Anadolu Tarım Bilim. Derg., 2010,25(2):106-112
Anadolu J. Agric. Sci., 2010,25(2): 106-112

Research
Araştırma

CHARACTERIZATION OF SOIL PROFILE DEVELOPMENT ON DIFFERENT LANDSCAPE IN SEMI –ARID REGION OF TURKEY A CASE STUDY; ANKARA-SOĞULCA CATCHMENT

Orhan DENGIZ[1*] **Oğuz BAŞKAN[2]**

[1]Ondokuz Mayis University, Department of Soil Science, 55139, Samsun-Turkey
[2]Soil Fertilizer and Water Resources Research Institute, 06172, Ankara-Turkey

[*]e-mail: odengiz@omu.edu.tr

Received Date: 03.12.2009 **Accepted Date: 22.03.2010**

ABSTRACT: The main objective of this research was to determine the relations between soil profile development and landscape in Ankara-Sogulca Catchment located in the semiarid region of Turkey. Dominant geological materials are marl, lime stone and sand stone in the study area. Six soil pedons were examined by field investigation on along transect (crosswise from East to West direction) of the Sogulca Catchment. Soil formations were highly associated with topographic positions which have influence on morphological and physico-chemical characteristics of the soils. Therefore, slope degree has been regarded as one of the most important factors that controls the pedogenic process on PI, PII and PV located on hillslope positions. Because, topography or relief affects how water and other material are added to and removed from soils. Thus, they can be defined as young soils due to minimum soil formation and classified as Entisol/Leptosol. In addition, pedon VI, Typic Xerofluvent/Eutric Fluvisol, formed on toeslope position and alluvial deposit has less soil profile development. Inceptisol/Cambisol and Calcisol (PIII and PIV) formed on plateau position had the greatest degree of pedogenesis. It was determined that main subsurface diagnostic horizons of Inceptisol are cambic and calcic horizons. This study clearly showed that landscape position strongly affects soil pedogenetic development either directly or indirectly in the local region.
Key Words: Topography, Soil formation, Classification, Semiarid region

TÜRKİYE'NİN YARIKURAK BÖLGESİNDE FARKLI ARAZİ ŞEKİLLERİ ÜZERİNDE TOPRAK PROFİL GELİŞİMİNİN ÖZELLİKLERİ PİLOT ÇALIŞMA; ANKARA-SOĞULCA HAVZASI

ÖZET: Bu çalışma Türkiye'nin yarı kurak bölgesinde yer alan Ankara Soğulca Havzasında toprak profil gelişimi ile arazi şekli arasındaki ilşkinin belirlenmesi amacıyla yürütülmüştür. Çalışma alanında yaygın jeolojik materyaller marn, kireç taşı ve kum taşıdır. Soğulca Havzasının doğu batı doğrultusunda yapılan kesit çalışmasında altı pedon incelenmiştir. Toprakların oluşumlarında topografik pozisyonların toprakların morfolojik, fiziksel ve kimyasal özellikleri üzerinde etkili oldukları belirlenmiştir. Bu nedenle, eğim derecesinin yamaç araziler üzerinde yer alan PI, PII ve PV pedonlarının toprak oluşum işlemleri üzerine önemli faktörlerden birisi olduğu düşünülmektedir. Çünkü topografya veya rölyef topraktan suyun ve diğer maddelerin eklenmesi veya uzaklaşmasınının sağlanmasında etkilidir. Bu topraklar oluşumlarının minimum seviyelerde olmaları nedeniyle genç topraklar olarak tanımlanmakta ve Entisol/Leptosol olarak sınıflandırılmıştır. Ayrıca, taban arazi pozisyonunda ve alluviyal depozitler üzerinde oluşan pedon VI, Typic Xerofluvent/Eutric Fluvisol zayıf toprak profil gelişimine sahiptir. Plato düzlüğü üzerinde oluşmuş Inceptisol/Cambisol ve Calcisol (PIII and PIV) en ileri toprak oluşum seviyesine sahiptirler. Inceptisollerin önemli yüzey altı tanı horizonları olarak cambic ve calcic horizonlar tespit edilmiştir. Bu çalışma lokal alanlarda arazi şekillerinin toprak oluşumu ve gelişmesinde gerek doğrudan gerekse de dolaylı olarak kuvvetli etkilerinin olduğunu açıkça göstermiştir.
Anahtar Sözcükler: Topografya, Toprak oluşumu, Sınıflandırma, Yarıkurak bölge

1. INTRODUCTION

The characteristics and properties of soils result from transformations affect the material of the Earth's crust. According to Joffe (1949), the formation of soil in a region can occur within a certain period of time depending on the geological material, successive climates, topography and biological and human activities of the region. Effects of these factors depend not only on the nature of the rock and their derived formations that have resulted from them, but also on landscape relief and the mitigation of matter in solution or in suspension in water (Arnold, 2006). Therefore, topography or relief is the most important factor for soil formation and affects how water and energy were added to and was lost from soil. Arnold (2006) indicated that a reference relief unit was a catchment or watershed area and the analysis of lateral transfers on, in and through the soils had to be considered to understand the functioning of the landscape units. The systems could be open or close relative to the flow of water and energy. In addition, Jenny (1980) argues topography is the primary factor in explaining soil variation. He thinks topography refers to the inclination in percent degrees, length of slope in meters, and slope aspect. Slope aspect results in microclimate and vegetation differences and, thus, soil differences. Soil erosion may differ in rate and scale in various topographic or landscape positions depending on slope gradient (Durak and Surucu, 2005; Birkeland, 1984). Graham (2006) notes that the movement of materials, including water and soil materials, on a landscape is influenced by the slope gradient and shape and the degree of connectivity of drainage networks. Thus, from pedologic perspective, topography is important because it exerts a strong influence on the disposition of energy and matter experienced by soils on the landscape. Topography can also indirectly affect the vegetation cover of an area (Brady and Weil, 2001). Consequently, topography or relief so strongly affects pedogenetic processes, many researchers stated that specific soils are associated with specific landforms and soil patterns are repeating and predictable (Amundson, 1994; Daniels and Hammer, 1992; Young and Hammer, 2000; Durak and Surucu, 2005).

The objectives of this study were to characterize the soils of the Ankara-Sogulca Catchment. i; to identify soil physical, chemical, and morphological features associated with specific landforms, different slope gradient, various parent material and land covers, ii; to interpret the genesis of these features, iii; to classify the soils in Soil Taxonomy (Soil Survey Staff, 1999 and FAO/ISRIC, 2006)

2. MATERIAL AND METHODS

2.1. Description of The Study Area

Sogulca Catchment is located at the south part of Ankara, 23 km far from Haymana district and is positioned between 4352734-4364382m N and 444495-458350m E (UTM). The area of the basin is approximately 5740 ha. (Figure 1). About 46.2 % and 52.7 % of this total area are being used as rainfed agriculture and rangeland, respectively (Baskan and Dengiz, 2008). Only 1.1 % of the study area is water surface. Average altitude above sea level ranges from 948 m to 1382 m. The study area has “mesic” soil temperature and “xeric” soil moisture regime according to the Soil Taxonomy (Soil Survey Staff, 1999). Quaternary new alluvium deposits formed on both sides of Sogutcesme stream and Palaeocene formations generally distributed over north and south parts and composed of limestone and sandstone in Sogulca Catchment (MTA, 1994). Digital satellite image (Landsat TM5, May 2003) and digital elevation model (DEM), aerial photographs, geological and topographical map were used to determine different land use and land cover types, landforms, slope and aspect. Six different soil profiles were classified and placed in Entisol and Inceptisol and Leptosol, Cambisol, Calcisol, and Fluvisol according to the Soil Taxonomy (Soil Survey Staff, 1999) and FAO/ISRIC (2006). GIS and RS or image processing software packages (TNT Mips v6.4 and Arc View 9.2) were used to generate digital elevation model (DEM) and transect from East to West direction.

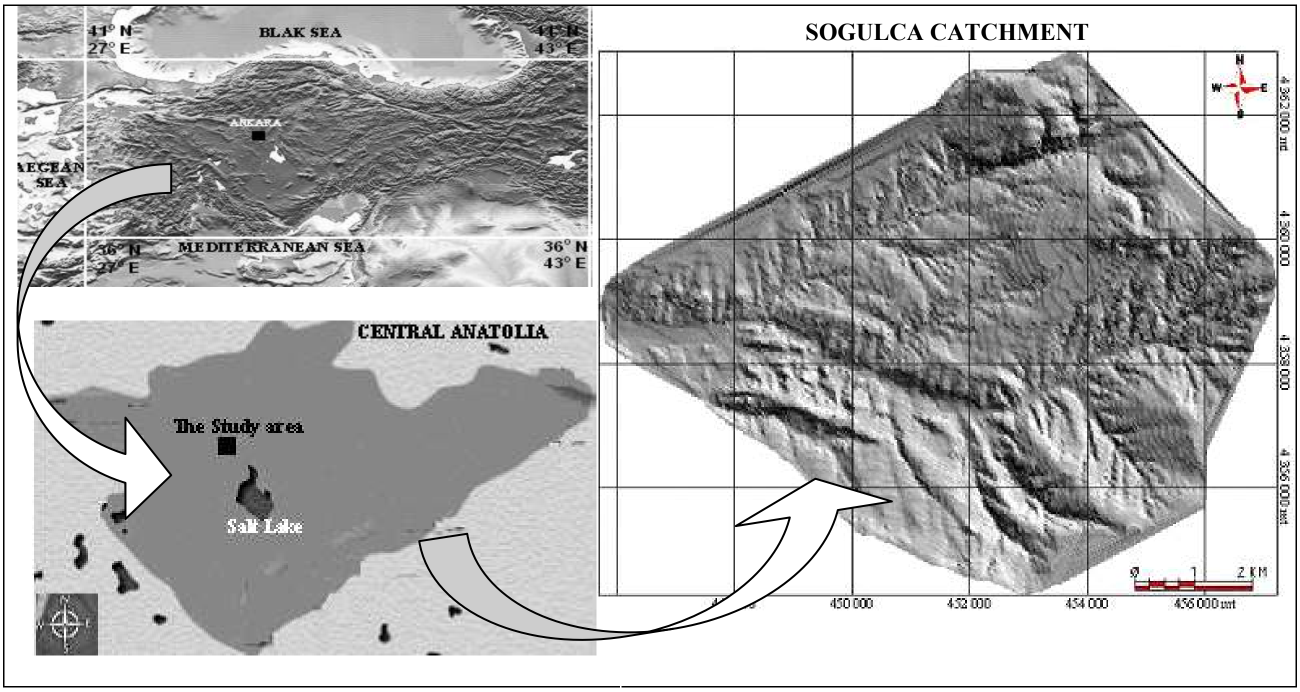

Figure 1. Location of the study area.

2.2. Soil Sampling and Profile Description

Soils have been studied on along transect (crosswise from East to West direction) with representative six profiles (Figure 2). Morphological properties of these six profiles in the field were identified and sampled by genetic horizons and classified according to Soil Survey Staff (1993 and 1999) and FAO/ISRIC (2006). 15 soil samples were taken to investigate for their physical and chemical properties at the laboratory. Disturbed soil samples were then air-dried and passed through a 2 mm sieve to prepare for laboratory analysis.

2.3. Soil Physico-Chemical Analysis

After soil samples were then air-dried and passed through a 2 mm sieve, particle size distribution was determined by the hydrometer method (Bouyoucos, 1951). Organic matter was determined using the Walkley-Black wet digestion method (Nelson and Sommers, 1982). pH, EC-electrical conductivity (of the saturation) by method of the (Soil Survey Labrotory, 1992). Lime content by Scheibler calsimeter (Soil Survey Staff, 1992). Exchangeble cations and cation exchange capacities (CEC) were measured using a 1 N NH_4OAC (pH 7) method (Soil Survey Labrotory, 1992).

3. RESULTS AND DISCUSSION

3.1. Soil morphology and classification

Pedogenetic development is significantly related to topographic position. Field morphology and profile description data for six representative pedons are reported in Table 1 and Figure 2. Soils located on five geomorphologic units along transect (crosswise from East to West direction) of the Sogulca Catchment display variation in terms of structure, colour, and depth in surface horizons. These variables are the obvious effect of eroding forces. Sommer et al. (2008) reported that in general, some parts of the landscape will erode faster than others depending on the local geomorphic situation and spatially varying soil erodibility. Other parts, which are not affected by soil erosion/sedimentation, e.g., flat plateaus, are characterized by further progressive soil development. Consequently, in a landscape we will find an intricate soil pattern reflecting different courses of soil development although overall a period of regressive soil development might prevail. The same results were also observed in the study area. Therefore, slope has been regarded as one of the most important factor that controls the pedogenic process on PI, PII and PV. Depth of the soils decreases with increasing slope degree. Profiles III, IV and VI located on flat plateaus and flood plain have higher solum depth and pedological development. Maximum structural formation (2msbk and 3msbk) was observed in flat plateaus soils. During the field study, it was observed common pebbles and cobbles within profiles of shoulder, upper and lower back slopes soils. In addition, structure has not well developed in their profiles.

The horizon orders of the profiles in the study area were defined to be A-B-C form except for especially I, II, V profiles which have A-C or A-R horizons. This means these soils have no diagnostic subsurface horizons and low pedogenetic development. They have only ochric epipedon overlying C or R horizon. Therefore, these soils can be defined as young soils. These pedons were classified as Lithic Xerorthent and Typic Xerorthent according to soil taxonomy (1999). Besides, they were classified as Lithic Leptosol and Eutric Leptosol FAO/ISRIC (2006).

Main soil formation process in the differentitation of soil profiles were structural formation and calcification that have occured in P III and P IV, respectively. These pedons formed on flat plateaus. The horizon orders of the PIII are defined to be Ap/A2/Bw1/Bw2. Main subsurface diagnostic horizon is cambic horizon developed as a result of structural formation in this profile. Especially, structural development was observed after 42 cm depth. According to soil taxonomy (1999) and FAO/ISRIC (2006) this pedon was classified as Typic Haploxerept and as Haplic Cambisol.

The morphology of P IV located on flat plateau was differently found from PIII. The horizon orders of this pedon are defined to be Ap/Bw/Bk1/Bk2. Soil color is 2.5 Y 5/4 in the Ap horizon, while, due to carbonate accumulation in depth color was change to 2.5 Y 7/2 in subsurface horizons. Secondary $CaCO_3$ nodules and myceliums were also identified in the profile IV, which apparently proofed the existence of carbonate leaching and accumulation (Table 2). Calcium carbonate nodules, starting in the Bk1 horizon at a depth of 55 cm, were increased in both thickness and diameter in the Bk2 horizon. This pedon was classified as Typic Calcixerept and Haplic Calcisol by taking into consideration of Soil Taxonomy (1999) and FAO/ISRIC (2006).

Profile IV located on floodplain formed on alluvium parent material. Ogg and Baker (1999) concluded that development of soils in the alluvial areas was highly affected by climate and time. This means this pedon has no diagnostic subsurface horizons and low pedogenetic development. Therefore, this soil can be defined as a young soil and classified as Typic Xerofluvent (Soil Taxonomy, 1999) and Eutric Fluvisol (FAO/ISRIC, 2006).

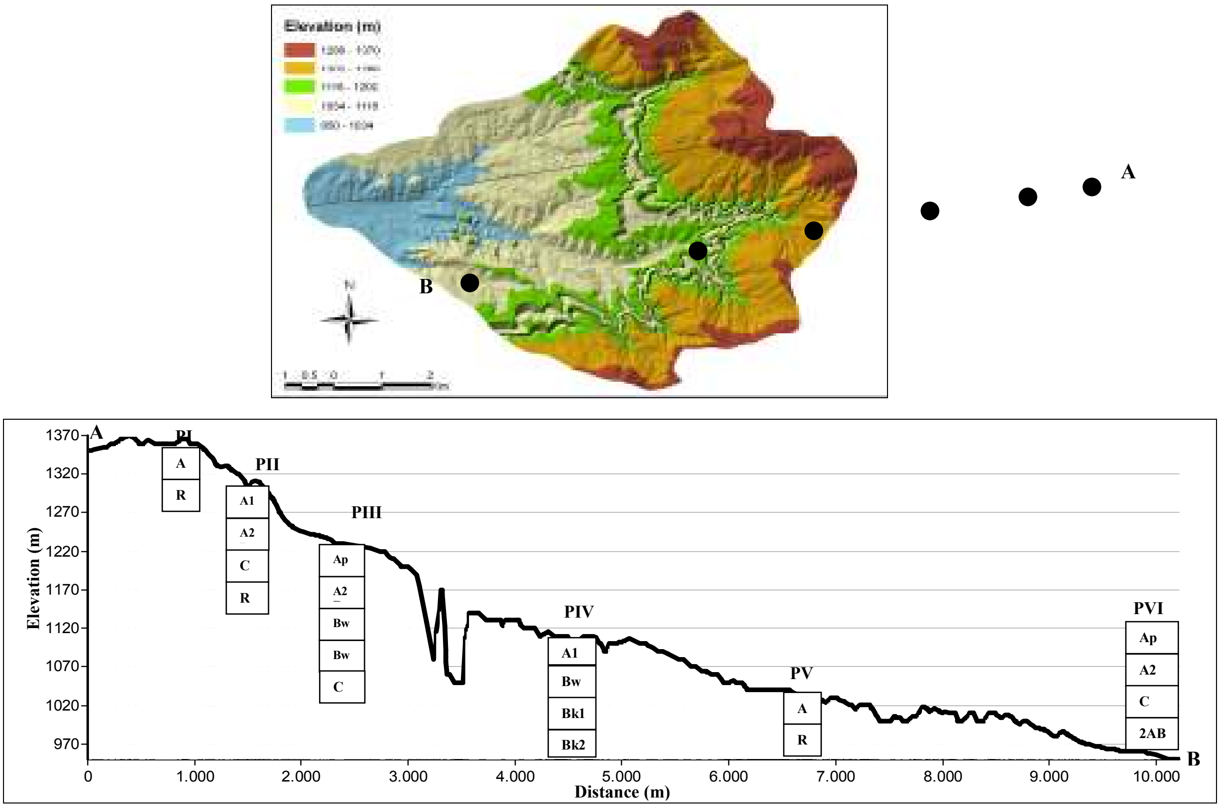

Figure 2. Different soil pedons on various topographic positions along the transect of the Sogulca Catchment.

3.2. Physical and Chemical Properties

The major physical and chemical properties of the soils are presented in Table 2. Furthermore, Figure 2 also schematically illustrates the pedological differences across transect. Soil physical and chemical properties that have been taken into consideration in this study showed variability as a result of dynamic interactions among natural environmental factors such as climate, parent material, land cover-land use, erosion and topography (Dengiz et al, 2006).

Soil texture is not significantly changing in top soil of all pedons whereas; sub surface soil texture varies clay, clay loam, silty clay and silty clay loam. Typic Calcixerept (Pedon IV) has the highest clay content while, Typic Xerofluvent (Pedon VI) has the highest sand content. The pH of the soils was moderately alkaline and there are no significant differences in the values of pH 7.40-7.91. In addition, all pedons have slightly soluble salt content. The lime content in soils formed over lime stone was quite high as compared to those formed over sand stone and fluvial deposites. CEC was between 16.40-36.70 cmol kg^{-1}. Exchangeable Ca and Mg cations were accounted for over 95% of the exchangeable complex as a result of dissolution of carbonates whereas, exchangeable K and Na levels were found rather low.

In general expectation, lower landscape positions usually have higher organic matter contents than those upslope due to higher water content on low lope potions yields more biomass and more incorporation of organic matter into soil. On the other hand, according to some researchers this case can be change in some situations. They states spatial variability in soil properties in landscapes affected by long-term tillage indicate that soil organic mater content is lower in arable areas than no tillage areas (Pennock et al., 1994; Heckrath et al., 2005; Papiernik et al., 2005). This trend was also observed in the study area. Pedon III, IV and VI used for agricultural activities have lower organic matter due to high decomposition and mineralization than those pedon I, II and V used for rangeland.

Table 1- Selected morphological and land characteristics of pedons.

Horizon	Depth (cm)	Boundary	Colors Dry	Colors Moist	Structure	Consistence	Position and Altitude	Land Use	Parent Material
Profile I (*Lithic Xerorthent /Lithic Leptosol*									
A	0-22	as	10 YR 5/6	10 YR 4/6	2fgr	sh fr st ps	Shoulder 1370 m	Range land	Lime stone
R	22+	-	-	-	-	-			
Profile II (*Typic Xerorthent /Eutric Leptosol*									
A1	0-18	aw	2.5 Y 5/4	2.5 Y 4/3	1vfgr	sh fr st ps	Upper back slope 1324 m	Range land	Marl
A2	18-36	cw	2.5 Y 6/3	2.5 Y 4/4	2fgr	sh fr st pt			
C	36+	-	-	-	massive	-			
Profile III (*Typic Haploxerept /Haplic Cambisol*									
Ap	0-20	as	5 Y 6/3	5 Y 4/3	1vfgr	sh fi st pt	Flat plateau 1238 m	Dry farming	Marl
A2	20-42	gw	5 Y 6/3	5 Y 4/3	2fsbk	sh fr st pt			
Bw1	42-75	cs	5 Y 6/3	5 Y 4/3	2msbk	sh fr st pt			
Bw2	75-125	-	5 Y 5/2	5 Y 4/3	2fpr	h fi st pt			
Profile IV (*Typic Calcixerept / Haplic Calcisol*									
Ap	0-20	sa	2.5 Y 5/4	2.5 Y 4/4	2mgr	sh fi st pt	Flat plateau 1160 m	Dry farming	Lime stone+ Marl
Bw	20-55	cw	2.5 Y 5/3	2.5 Y 4/4	3msbk	h fi st pt			
Bk1	55-105	di	2.5 Y 5/4	2.5 Y 4/4	2msbk	h fi st pt			
Bk2	105+	-	2.5 Y 6/4	2.5 Y 5/5	2fsbk	sh fr st pt			
Profile V (*Lithic Xerorthent / Lithic Leptosol*									
A	0-18	cs	5 Y 6/3	5 Y 4/3	1fvgr	sh fr st pt	Lower back slope 1050 m	Range land	Sandstone
R	18 +	-	-	-	-	-			
Profile VI (*Typic Xerfluvent /Eutric Fluvisol*									
Ap	0-13	aw	5 Y 7/2	5 Y 5/3	2fgr	sh fi st pt	Toe slope and Flood plain 935 m	Dry farming	Fluvial deposits
A2	13-32	cw	5 Y 7/2	5 Y 5/3	2mgr	h fr st pt			
C	32-68	gw	5 Y 6/3	5 Y 5/3	sg	lo lo so po			
2ABb	68-75	cw	5 Y 6/3	5 Y 5/3	2msbk	h fi st pt			
2C	75+	-	-	-	m	h fr st pt			

Abbreviations:
Boundary: a = abrupt; c = clear; g = gradual; d = diffuse; s = smooth; w = wavy; i = irregular
Structure: 1 = weak; 2 = moderate; 3= strong; vf = very fine; f = fine; m =medium; c = coarse; gr = granular; pr = prismatic; abk = angular blocky; sbk = subangular blocky; sg = single grain; m = massive;
Consistance: Dry : lo = loose; so = soft; sh = slightly hard; h = hard; Moist: lo = loose; vfr = very friable; fr = friable; fi = firm; et : so = nonsticky; ss = slightly sticky; st= sticky; po = nonplastic; ps = slightly plastic; pt= plastic

Table 2. Selected physical and chemical properties of pedons.

Pedons	Horizon	Depth (cm)	Particle size (%)				pH 1:1	TSS (%)	$CaCO_3$ (%)	O.M (%)	CEC (cmol kg^{-1})	Exchangeable cations (cmol kg^{-1})		
			Sand	Silt	Clay	Class						Na^+	K^+	Ca^{+2} + Mg^{+2}
Lithic Xerorthent / Lithic Leptosol														
PI	A	0-22	25.54	50.02	34.44	SiCL	7.60	0.044	37.79	2.10	29.50	0.18	0.55	28.76
Typic Xerorthent / Eutric Leptosol														
PII	A1	0-18	17.10	50.46	32.44	SiCL	7.40	0.044	55.13	2.60	20.90	0.161	0.585	20.15
	A2	18-36	11.94	52.62	35.44	SiCL	7.50	0.044	34.27	1.40	20.10	0.290	0.313	19.49
	C	36+	-	-	-	-	-	-	-	-	-	-	-	-
Typic Haploxerept / Haplic Cambisol														
PIII	Ap	0-20	15.06	45.50	39.44	SiCL	7.91	0.031	13.04	0.80	26.10	0.238	0.533	25.329
	A2	20-42	14.04	47.52	38.44	SiCL	7.84	0.028	13.41	0.60	26.20	0.207	0.295	25.698
	Bw1	42-75	18.14	46.42	35.44	SiCL	7.89	0.025	13.41	0.30	26.30	0.203	0.222	25.875
	Bw2	75-125	10.88	39.68	49.44	C	7.80	0.046	7.82	0.25	35.40	0.305	0.520	34.580
Typic Calcixerept / Lithic Leptosol														
PIV	Ap	0-20	12.22	41.34	46.44	SiC	7.85	0.043	13.41	1.00	36.40	0.209	0.736	35.455
	Bw	20-55	10.54	38.02	51.44	C	7.80	0.056	15.64	0.80	36.70	0.124	0.624	35.952
	Bk1	55-105	10.92	36.64	52.44	C	7.70	0.051	21.60	0.30	34.00	0.209	0.545	33.246
	Bk2	105+	17.70	38.86	43.44	C	7.80	0.045	40.97	0.10	27.90	0.214	0.409	27.277
Lithic Xerorthent / Haplic Calcisol														
PV	A	0-18	2.18	55.38	42.44	SiC	7.80	0.031	10.78	1.20	22.80	0.186	0.401	22.213
Typic Xerfluvent / Eutric Fluvisol														
PVI	Ap	0-13	5.02	55.54	39.44	SiCL	7.70	0.043	13.04	0.80	16.40	0.218	0.738	15.44
	A2	13-32	12.60	43.96	43.44	SiC	7.70	0.044	14.15	0.40	18.80	0.202	0.603	17.99
	C	32-68	28.32	37.24	34.44	CL	7.80	0.035	17.13	0.60	17.60	0.221	0.508	16.87
	2ABb	68+	6.92	43.64	49.44	SiC	7.90	0.046	15.64	0.70	20.80	0.234	0.445	20.12

CL: Clay Loam, C: Clay, SiC: Silty Clay, SiCL: Silty Clay Loam O.M: Organic Matter, CEC: Cation Exchange Capasity, TSS: Total Soluble Salt

4. CONCLUSION

In the study area, the main negative impact of soil forming factor on profile development in hillslope positions (shoulder and back slope) is soil erosion. Graham and Boul (1990) indicated that in mountainous terrain, soil erosion and mass movement or landslides are important geomorphic processes. While soil development proceeds on all parts of the regolith-covered landscape, it can be interrupted at any stage by mass movement event. This interruption is relatively common on high slope degree, so Entisol often predominant there. Therefore, these soils can be defined as young soils. Soils in lower slope position (flat plateaus) showed marked differences in terms of more development sub surface profile due to no interruption events. Main subsurface diagnostic horizons of these soils are cambic and calcic horizons. The results clearly showed that topographic condition strongly affects on soil formation either directly or indirectly in the local region. In addition, topographic data collection using traditional land survey methods require too much cost and time consuming. Today advanced computer programs such as Geographic Information System and Remote Sensing contribute to analyse topographic data in form of DEM to study terrain attributes that theoretically influence pedogenesis ((Dengiz and Akgül, 2005; Graham, 2006). It is also very easy to update or modify data involved in GIS database in future.

5. REFERENCES

Amundson, R. 1994. Factors of Soil Formation. A System of Quantitative Pedology. Foreword by R. Amundson. Dover Publ.Inc. NY.USA., pp:281

Arnold, R.W. 2006. Soils : Basic Concepts and Future Challenges, ed. Giacomo Certini and Riccardo Scalenghe. Published by Cambridge University Press, p 1-10.

Baskan, O and Dengiz, O. 2008. Comparison of Traditional and Geostatistical Methods to Estimate Soil Erodibility Factor. Arid Land Research and Management 22: 1, 29-45.

Birkeland, P.W. 1984. Soils and Geomorphology: Oxford University Press, New York, 372 p.

Brady, N.C., Weil, R.R., 2001, The Nature and Properties of Soils (13th ed.): Prentice Hall, Upper Saddle River, NJ, 960 p.

Bouyoucos, G.J.1951. A Recalibration of the Hydrometer Method for Making Mechanical

Analysis of soils. Agronomy Journal, 43; 435-438.

Daniels, R.B. and R.D. Hammer. 1992. Soil Geomorphology. John Wiley and Sons. New York, pp: 236.Durak, A. and Surucu, A. 2005. Soil Formation on Different Landscape in a Semi-humid Region of Turkey. Journal of Agronomy 4(3): 191-195.

Dengiz, O., Akgül, S. 2005. Soil erosion risk assessment of the Golbasi Environmental Protection Area and its vicinity using CORINE Model. *Turk J. Agric. For.* **29**, 439-448. Tubitak, Ankara.

Dengiz, O., Göl, C., Karaca, S., Yüksel, M. 2006. Effects of Different Landscape Position and Parent Material on Soil Variability and Land Use in Both Sides of Acicay River-Çankırı. International Soil Meeting on Soil Sustaining Life on Earth, Managing Soil and Technology Proceeding Vol. II, 745-751, Şanlıurfa-Turkey.

FAO/ISRIC, 2006. World References Base for Soil Resources. World Soil Rep., No,103. Rome, 128 p.

Heckrath, G., Djurhuus, J., Quine, T.A., Van Oost, K., Govers, G., Zhang, Y., 2005. Tillage erosion and its effect on soil properties and crop yield in Denmark. J. Environ. Qual. 34, 312–324.

Jenny, H. 1980. The Soil Resource. Springer-Verlag, New York, 377 pp.

Graham, R.C and Boul, S.W. 1990. Soil-geomorphic Relations on the Blue Ridge Front. II: Soil Characteristics and Pedogenesis. Soil Sci. Soc. Am. J., 54:1367-1377.

Graham, R.C. 2006. Basic Concepts and Future Challenges, ed. Giacomo Certini and Riccardo Scalenghe. Published by Cambridge University Press, p 151-163.

MTA. 1994. General Directorate of Mining Technical Research. Ankara, Turkey.

Nelson, D.W., L.E. Sommers.1982. Total Carbon, Organic Carbon and Organic matter. In: Page, L.A., Miller, R.H., Keeney, D.R (Eds.), Methods of Soil Analysis, Part 2. Chemical and Microbiological Methods (2 nd ed). American Society of Agronomy, Madison, WI, pp 539-579 (1982).

Ogg,C.M. and J.C. Baker. 1999. Pedogenesis and Origin of Depply Weathered Soils Formend in Alluvial Fans of Viriginia Blue Ridge. Soil Sci. Soc. Am. J., 63 : 601-606.

Papiernik, S.K., Lindstrom, M.J., Schumacher, J.A., Farenhorst, A., Stephans, K.D., Schumacher, T.E., Lobb, D.A., 2005. Variation in soil properties and crop yield across an eroded prairie landscape. J. Soil Water Conserv. 60, 388–395.

Pennock, D.J., Anderson, D.W., de Jong, E., 1994. Landscape-scale changes in indicators of soil quality due to cultivation in Saskatchewan, Canada. Geoderma 64, 1–19.

Soil Survey Staff.1992. Procedures for Collecting Soil Samples and Methods of Analysis for Soil Survey. Soil Surv. Invest. Rep. I. U.S. Gov. Print. Office, Washington D.C. USA.

Soil Survey Staff. 1993 Soil Survey Manuel. USDA Handbook. No: 18, Washington D.C. USA.

Soil Survey Staff. 1999. Soil taxonomy. A Basic of Soil Classification for Making and Interpreting Soil Survey. USDA Handbook No: 436, Washington D.C.

Sommer, M., Gerke, H.H. and Deumlich, D. 2008. Modelling soil landscape genesis-A “time split” approach for hummocky agricultural landscapes. Geoderma 145 (2008) 480–493.

Young, F.J. and R.D. Hammer. 2000. Soil-landform Relationships on a Loess-Mamtled Upland Landscape in Missouri. Soil Sci.Soc. Am. J., 64: 1443-1454.