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Physico-Chemical and Morphological Properties of Soils for *Castanea sativa* in the Central Black Sea Region

O. Dengiz, S. Ic and F.E. Sarioglu
Department of Soil Sciences and Plant Nutrition, Faculty of Agriculture, Ondokuz Mayis University, Samsun, Turkey

Corresponding Author: O. Dengiz, Department of Soil Sciences and Plant Nutrition, Faculty of Agriculture, Ondokuz Mayis University, Samsun, Turkey Tel: +90 362 3121919/1463 Fax: +90 362 4576034.

ABSTRACT
This study is focused on the soil physico-chemical, morphological properties and soil classification of forest sites where *Castanea sativa* wood stands located in the central black sea region. Some physiographic factors of the study area such as slope gradient, aspect, relief and average altitude were determined and evaluated by using GIS program. This study was carried out in Derekoy catchment that covers about 6.5 km^2 and its current climate is semi-humid. In this study, the changes in the properties of four different pedons were investigated and classified as Typic Haplustult, Vertic Dystrustept, Mollic Ustifluvent and Mollic Ustorthent. These soils were formed on basalt, sandstone, marl and alluvial material. The formation of soils was highly associated with major climatic factors and parent materials influenced the soils morphological and physico-chemical characteristics in the study area. Due to high clay content in all soil profiles of the study area, it should be avoided from driving high ground pressure equipment, such trucks and tractors in the orchard lead to soil compaction and this compaction causes reduced diffusion of water and gasses, poor drainage, restricted root growth and decreased chestnut yield. Thus, best management practices including reduce tillage, residue incorporation, surface and subsurface drainage, rotational cultivation, integrated pest management and intercropping can increase levels of both productivity and environmental quality significantly. Therefore, to perform all these agricultural managements for *Castanea sativa,* decision-makers should take into soil physico-chemical, morphological characteristics consideration.

Key words: Soil morphology, soil physico-chemical properties, *Castanea sativa,* black sea region

INTRODUCTION
It was known thirteen chestnut species in the world and these species have located in northern hemisphere. One of the chestnut species is a *Castanea sativa* Mill. (European chestnut) which is native to Asia Minor (Soylu and Erturk, 1999). It spread from the eastern coast of the black sea, through the Black Sea region and then arrives at the Marmara and Aegean regions, up to the mountainous areas of the Mediterranean Basin. Turkey is one of the few countries such as China, Korea, Italy, Portugal, Japan and Greece in the world with a favourable climate for chestnut production. Total annual chestnut production is about 1.223.385 ton in the world. While China the main chestnut producing country and has been produced 75% of the total chestnut production, Turkey is third rank with 63000 ton chestnut production in the world (FAO, 2004).

The distribution of chestnut trees in forest areas depend on the ecological conditions of regions. In the eastern black sea region chestnut trees grow naturally from sea level up to 1200 m and exist as pure chestnut stands or mixed with other broadleaved forest trees such as alder, elm and beech trees. In this area, the chestnut is the dominating forest tree species. In central and western black sea regions, chestnut areas are more restricted and stands are much smaller. The chestnut tree has many beneficial traits particularly an essential source of income for rural area's people and agroecosystem in Black Sea Region. The chestnut trees are utilized in many ways in Turkey. It is valuable for its timber, fruits, flowers, leaves etc. As one of the most profitable productive systems of the region, there is a great concern about the intensive management practices which are commonly used in those plantations, such as soil tillage, fertilization, irrigation etc. (Portela *et al.*, 1999; Martins *et al.*, 2005). Although chestnut (*Castanea sativa* Mill.) grows on wide variety of soils, optimal conditions for this species are deep, moderate fertile and acid soil, pH 4.0-4.5 (Kerr and Evans, 1993). Other authors consider optimum pH around 5.5 (Bourgeois *et al.*, 2004). However, this soil information for chestnut is not enough and a gap that will be considered at further research. Therefore, there is no detailed inventory and soils for *Castanea sativa*'s ecological requirements, not only at regional but also national level. The main objective of this study is to determine main physico-chemical and morphological properties soil and soil classification of chestnut woods in central black sea region.

MATERIALS AND METHODS

Field description: This study was carried out between 2008-2010 years in Derekoy catchment located in central coast of the black sea region (Fig. 1). The study area is 10 km far from the west of the Samsun province (4584800-4588000m N- 252500-254500m E UTM). It covers 653.1 ha and it lies at an elevation from sea level 430-1000 m.

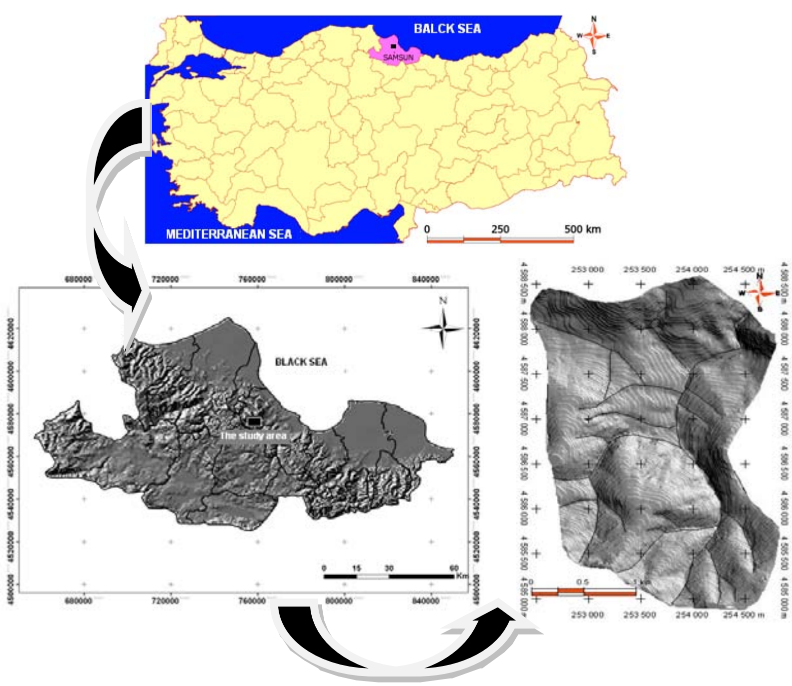

Fig. 1: Location of the Derekoy catchment

The current climate in the region is semi-humid. The summers are warmer than winters (the average temperature in July is 22.2 and in January is 6.9°C). The mean annual temperature, rainfall and evaporation are 13.6°C, 764.3 mm and 726.7 mm, respectively. According to Thornwaite method it has been identified that termed by C2B1's2d symbols half humid-humid mezothermal, having abundant moderate water supply in summer, maritime climate climate type has determined. According to Soil Survey Staff (1999), the study site has mesic soil temperature regime and ustic moisture regime. Elm, beech trees, pine, hazelnut and chestnut trees are dominant species in mixed forest. From the bedrock point of view, *Castanea sativa* trees are predominantly located on basalt, sandstone, marl, alluvial material carried by Derekoy River.

Physical, chemical and morphological analysis: A total of 16 undisturbed and disturbed soil samples were collected from each horizon in Derekoy catchment located in central coast of the black sea region for laboratory analysis. The soil samples were air dried, crushed and sieved using a 2 mm sieve. Particle size distribution was determined by the hydrometer method (Bouyoucuos, 1951) and bulk density was determined from undisturbed samples (Blacke and Hartge, 1986). Organic matter in air-dried samples was determined by the Walkley-Black wet digestion method (Nelson and Sommers, 1982). pH and EC-electrical conductivity were determined according to the methodology of the Soil Survey Staff (1992). Lime content was determined by Scheibler calsimeter (USDA, 1993). Exchangeable cations and Cation Exchange Capacities (CEC) were measured by using the 1 N NH_4OAC (pH 7) method (Soil Survey Staff, 1992). Total N and available P forms were determined by Kjeldahl (Bremmer and Mulvaney, 1965) and Bray and Kurtz (1945) methods. Micro nutrient elements (Fe, Cu, Zn, Mn) were determined using AAS (Anonymous, 1990). In addition, morphological properties of the four profiles were determined by sampling genetic horizons in the field, and soils were classified according to the methodologies of the Soil Survey Staff (1999), FAO/ISRIC (2006) and USDA (1993). Moreover, to generate hillshade, aspect, slope and elevation maps of the study area, ArcGIS 9.3v geography information system program was used.

RESULTS AND DISCUSSION

Soil morphology and classification: The topographic (elevation, dem, aspect and slope) characteristic of the catchment where the study is implemented is given in Fig. 2. Topography in the basin is moderately undulated and the basin is characterized mainly by rounded hilltops. Drainage pattern of the Derekoy catchment is dendritic drainage. A dendritic drainage pattern is the most common form and looks like the branching pattern of tree roots. It develops in regions underlain by heterogeneous material. That is, the subsurface geology has a different resistance to weathering so there is no apparent control over the direction the tributaries take. In addition, some topographic attributes such as slope gradient, aspect, relief and average altitude were calculated from Digital Elevation Models (DEM) with a 10 m grid-cell size. The 24.5% of the study area has less than 20% slope and 46% of the area is between 20-40% slope gradient and 29.5% of the study area has more than 40% slope varied from steep to very steep from which runoff can easily occur. In addition from the aspect point of view, 28.1% of the study area has north, northeast and northwest aspects while, 19.5% of the total area has south, southeast and southwest aspects.

The investigated morphology and physical characterization data for representative profiles of the soils developed from basalt, sandstone, marl and alluvial material are presented in Table 1. Soils display significantly variation in terms of participle distribution, structure, color and depth in their

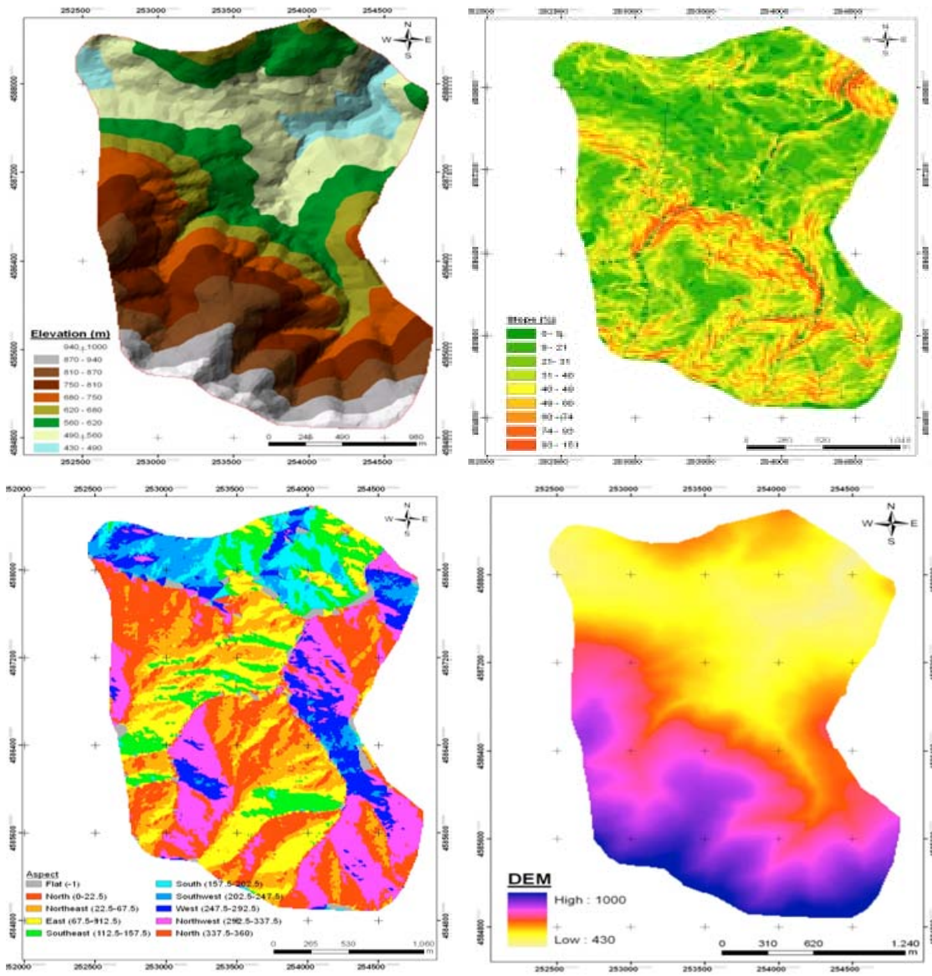

Fig. 2: Elevation, slope, aspect and DEM maps of the Derekoy catchment

profiles because of different parent material and topography. Profile I (P I) has more than 1 m depth and developed on mixing sand stone and marl parent materials. Clay was the dominant texture in PI. Soil color was 2.5 Y 4/3 in the A horizon while, due to leaching process and more than 1.5 m carbonate accumulation at depth, the color changed to 2.5Y 6/3 in E horizon and 2.5Y 7/4 in Ck horizon. Due to clay illuvation (movement of clay from upper horizons), clay accumulation was observed between 44 and 150 cm depth. Between these depths, the morphological property known as clay cutans was also observed. Albic horizon from where clay and basic cations have been removed and become a light color horizon was also identified under A horizon (Table 1). Due to high clay content, consistency of this soil is sticky and plastic in wet condition. In addition, calcium carbonate nodules were determined in the Ck horizon. The main diagnostic horizons were the albic and argillic horizon developed formation of this profile. Using the study of Soil Survey Staff (1999) and FAO/ISRIC (2006), this profile was classified as Typic Haplustult and Albic Acrisol.

The morphology of P II located on marl parent material was different from PI. The horizon orders in PII were defined as A-A2-Bw-C-2Ab-2Ck. All profiles had a clay loam texture. The occurrence of cracks 1-5 cm in width at the surface of this soil during dry periods is the result of

Table 1: Selected morphological characteristics of profiles

Horizon	Depth (cm)	Texture class	Boundary	Colors Dry	Colors Moist	Structure	Consistence	Special features
Profile I (Typic Haplustult/Albic Acrisol)								
A	0-20	C	cw	2.5Y 4/3	2.5Y 3/3	2 mgr	sh fr st pt	
E	20-44	C	cw	2.5Y 6/3	2.5Y 5/3	2 msbk	sh fi st pt	Albic horizon
Bt1	44-83	C	dw	2.5Y 5/4	2.5Y5/3	3 mabk	h fi st pt	Clay illuviation, clay cutans
Bt2	83-118	C	dw	2.5Y 5/4	2.5Y5/6	3 mabk	h fi st pt	Clay illuviation, clay cutans
Bt3	118-150	C	dw	2.5Y 5/4	2.5Y 5/4	3 mabk	h fi st pt	Clay illuviation, clay cutans
Ck	150+	C	-	2.5Y 7/4	2.5Y 7/6	m	h fi st pt	Carbonate nodules
Profile II (Vertic Dystrustept/Dystric Cambisol)								
A	0-20	C	cw	2.5Y 4/3	2.5Y 3/2	2 mgr	sh fi st pt	Cracks
A2	20-40	C	cw	2.5Y 4/4	2.5Y 4/4	2 msbk	h fi st ps	Cracks
Bw	40-89	C	dw	2.5Y 6/4	2.5Y 5/4	3 msbk	h fi st pt	
C	89-129	C	aw	2.5Y 7/3	2.5Y 6/3	m	h fi st pt	
2Ab	129-150	C	dw	2.5Y 5/4	2.5Y 4/4	2 mgr	h fi st pt	
2Ck	150+	C	-	2.5Y 6/4	2.5Y 5/4	m		Common carbonate nodules
Profile III (Mollic Ustifluvent/Mollic Fluvisol)								
A	0-20	C	aw	10YR 3/2	10YR 3/1	2 mgr	sh fr st pt	
C1	20-50	C	-	10YR 4/3	10YR 2/2	c	h fi st pt	Common coarse fragments
Profile IV (Mollic Ustorthent/Mollic Leptosol)								
A1	0-12	C	as	10YR 3/3	10YR 3/2	2 mgr	sh fr ss ps	
A2	12-29	CL	aw	10YR 5/6	10YR 5/4	1 fgr	sh vfr ss ps	
R	29+	-	-	-	-	-	-	

Boundary; a: Abrupt, c: Clear, g: Gradual, d: Diffuse, s: smooth, w: Wavy, i: Irregular, Structure; 1: weak, 2: Moderate, 3: Strong, sg: Single grain, m: massive, vf: very fine, f: fine, m: medium, c: coarse, gr: granular, pr: prismatic, abk: angular blocky; sbk: subangular blocky. Consistence; (Dry) lo: Loose, so: Soft, sh: slightly hard, h: hard, (Moist) lo: Loose, vfr: Very friable, fr: Friable, fi: firm, (Wet) so: Nonsticky, ss: slightly sticky, st: sticky, po: non-plastic, ps: slightly plastic, pt: plastic, Horizons; A: Surface horizon, Ab: Buried soil, E: Albic horizon, Bt: Argillic horizon, Bw: Cambic horizon, C: Parent Material, R: Rock, Texture; C: Clay, CL: Clay loam

high levels of clay. Many study reported that soil structure is critical for soil formation and also germination and growth of plants to transport water through the unsaturated zone underlying agricultural fields (Pirmoradian *et al*., 2005; Zolfaghari and Hajabbasi, 2008). Moderate granular and medium subangular blocky structures were observed in surface horizons, while a strong blocky structure characterized subsoil horizons. The main diagnostic horizon was the cambic horizon developed in the structural formation of this profile. Structural development was most noticeable between 15 and 123 cm. Using Soil Survey Staff (1999) and FAO/ISRIC (2006), this profile was classified as Vertic Dystrustept and Dystric Cambisol.

There was no epipedon in surface soils of all the in Profile III and IV, which had a mollic epipedon. Mollic epipedon has a Munsell color value less than 3. In addition, it also includes a horizon of organic materials that is too thin to meet the requirements of a mollic epipedon (Soil Survey Staff, 1999). Therefore, Profile III and IV can be defined as a young soil and classified as Mollic Ustorthent the study of (Soil Survey Staff, 1999) and Mollic Leptosol (FAO/ISRIC, 2006).

Physical and chemical properties: Soil physical and chemical properties show variability as a result of dynamic interactions among environmental factors such as climate, parent material, topography and land cover/land use (Dengiz *et al*., 2006; Dengiz, 2010). The major physical and chemical properties of the soils in the current study are presented in Table 2. Their pH varied from

Table 2: Results of some chemical analyses of soils of the study area

Horizon	Depth (cm)	pH	EC (dS m^{-1})	$CaCO_3$ (%)	O.M (%)	CEC (cmol kg^{-1})	Exchangeable cations (cmol kg^{-1}) Na^+	K^+	Ca^{++}	Mg^{++}	H^+
Profile I (Typic Haplustult /Albic Acrisol)											
A	0-20	6.62	0.496	2.2	5.00	28.70	0.24	0.11	15.63	9.08	3.64
E	20-44	5.83	0.145	2.1	0.98	25.13	0.18	0.09	12.10	6.13	7.63
Bt1	44-83	5.82	0.267	1.7	0.46	35.24	0.21	0.23	20.99	2.67	11.14
Bt2	83-118	6.14	0.517	1.9	0.43	42.62	0.17	0.23	25.03	6.54	10.65
Bt3	118-150	7.33	0.880	2.5	0.38	43.70	0.17	0.18	34.19	8.66	-
Ck	150+	7.67	0.468	27.7	0.69	29.46	0.34	0.13	23.37	4.88	-
Profile II (Vertic Dystrustept / Dystric Cambisol)											
A	0-20	5.76	0.247	1.6	3.85	29.82	0.27	0.10	13.51	6.19	9.75
A2	20-40	5.52	0.335	1.1	1.29	34.20	0.10	0.16	22.21	5.87	5.86
Bw	40-89	6.02	0.392	1.7	0.68	44.79	0.19	0.22	29.54	6.53	8.31
Ck	89-129	7.67	0.418	41.3	0.49	26.24	0.09	0.11	19.22	6.01	-
2Ab	129-150	7.66	0.636	1.5	0.64	39.96	0.12	0.24	35.78	3.72	-
2Ck	150+	7.84	0.403	31.5	1.97	30.37	0.44	0.15	28.66	1.45	-
Profile III (Mollic Ustifluvent /Mollic Fluvisol)											
A	0-20	4.49	0.309	1.9	8.02	36.80	0.13	0.27	13.39	8.30	14.71
C1	20-50	5.48	0.469	1.3	2.56	36.81	0.20	0.22	15.51	9.19	11.69
Profile IV (Mollic Ustorthent / Mollic Leptosol)											
A1	0-12	6.28	0.625	1.1	4.24	37.83	0.14	0.16	19.86	8.81	7.86
A2	12-39	5.54	0.244	2.1	1.36	34.93	0.22	0.07	17.51	4.88	12.25
R	39+	-	-	-	-	-	-	-	-	-	

A: Surface Horizone, Ab: Buried Soil, E: Albic horizone, Bt: Argillic horizone, Bw: Cambic horizone, C: Pareut, R: Rock, OM: Organic matter, CEC: Cation exchange capicity

acid to moderately alkaline (4.49-7.84). It was found correlation between pH and acidic and basic cations in all profiles. An increasing pH values decreased H ion concentration. Janirawuttikul *et al.* (2011) studied about pedogenesis of acid sulfate soils in 15 soil profiles. According to their results, they found base saturation had a strong relationship with exchangeable acidity. In addition, all profiles had very low EC values. All profiles had a clay texture, except the A2 horizon of Mollic Ustorthent, which had a clay loam texture. Vertic Dystrustept had the highest clay content, while Mollic Ustorthent had the highest sand content. Soil CEC varied between 25.13 and 44.79 cmol kg^{-1}. The soil with the highest CEC was the Vertic Dystrustept which had the highest clay and organic matter content. The calcium carbonate content of profiles was very low except for C horizon of Typic Haplustult and Vertic Dystrustept. Because they formed on marl parent material and carbonate accumulation (Table 2). On the other hand, the low amount of $CaCO_3$ may be explained by leaching of $CaCO_3$ from the profiles. Exchangeable Ca and Mg cations accounted for over 73% of the exchangeable complex as a result of the dissolution of carbonates, whereas exchangeable K and Na levels were rather low. Base saturation of soil varied between 60 and 87% in surface soils due to low pH and H ions concentration whereas this ratio increased more than %95 in C horizons of Typic Haplustult and Vertic Dystrustept. For all soils, the organic matter level was highest in the surface horizon and decreased sharply to its lowest level in the subsoil.

Physical and chemical fertilizing status: Although sweet chestnut (*Castanea sativa* Mill.) grows on a wide variety of soils, productivity of the *Castanea sativa* is highly influenced from poor physical, chemical and nutrient conditions of soils. Nitrogen is an important element for plant nutrition. Nutrient element concentration threshold levels were evaluated according to some researchers reports (Lindsay and Norvell, 1978; Schlincting and Blume, 1960; Pizer, 1967; Boutard, 2001; Milosevic *et al.*, 2009). Nitrogen is important for growth due to the fact that it is a major constituent element of all amino acids, which are the building blocks of all proteins, including the enzymes, which control virtually all biological processes (Brady and Weil, 1999). Nitrogen content of soils is much higher in surface soil than sub surface and nitrogen values shows a decreasing pattern with soil depth as expected. Phosphorus is essential for fertilization and fruit s*et al*though chestnut shows minimum response when increasing rates of this element are applied (Painter, 1963; Baron *et al.*, 1985). It was found that P is enough in all soil profiles and ranges from 4.4-14.6 mg kg^{-1} (Table 3). This case can be explained that the high P content is related to heavy fertilizer application. Of all the essential elements, potassium is the third most essential, after nitrogen and phosphorus, to limit plant productivity (Munshower, 1994). In addition to that, potassium plays an important role in increasing the production quality. However, K content is not enough for chestnut tree in most of the soils and varied between 27.3-105.3 mg kg^{-1}. Low amount of K may be explained by leaching of K ions from the profiles. As observed Table 3, in the surface horizons of all soil profile show extremely high micronutrient element concentrations. Lindsay (1979) and Khanna and Mishra (1978) indicated that most soils are acidic and very acidic, propitiating though the solubility of Fe, Mn, Zn and Cu which are greatly determined by the soil pH.

Physical properties of soils are also very important for growing of chestnut trees. Repeated entries with tractors, trucks and other machinery can lead to soil compaction and this compaction causes reduced diffusion of water and gasses, poor drainage, restricted root growth and lowered crop yield. This case agrees with the findings by Malgwi and Abu (2011) which indicates

Table 3: Results of plant nutrition elements of the study area

Horizon	Total N (%)	P (mg kg^{-1})	K (mg kg^{-1})	B (mg kg^{-1})	Fe (mg kg^{-1})	Mn (mg kg^{-1})	Zn (mg kg^{-1})	Cu (mg kg^{-1})
Profile I (Typic Haplustult /Albic Acrisol)								
A	0.27	4.4	42.9	3.00	95.25	53.03	2.45	2.02
E	0.05	4.8	35.1	0.78	26.06	64.71	0.76	0.68
Bt1	0.03	5.3	89.7	2.69	23.36	23.35	1.19	1.02
Bt2	0.02	5.3	89.7	3.66	20.67	29.48	0.89	1.07
Bt3	0.02	5.5	70.2	2.04	9.35	6.53	0.69	0.74
Ck	0.04	6.2	50.7	0.47	8.90	5.98	0.84	0.65
Profile II (Vertic Dystrustept / Dystric Cambisol)								
A	0.21	8.6	39.0	3.73	57.51	95.77	1.57	1.39
A2	0.07	8.1	62.4	1.51	19.77	56.39	1.07	0.89
Bw	0.04	11.1	85.8	3.11	27.86	37.79	1.07	1.32
Ck	0.03	6.1	42.9	1.35	8.63	4.55	0.89	0.65
2Ab	0.03	6.1	93.6	1.91	10.69	12.66	0.67	0.99
2Ck	0.11	6.6	58.5	1.73	8.72	6.53	0.55	0.65
Profile III (Mollic Ustifluvent /Mollic Fluvisol)								
A	0.43	12.6	105.3	3.51	146.47	63.32	3.27	1.92
C1	0.14	13.6	85.8	3.38	38.64	25.52	1.03	1.27
Profile IV (Mollic Ustorthent / Mollic Leptosol)								
A1	0.23	14.6	62.4	4.69	31.45	37.40	2.38	0.79
A2	0.07	12.6	27.3	3.00	19.77	23.74	0.82	0.40

A: Surface Horizone, Ab: Buried Soil, E: Albic horizone, Bt: Argillic horizone, Bw: Cambic horizone, C: Pareut, R: Rock, OM: Organic matter, CEC: Cation exchange capicity continuous cultivation led to increased bulk density and compaction, reduced porosity, organic matter. The epipedons (surface horizons) compared to the endopedons (sub-surface horizons) of all pedons had higher organic matter which promotes better aggregate stability, distribution of pore size and moisture retention. Even on a well tiled field, compaction can lead to waterlogged soils and an important negative impact on productivity. Avoid driving high ground pressure equipment, such trucks and tractors, in the orchard in which has high heavy soils, especially when the soil is wet. This case is also supported by Dengiz (2007). Researcher found low aeration capacity and high buck density under surface soil for heavy clay texture soils in some soil series (Gedikli, Soguttepe Cesmesi, Tabakli) in Ankara-Sogulca Catcment due to intensive field traffic. Encourage the growth of deep rooted vegetation such clovers, bell beans, lupines, dandelions, chicory, mustard, rape and supplementation of manure help prevent and reverse soil compaction. Moreover, abundance of these organic matter is also essential for soil life in the soil increases numbers and diversity of the organisms. Drought stress has also been important case. Therefore, it should be considered irrigation schedule which is essential for a chestnut orchard of good vigor.

CONCLUSIONS

This study presented an example to determine main soil characteristics, soil classification, and agricultural managements by considering environmental conditions of chestnut woods in Central Black Sea Region. From the soil habitat perspective, chestnut forest sites Derekoy River catchment show the following important features. Soils are developed on different parent materials such as basalt, sandstone, marl and alluvial material. Their mainly soil texture is clay. The main diagnostic surface and subsurface horizons were determined as mollic, vertic, agric, cambic and argillic horizons and all profiles were classified as Typic Haplustult, Vertic Dystrustept, Mollic Ustifluvent and Mollic Ustorthent. Due to high clay content in all soil profiles, it should be avoided from driving high ground pressure equipment, such trucks and tractors in the orchard lead to soil compaction and this compaction causes reduced diffusion of water and gasses, poor drainage, restricted root growth and lowered crop yield. Therefore, best management practices including reduce tillage, residue incorporation, surface and subsurface drainage, windbreaks, rotational cultivation, integrated pest management and intercropping can increase levels of both productivity and environmental quality significantly. Consequently, foresters who try to establish chestnut tree plantations in marginal lands should take this information about soil characteristics into consideration.

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