J. BIOL. ENVIRON. SCI.,
2007, 1(1), 5-10

Characterization, classification and agricultural usage of vertisols developed on neogen aged calcareous marl parent materials

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ABSTRACT

Vertisols that strongly influenced by argillipedoturbation, contain high levels of plant nutrients and well productive when irrigated. However, owing to their high clay content, they are not well suited to cultivation without painstaking management. The aim of this research was to determine physical, chemical and morphological properties and classification of the Vertisols formed on neogene clay lime deposits under intensive agricultural actives in the Bursa province which is the fourth most industrialized and populated city in Turkey. Vertisols comprise 23.693 hectares or 2,1 percent of the land area of Bursa Province. Most of the Vertisols are under the rain-fed agriculture practices and cereals (wheat and barley), tobaccos, and sunflowers are the most important cash crops. Some of them are irrigated for horticultural crops (tomato, pepper and onion) and sugar beets production. According to findings from preliminary field-works and the existing maps and reports, eleven different soil profiles formed on the neogene aged calcareous marl parent materials were described and sampled. All studied Vertisols are found to be generally deep, dark colored with strong wedge-shaped structure, high in CEC and base saturation with calcium and magnesium occupying more than 90 percent of the exchange site, low organic material and have sufficient amounts of nutrients for crops. The agricultural potential of the soils were also found to be limited due to high clay and $CaCO_3$ contents of sub surface horizons, steep slopes and a hard pan formation due to inappropriate soil tilling. On the basis of morphological and physicochemical analysis, soil profiles were classified as a Typic and Chromic Haploxerert according to Soil Taxonomy (Soil Survey Staff, 1975 and 1999) and as an Eutric Vertisol according to FAO/Unesco Soil Map of the World Legend (FAO/Unesco, 1974 and 1990) classification systems.

Key Words: Vertisol, Soil Morphology, Classification, Soil Tillage.

INTRODUCTION

The unique properties special to Vertisols are high clay content, volume changes with moisture, cracks that split and merge periodically, and evidence of soil movement in the form of slickensides and of wedge-shaped structural aggregates that are tilted with an angle from the horizon. The shrink-swell phenomenon, which is responsible for the genesis and behavior of the vertisols, is a complex, dynamic, and yet incompletely understood set of processes. Expressions of this phenomenon are linear and normal gilgai, cylic horizons, surface cracks due to desiccation, and the formation of slickensides. Shrink-swell processes in soils are related to total clay content, fine clay content, and minerals. Vertisols generally have high clay content (50 to 70 percent) and relatively large proportion of fine clay in the clay fractions (Soil Survey Staff, 1999). Smectite and 'mixed layer' clays have been reported to comprise an important part of the clay fraction in most areas where vertisols have been studied.

Vertisols exhibit cracks a depth of 50 cm down that are at least 1 cm wide and extend upward to the surface or the base of the plough layer or surface crust. These soils exhibit minimal horizon differentiation as a result of pedoturbation. They are also very plastic and sticky when wet (Soil Survey Staff, 1975).

Vertisols cover a total of 311 million hectares or 2,4 percent of the global land area. An estimated 150 million hectares is potential crop land (Driessen and Dudal, 1989). According to a map called the Turkey Soil Zones Map at the scale of 1:2.000.000 prepared from the results of the Turkey Development Soil Maps Survey at a scale of 1:100.000, Vertisols comprise 598.693 hectare or 0,86 percent of the land area of Turkey (Anonymous, 1999). They are almost saturated with water during wet winter seasons (November-May), and become very dry and desiccated throughout the soil profile in summer seasons (June-September).

Although these soils are considered among the most fertile soils when irrigated, some of their physical properties such as high clay contents, the shrink-swell movements, deep cracks and compactions are undesirable especially for agricultural usages, and for some other engineering usages as well.

Since the genesis of a soil may be misunderstood or may be disputed, it can be used only as a guide to our thoughts in selection criteria and concept formations (Soil Survey Staff, 1999).

The aim of this study was to investigate the formations and chemicals, physicals and morphological characteristics of Vertisols formed on neogene aged calcareous marl parent materials and to investigate their limited agricultural potential factors. Therefore, it would be possible to provide soil information to use especially in agricultural purposes, farm planning and other engineering practices such as buildings, roads

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and forest area designs. The genesis and classification of these soils according to soil taxonomy are also discussed.

MATERIALS AND METHODS

Vertisols formed on calcareous marl parent material are located on the south-west part of the Bursa province, 20 km far from the city center of Bursa that lies between 4.444.500 m and 4.466.000 m North latitude and 599.500 m and 672.500 m East longitude according to UTM coordinate system. The province occupies an area of 11.043 km^2 and 23.436 ha of the land area comprised by the Vertisols formed on calcareous marl (Anonymous, 1995). The area has a Mediterranean type climate with annual precipitation around 700 mm and rainy season extends from November to May and possesses "*Mesic*" soil temperature and "*Xeric*" soil moisture regime according to Soil Taxonomy (Soil Survey Staff, 1999). Terrestrial neogene formations and quaternary new and old alluvium deposits occur in the study area. Generally, the neogene is composed of clay and marl.

Soil samples were collected from 11 sites representing the Vertisols formed on calcareous-marl parent materials. The coordinates of the soil profiles were given in Table 1. Some physico-chemical properties of these soils were studied. Morphological properties of the soil profiles in the field were accomplished according to the Soil Survey Staff (1962 and 1975) and FAO-Unesco (FAO/Unesco, 1977). Necessary analyses as pH, salinity, texture, $CaCO_3$, cation exchange capacity (CEC), exchangeable cations and organic material were analyzed according to Soil Conservation Service (1972).

RESULTS AND DISCUSSION

The soils in the study area developed on neogene clay-lime deposits. The parent materials become firmed through years as cemented with lime. The physical, chemical and morphological properties of these vertisols are under the influence of their parent material. The lime, in upper horizons, is washed down to AC and C horizons by rains and/or irrigation waters in deep depth profiles. But the high lime contents in these horizons were much more due to lime-clay, marl or calcareous marl parent materials, than lime leaching from upper horizons by water.

They have generally smooth and almost smooth slightly wavy topography and resemble a bowl, lying south-north direction. Most of the lands in the study area have a slope range of 1 % to 6 %, clay texture, and less infiltration, due to their parent material. Their colours are brownish-black (10YR 3/2-2/2) throughout the profile, but dark-reddish-brown (5YR 3/3) in profile 8, grayish-yellow-brown (10YR 4/2) in profile 10 and dark-brown (7,5YR 3/3) in profile 11 when moist. Some important physical and chemical properties of soil series were given in Table 1.

During the field works, 1-4 cm wide and 50-100 cm deep cracks and gilgai microrelief were observed at the surface, cause of pedoturbation, which is one of the special characteristics of the Vertisols that were rich in smectitic clay minerals. The formation of slickensides was also observed in all profiles. The clay contents of the Vertisols in the area were generally more than 50 % (Table 1). They are especially rich in smectitic clay minerals, causing cracks in summer time. According to the X-Ray diffraction results of the soil profiles, smectite was found to be dominant clay minerals and fallowed by the kaolinite. Investigated soils also contain low amount palygorskite and illite.

Cracks are a unique feature in soils with strong shrink–swell potential and are used as one of the criteria in defining Vertisols and vertic intergrades in soil taxonomy (Soil Survey Staff, 1992).

The organic matter values varied from 0,12 % to 2,52 %. The organic matter contents were very low especially in lands under intensive agriculture. The CEC was very high due to high clay content, montmorillonit type clay minerals and organic matter. The CEC values varied from 21,99 to 65,02 cmol kg^{-1}. The pH values ranged from 6,36 to 7,94 and increased with depth. The $CaCO_3$ content of the soils increased with depth and values varied from 0,20 % to 64,67 %. The highest values were observed at the lowest horizons due to calcareous parent material (Table 1). Because of these properties, the basic cations cannot leach from the profile. This forms the studied vertisols had high in basic cation contents, saturated with Ca^{2+} and Mg^{2+} cations, neutral or smooth alkaline reaction. The exchangeable Ca^{2+} + Mg^{2+} was 21,34 to 62,67 cmol kg^{-1} respectively. Sodium varied from 0,14 to 2,34 cmol kg^{-1}. Base saturation was 100 % throughout all the profiles, due to the alkaline parent material and climate. Problem related to salinity and alkalinity was not found in the studied Vertisols (Table 1).

Table 1. Some important physical and chemical properties of the study sites

Horizon	Depth (cm)	pH 1:1	Water Soluable Total Salt (%)	C.E.C. (cmol kg^{-1})	E.C. (cmol kg^{-1})			$CaCO_3$ (%)	Organic Matter (%)	Particle Size Distribution (%)			Texture Class
					Na^+	K^+	$Ca^{2+}+Mg^{2+}$			Sand	Silt	Clay	
PROFILE 1 (UTM Coordinates: 4454632 m North Latitude; 658576 m East Longitude)													
A_1	0-26	6,42	0,038	47,95	0,21	1,17	46,57	0,59	1,62	29,16	14,96	55,88	C
Ass	26-60	6,72	0,046	48,59	0,25	0,95	47,39	0,59	0,83	28,09	14,66	57,25	C
AC	60-80	7,53	0,027	35,02	0,21	0,49	34,32	34,06	0,56	21,79	20,25	57,96	C
C	80+	7,72	0,020	27,23	0,21	0,39	26,63	40,32	0,21	27,02	26,41	46,57	C
PROFILE 2 (UTM Coordinates: 4454144 m North Latitude; 657915 m East Longitude)													
Ap	0-26	6.65	0.045	51.36	0.27	0.97	50.12	0.39	1.51	27.37	15.72	56.91	C
Ass_1	26-56	6.50	0.032	51.19	0.26	0.87	50.06	0.39	0.83	22.98	16.04	60.98	C
Ass_2	56-80	7.29	0.041	62.14	0.33	0.95	60.86	3.63	0.80	22.75	15.73	61.52	C
AC	80-114	7.61	0.024	44.12	0.30	0.62	43.20	33.78	0.59	16.34	17.87	65.79	C
C	114+	7.84	0.017	23.79	0.29	0.28	23.22	63.56	0.18	31.11	22.87	46.02	C
PROFILE 3 (UTM Coordinates: 4456207 m North Latitude; 659445 m East Longitude)													
A_1	0-22	6.36	0.036	59.84	0.34	1.19	58.31	0.44	1.92	22.15	14.96	62.89	C
Ass_1	22-48	6.43	0.042	58.95	0.40	0.96	57.59	0.14	1.03	20.02	14.95	65.03	C
Ass_2	48-81	6.93	0.033	56.90	0.69	1.08	55.13	0.29	0.91	20.32	14.65	65.03	C
Ass_3	81-122	7.25	0.034	65.02	1.46	0.89	62.67	0.74	0.80	17.55	14.45	68.00	C
ACss	122-152	7.72	0.042	60.23	2.34	0.77	57.12	7.11	0.50	18.24	13.76	68.00	C
C	152+	7.90	0.027	38.36	1.49	0.44	36.43	52.83	0.24	23.21	23.71	53.08	C
PROFILE 4 (UTM Coordinates: 4456058 m North Latitude; 657731 m East Longitude)													
Ap	0-25	7.03	0.041	47.70	0.47	0.99	46.24	0.49	2.42	32.87	19.00	48.13	C
Adss	25-54	6.56	0.052	51.57	0.43	0.91	50.23	0.39	1.12	30.80	17.45	51.75	C
Ass_1	54-84	7.20	0.050	49.23	0.59	0.82	47.82	0.39	0.83	35.95	13.21	50.84	C
Ass_2	84-125	7.60	0.045	48.45	1.33	0.76	46.36	6.71	0.74	30.38	17.65	51.97	C
Ass_3	125-142	7.85	0.044	49.50	2.07	0.59	46.84	9.48	0.68	32.61	13.75	53.64	C
AC	142+	7.90	0.036	43.14	1.84	0.43	40.87	33.08	0.33	31.34	21.61	47.05	C
PROFILE 5 (UTM Coordinates: 4456730 m North Latitude; 657495 m East Longitude)													
Ap	0-25	6,52	0,026	42,13	0,19	0,75	41,19	0,20	1,45	40,34	15,16	44,50	C
Adss	25-52	6,40	0,023	45,54	0,22	0,76	44,56	0,20	0,62	36,49	15,17	48,34	C
Ass	52-97	6,73	0,021	45,84	0,24	0,55	45,05	0,39	0,56	35,74	15,34	48,92	C
AC	97-114	7,56	0,031	46,16	0,32	0,67	45,17	15,00	0,59	27,19	17,72	55,09	C
C	114+	7,81	0,018	38,61	0,22	0,31	38,08	63,26	0,27	25,75	20,36	53,89	C
PROFILE 6 (UTM Coordinates: 4457464 m North Latitude; 657218 m East Longitude)													
Ap	0-30	6,89	0,038	43,20	0,25	1,40	41,55	0,20	1,59	33,35	18,11	48,54	C
Ass_1	30-55	7,02	0,032	48,70	0,24	0,82	47,64	0,59	0,74	32,30	17,45	50,25	C
Ass_2	55-73	7,20	0,033	49,70	0,26	0,81	48,63	7,83	0,65	32,30	14,99	52,71	C
ACk	73-91	7,51	0,027	43,65	0,24	0,57	42,84	28,26	0,41	30,46	14,10	55,44	C
Ck	91+	7,64	0,016	29,72	0,20	0,36	29,16	53,83	0,24	35,81	18,11	46,08	C

Table 1. Some important physical and chemical properties of the study sites (Continue)

Horizon	Depth (cm)	pH 1:1	Water Soluable Total Salt (%)	C.E.C. (cmol kg^{-1})	E.C. (cmol kg^{-1})			$CaCO_3$ (%)	Organic Matter (%)	Particle Size Distribution (%)			Texture Class
					Na^+	K^+	Ca^{2+}+Mg^{2+}			Sand	Silt	Clay	
PROFILE 7 (UTM Coordinates: 4458332 m North Latitude; 657181 m East Longitude)													
Ap	0-29	7,40	0,060	48,33	0,79	1,39	46,15	1,08	2,21	24,90	23,66	51,44	C
Adss	29-44	7,70	0,036	48,33	0,47	0,87	46,99	4,42	0,83	27,90	19,16	52,94	C
Ass_1	44-74	7,70	0,031	51,02	0,47	0,67	49,88	5,01	0,74	26,43	17,86	55,71	C
Ass_2	74-99	7,70	0,035	54,37	0,37	0,80	53,20	7,86	0,21	23,07	17,27	59,66	C
Ass_3	99-120	7,81	0,036	55,13	0,31	0,84	53,98	12,18	0,35	20,35	17,73	61,92	C
Ass_4	120-160	7,94	0,037	59,78	0,35	0,73	58,70	13,26	0,27	18,33	19,01	62,66	C
PROFILE 8 (UTM Coordinates: 4459124 m North Latitude; 658165 m East Longitude)													
Ap	0-21	6,43	0,023	40,90	0,23	1,19	39,48	0,39	1,99	35,48	18,58	45,94	C
Ass_1	21-39	6,48	0,019	49,57	0,21	0,58	48,78	0,30	0,82	32,83	15,21	51,96	C
Ass_2	39-55	6,88	0,034	46,72	0,26	0,75	45,71	2,17	0,79	32,68	13,27	54,05	C
ACk	55-66	7,58	0,018	33,84	0,20	0,36	33,28	36,63	0,70	30,59	17,45	51,96	C
Ckm	66+	7,84	0,009	25,27	0,15	0,13	24,99	49,36	0,26	40,79	24,33	34,88	CL
PROFILE 9 (UTM Coordinates: 4454310 m North Latitude; 659516 m East Longitude)													
A_1	0-28	7,50	0,033	46,40	0,22	2,30	43,88	2,96	2,52	30,21	16,31	53,48	C
Ass_1	28-51	7,50	0,028	48,85	0,25	1,50	47,10	3,56	1,20	24,50	18,41	57,09	C
Ass_2	51-80	7,48	0,034	49,72	0,25	1,37	48,10	7,41	1,03	24,72	15,69	59,59	C
ACk	80-101	7,24	0,028	43,77	0,24	1,04	42,49	28,55	0,82	20,41	20,90	58,69	C
Ck	101+	7,62	0,012	21,99	0,14	0,51	21,34	64,67	0,12	17,12	44,23	38,65	SiCL
PROFILE 10 (UTM Coordinates: 4457734 m North Latitude; 660908 m East Longitude)													
Ap	0-20	7,76	0,039	53,72	0,22	1,28	52,22	6,50	1,23	23,16	14,55	62,29	C
Ass_1	20-38	7,67	0,035	55,45	0,23	0,84	54,38	8,37	0,82	21,96	14,37	63,67	C
Ass_2	38-57	7,68	0,038	49,74	0,23	0,72	48,79	18,51	0,67	22,92	15,26	61,82	C
ACk	57-68	7,70	0,026	36,50	0,19	0,47	35,84	47,27	0,38	25,34	16,35	58,31	C
Ck	68+	7,82	0,017	27,69	0,15	0,23	27,31	60,78	0,20	36,35	15,07	48,58	C
PROFILE 11 (UTM Coordinates: 4454475 m North Latitude; 660193 m East Longitude)													
A_1	0-13	7,13	0,032	54,03	0,25	0,94	52,84	0,64	1,32	24,58	17,61	57,81	C
Ass_1	13-43	6,75	0,029	55,11	0,25	0,78	54,08	0,44	1,09	23,37	17,24	59,39	C
Ass_2	43-70	7,07	0,042	57,69	0,29	0,91	56,49	0,79	0,73	21,33	17,87	60,80	C
AC	70-87	7,49	0,025	45,52	0,28	0,60	44,64	26,18	0,53	22,52	18,09	59,39	C
C	87+	7,72	0,009	30,26	0,16	0,27	29,83	52,04	0,12	33,71	31,23	35,06	CL

Soil profiles investigated in the area have only ochric epipedon as diagnostic surface horizon at the surface. The clay contents of the Vertisols were generally more than 50 % throughout to profile. They are especially rich in smectitic clay minerals reason to have 1-4 cm wide cracks at the surface of the profiles in summer time and to form slicensides that produced by one mass sliding past another with polished and groved surface due to changes in moisture content. Based on morphological, physicochemical analysis and soil moisture regime, soil profiles were classified according to Soil Taxonomy (Soil Survey Staff, 1975 and 1999) and FAO-Unesco Soil Map of the World Legend (FAO/Unesco, 1974 and 1990) classification systems as a Typic and Chromic Haploxerert sub groups and as in Eutric Vertisol soil units, respectively.

CONCLUSIONS

For long term productivity, soils must have a good and right soil management. Depending on this, soil survey works become more important spontaneously. Inappropriate soil tilling and using unsuitable instruments, especially in vertisols, firstly cannot manage healthy plant growth and cause soil degradation in long time periods. This is why soil tillage is important for agriculture.

Cultivation practices change soil water content, aeration, and the degree of mixing of crop residues within the soil matrix, thereby affecting soil organisms, which have important functions in soils such as structure improvement, nutrient cycling and organic matter decomposition (Kladivko, 2001).

Zero till is commonly advocated as a preferred cropping system to conventional, multicultivation practices. Zero till is particularly attractive on clay soils to minimize compaction and induce natural structure formation. In particular, the soil structure of Vertisols has strong potential to attain optimal conditions for plant growth through activation of their inbuilt resiliency via shrink-swell cycles (McGarry, 1996; Pillai and McGarry, 1999).

It is accepted that the major purposes of tillage are to reduce bulk density and soil strength and to control pests and diseases (Culpin, 1981; Hill, 1990). However, soil cultivation affects soil quality in various ways. With high clay content, cultivation may lead to the formation of a hard pan below the plough layer that restricts root penetration and downward movement of water (Singh and Singh, 1996).

In the studied vertisols, we observed a hard pan below the surface horizons. It was significant in profiles 4, 5 and 7 and at the beginning stage for the others. These soils are disked intensively under cultivation. The cultivation practices form this layer. Therefore, attention must be given especially the ones under intensive agriculture. Zero or minimum till practices must be carried out in these areas. The main limitation factors regarding soil productivity for the studied Vertisols are summer drought, low organic matter content, high contents of clay and $CaCO_3$ and formation of the hard pan limiting healthy root growth and infiltration.

Over all we found that the soils are very high in clay and $CaCO_3$ contents, but very low in organic matter. They also have a hard pan that restricts root penetration and downward movement of water below the surface horizon due to inappropriate soil tilling. Hence, we strongly recommend that close attention should be paid for the soil cultivation, irrigation system and time depending on the soil types. All the studied soils were classified according to USDA Soil Taxonomy (Soil Survey Staff, 1975 and 1999) as Typic and Chromic Haploxerert and FAO/UNESCO (1974 and 1990) as Eutric Vertisol.

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