity, stickiness, consistency, COLE, structure grade, size, and type, and pore size and quantity) and parametric (clay and sand content, Ks, PR, FC, WP, SSA, and Db) properties were loaded on Factor 1 and explained 51.61% of the variance of the grassland soils. Soil morphological properties have become more dominant in both land use. Therefore Factor 1 was named as ‘hydropedology factor’ for paddy and grassland soils.

In paddy soils, mostly parametric properties (silt content, $CaCO_3$, and SOM) loaded in Factor 2 and it described 8.37% of variation. It was named as ‘silt and soil chemistry factor’.

Table 3. Factor analyse of soil parametric and morphological properties for the paddy soils (n=50)
Çizelge 3. Çeltik topraklar için toprak parametrik ve morfolojik özelliklerin faktör analizi (n=50)

Soil variables	Factors				
	1	2	3	4	5
Clay, %	-0.95				
Stickiness	-0.94				
Plasticity	-0.94				
PQ	0.94				
PS	0.93				
K_s, cm h^{-1}	0.93				
COLE	-0.93				
SS	0.93				
Consistency	-0.93				
SG	0.92				
FC, %	-0.86				
WP, %	-0.87				
Sand, %	0.86				
ST	0.80				
D_b, g cm^{-3}	0.76				
PR, MPa	-0.75				
CEC, $CmolcKg^{-1}$	-0.69				
SSA, m^2 g^{-1}	-0.61				
Silt, %		0.75			
$CaCO_3$, %		0.73			
SOM, %		0.63			
Color		0.57			
RQ			0.83		
RS			0.84		
pH				0.73	
Mottles				0.57	
ASI					0.83
Variation, %	58.06	8.37	5.35	4.19	4.05

PQ: Pore quantity, PS: Pore size, K_s: Saturated hydraulic conductivity, COLE: Coefficient linear expansion, SS: Structure size, SG: Structure grade, FC: Field capacity, WP: Wilting point, ST: Structure type, D_b: Bulk density, PR: Penetration resistance, CEC: Cation exchange capacity, SSA: Specific surface area, $CaCO_3$: Calcium carbonate, SOM: Soil organic matter, RQ: Root quantity, RS: Root size, pH: Soil reaction, ASI: Aggregate stability index

Root size and quantity loaded in Factor 3. The Factor 3 described 5.35% of variation in the paddy soils, and it was named as ‘root factor’. In Factor 4, soil pH and mottles described 4.19% of variation. Factor 4 was named as “pH and mottles factor”. Structure stability index described 4.05% of variation and it loaded in Factor 5. Therefore, it was named as ‘aggregation factor’.

In grassland soils, root size and root quantity loaded in Factor 2 and it described 11.89% of the variation. It was also named as ‘root factor’. In Factor 3, soil pH, mottles, and silt content described 7.56% of variation. Factor 3 was named as ‘silt and soil chemistry factor. In Factor 4, SOM and CEC described 5.31% of variation and it was named as ‘soil chemistry factor’. In Factor 5, soil color and $CaCO_3$ content described 4.09% of variation and it was named as ‘color and soil chemistry factor’. In factor 6, as similarly with factor 5 in paddy soils, the structure stability index described 3.95% of the variation, and it was named as ‘aggregation factor’ (Table 4).

Soil parametric properties have consistent values reported in the literature (e.g., Mulla and Mc Bratney, 2002). Loadings in Factor 1 indicated that clay content is the key variable in paddy and grassland soils. The stickiness of soils is related to the amount of water and the degree of destruction of the soil structure. Soil consistency indicates the degree of cohesion or adhesion of the soil mass, and it is mainly controlled by the amount and type of clay, organic matter, and water content of the soil (FAO, 2006). Soil structural and consistency parameters refer to basic soil properties related to soil hydraulic properties. Therefore, these properties determine the soil water retention (Rawls and Pachepsky, 2002). Stickiness, plasticity, consistency, COLE, FC, WP, PR, CEC, and SSA are associated positively with the clay content as expected in Factor 1(Table 3).

Table 4. Factor analyse of soil parametric and morphological properties for the grassland soils (n=70)
Çizelge 4. Mera toprakları için toprak parametrik ve morfolojik özelliklerin faktör analizi (n=70)

Soil variables	Factors					
	1	2	3	4	5	6
Clay, %	0.98					
Plasticity	0.97					
Stickiness	0.95					
Consistency	0.95					
SG	-0.94					
PS	-0.92					
PQ	-0.92					
K_s, cm h^{-1}	-0.91					
SS	-0.91					
COLE	0.90					
Sand, %	-0.89					
PR, MPa	0.82					
ST	-0.79					
FC, %	0.74					
WP, %	0.72					
SSA, m^2 g^{-1}	0.70					
D_b, g cm^{-3}	-0.57					
RQ		0.87				
RS		0.84				
Silt, %			0.87			
Mottles			0.78			
SOM, %				-0.81		
CEC, $CmolcKg^{-1}$				0.60		
Color		0.57			0.69	
$CaCO_3$, %					0.69	
ASI						0.93
Variation, %	51.61	11.89	7.56	5.31	4.09	3.95

SG: Structure grade, PS: Pore size, PQ: Pore quantity, K_s: Saturated hydraulic conductivity, SS: Structure size, COLE: Coefficient linear expansion, PR: Penetration resistance, ST: Structure type, FC: Field capacity, WP: Wilting point, SSA: Specific surface area, D_b: Bulk density, RQ: Root quantity, RS: Root size, SOM: Soil organic matter, CEC: Cation exchange capacity, $CaCO_3$: Calcium carbonate, ASI: Aggregate stability index

In addition, soil pore and structure properties, and D_b are positively associated with K_s. However, these properties were found in negative relation with the clay content in both of the two land uses. Strong and moderate soil structure grade and blocky/angular and sub-angular soil structure type accurate the macropores. This causes the soil structure to increase the water flow.

Soils with blocky structure type show a positive correlation with saturated hydraulic conductivity because they are less water than other types of structures (Pachepsky et al. 2006). Our positive relationship between soil structure type and K_s was consistent with those found in the study of McKeague et al. (1982).

Pagliai and Vignozzi (2002) reported that water movements in soil depend on the size and type of soil structure and pores. The results are consistent with those reported in many studies, showing positive relations between macropores and K_s (Jarvis 2007; Dexter and Richard, 2009; Van Tol et al. 2012). However, soil macropores and voids can increase K_s, which are not completely related to unsaturated hydraulic conductivity $K_{(h)}$ (Libohova et al., 2018). Structural macropores and/or root macropores have important contributions to K_s variability (Perret et al. 1999; Watson and Luxmoore, 1986; White 1985). Nemes et al. (2005) reported that greater porosity will result in greater hydraulic conductivity. We found strong relations between K_s and pore size (0.93) and K_s and pore quantity (0.94) in paddy soils. These values were found as (0.87) and (0.81) for grassland soils.

In general, increased clay content reduces the formation of macropores (Karahan and Erşahin, 2017), while the roots enhance macropore formation. Gardner (1960) assumed that the soils around the roots have uniform soil properties including hydraulic properties.

Wu et al. (2017) reported that soil water transport is increased by macropores. Root properties influence the uptake of soil water in water-limited regions (such as semi-arid conditions) (Ahmed et al. 2018).

We found positive correlations between root properties and clay content. However, we found negative correlations between K_s, soil structure, and pore properties, and bulk density in grassland soils. Ahmed et al. (2018) noted that hydraulic conductivity decreases rapidly when the soil dries. As soil water potential decreases more rapidly around roots, hydraulic conductivity decreases even faster. However, in paddy soils, it was found a negative relation contrary to expectation between the clay content and root properties. The reason for this may be that the roots are disturbed during tillage.

Calcium carbonate is known to increase soil aggregation. Virto et al. (2011) reported that the high content of calcium carbonate in the fine-textured soil has also contributed to its structural stabilization. However, Chan and Heenan (1998) found a reduction in macroaggregate (>2 µm) stability after liming. They reported that the decrease in structural stability is the result of the lime-induced increases in biological decomposition and the resulting soil organic carbon losses. Our values for $CaCO_3$ range from 5.10 to 24.15 % and there is a positive relation between $CaCO_3$ and K_s, structure, and pore properties in paddy soils but they are found in negative relation in grassland soils.

The soil color can provide information on some soil properties such as organic matter, and water can influence soil color. Although organic matter content is found high in this study (Table 1 and 2), there was no a

strong relationship between organic matter content and K_s for paddy (0.26) and grassland (0.29) soils. Whereas, it is known that higher SOM content in the soil results in higher K_s. It has been reported that an increase in K_s with increasing SOM content, a soil property that improves soil structure (Nemes et al. 2005).

In our study, we detected structural pores related to some voids (interstitial, tubular, dendritic, irregular, and vascular in shape) between soil aggregates. However, these voids located between aggregates, but there is not a significant relationship between ASI and K_s (0.04 and 0.16). Because the aggregation values of our study are low and range from 0.18 to 0.58%. In fact, clay may protect the soil's organic matter against degradation. It is thought that the reason for it is alluvial and colluvial parent materials in the study area. Sağlam et al (2011) reported that the clay content of the alluvial soil is higher. The study area is characterized by the fact that soils in alluvial lands are typically heavier textured (Günal 2006) as they move away from the river bed.

Mottles show temporary wet conditions within the soil (Karahan and Erşahin, 2017) and it is a redoximorphic soil property, tidely related to clay content. The presence of mottles can be attributed to influence of the parent material as well as poor drainage. The mottles and K_s show an inverse relationship. However, although it is not important (0.09), we found a positive relation between K_s and mottles in paddy soils. In addition, the mottles on the surface may be gypsum deposits which found on the impermeable layer is present.

4. Conclusion

Understanding of hydropedological processes is important for soil and water management in arid and semiarid soils. In this study, soil hydropedological properties were evaluated in paddy and grassland soils by factor analysis in Gypsic Ustorthent and Typic Ustifluvent. The relations between soil morphologic and parametric properties have been investigated for the first time in a semi-arid condition in Turkey. Our results showed that morphological properties were tidely related to water movement in study soils. Therefore, it is in line with numerous recent studies dealing with the issue of hydropedology. However, there is limited literature on the effect of morphological properties on soil water relations. The contribution of morphological properties to water flow in hydropedology research is not fully reflected. We cannot think that the results of soil water modeling research are fully complete due to neglecting of hydropedological properties. They should take account because soil hydropedological properties are crucial in characterizing hydraulic behavior in soil. In addition, new studies on hydropedology can be used to interpret more complex systems involving soil and vegetation.

Acknowledges

The author thanks the Scientific and Technological Council of Turkey (TUBITAK) for the financial support given under the grant of BIDEP (2233) and Cankırı Karatekin University for partially supporting this study under the grant of BAP (2012/08).

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