

Genesis and Classification of Some Soils in Kalar City-Northern Iraqi Kurdistan Region

Salim Neimat Azeez¹ and Ahmad Saleh Muhaimed²

¹Lecture Sulaimani Polytechnic University Darbandikhan Technical Institute Darbandikhan, Sulaimani, Kurdistan Region, Iraq

²Professor Baghdad University College of Agriculture Baghdad, Iraq

Abstract: Four pedons were selected in Kalar city-Northern Iraqi Kurdistan region in order to define the genesis, pedogenic processes and to classify them. All pedons were morphologically described and sampled to determine some physical and chemical properties. The results indicated that all pedons are developed with A-Bt-C sequences with Mollic epipedons and Argillic and Calcic endopedons. The increment of total and fine clay in Bt horizons may be due to the effect of some pedogenic processes including eluviation and illuviation and to some extent to the new formation of clay minerals. According to the morphological, physical and chemical properties of the studied pedons, soils were classified as Typic Argixerolls as they have Mollic surface horizons with more than 50% base saturation for more than 180 cm depth. They have Argillic subsurface horizons and Calcic. The main pedogenic processes affecting soil development are eluviation, illuviation, decalcification and calcification.

Keywords: Soil, Soil Genesis, Soil Classification.

I. Introduction

Soil is one of the main resources for most terrestrial life. Soil sciences study soils from many different perspectives for agriculture, construction and mining. Agriculturally, Soil science has two main branches, Edaphology and Pedology. Edaphology was defined by Porta et al., (1994) as “the study of the community of microflora and microfauna in the soil (edaphon) and the processes that govern their existence and development (edaphogenesis)”. Pedology was defined by Gregorich et al., (2001) as “the study of soils that integrates their distribution, formation, morphology and classification as natural landscape bodies”.

Iraqi soils show different degrees of development according to the effects of local conditions: calcareous parent materials, geomorphology, semidry climatic, and grass. They are generally classified as Aridisols, Inceptisols, Entisols, Mollisols and Vertisols Muhaimed and Sulaiman, 1990; Muhaimed, 1994; Al-Agidi, 1986; Muhaimed et al., 2000 and Muhaimed et al., 2014. Inceptisols include a wide variety of soils. In some areas these soils have minimal development, whereas in other areas these soils have diagnostic horizons that merely fail the criteria of other soil orders. They have many kinds of diagnostic horizons and epipedons. The most common horizon sequence is Ochric epipedon over a Cambic horizon. Mollisols commonly are dark-colored, base-rich mineral soils of the steppes. Nearly all of these have a Mollic epipedon, and many have an Argillic, and Calcic horizon. Many of these soils developed under grass and many apparently were forested. Soils of Kalar city, located in Northern Iraqi Kurdistan region, are the main source for food production in the region as they are highly fertile soils with high organic matter and available nutrients. They are mostly belong to Mollisols and Inceptisols formed from calcareous parent material and under grasses vegetation Muhaimed et al., 2013.

Due to the lack of the semi detail work on the genesis and classification of soils in the study area, this study was conducted in order to:

- 1- To define the dominant pedogenic processes responsible for soil formation of the study area.
- 2- To classify soils of the study area using Soil Taxonomy.

II. Materials and Methods

Location of the study area

The study area is located in Iraqi Kurdistan region, Garmian, Kalar city, alongside with Serwan river. Two sites were chosen, the first was in Banzamen village laying between 34° 39' 52.2" N and 45° 25' 02.2" E with elevation of 205.4 msal (meter above sea level), whereas the second was in Qaracham village at 34° 50' 26.5" N and 45° 32' 15.4" E with elevation 308 msal (Figure1).

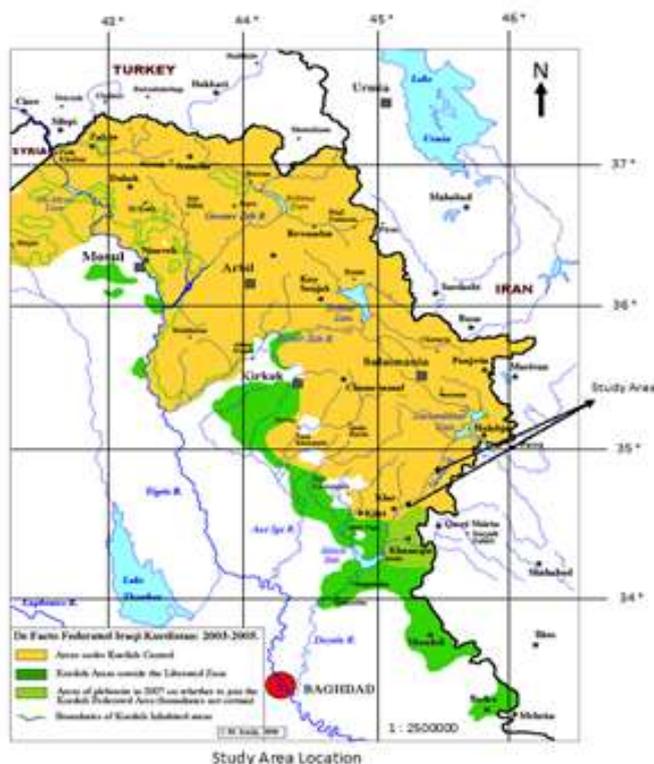


Figure 1 : Location of the study area

Geology of the study area

The study area is located in foot hill physiographic unit (Buring, 1960), but in tectonic side the study area is lies within folds zone as pointed by Dunnington(1958). The region is formed through Miocene and Pliocene duration Buring (1960), Where Miocene duration include Lower Fars sediments which formed from gypsum rocks, limestone and maral while the Upper Fars which formed from siltstone, limestone and maral Naqash and Hambarsom (1985). But the Pliocene duration include Lowe Bakhtiary formation which include siltstone, sandstone, maral with gravel and Upper Bakhtiary which include thick sediments of conglomerate Buring (1960).

Climate of the study area

The climate of the study area is continental semi arid Kharrufa (1985), the precipitation is mostly rainfall with few snow falling especially in winter and the first month of the spring, the average of rainfall is (330 mm/year) while the average of temperature is (22 C°), the highest rainfall was in 2004 with (550 mm/year) but the lowest was in 2008 which recorded (168 mm/year) from years 2001-2014 (Garmian Agriculture Office).

Land use and natural vegetation

There are several types of natural plants such as *Carthamusoxyacanthus*, *Loliumrigidum*, *Cynodondactylon*, *Ammi majus*, *Phalaris minor*, *Trifoliumresupinatum*, *EuphorbiaPeplus*, *Lagonychiumfarctum*, *Hordeumglaucum*, *Centaureaiberica*, *Avenafatua*, *Alhagigraeccorum* FAO (2000). The study area is used for field crops production especially *Triticum spp* and *Hordeum spp* also used for vegetation crops, under dry farming and supplemental irrigation system using water irrigation from Serwan river.

Field works

A topographic map (Ahmad, 2005) and a reconnaissance soil survey map Muhaimed et al., (2014) were used as basic maps for this study. Four pedons sites were selected represent all the variations in the study area. A Pedon was drilled in each location, all pedons were described morphologically according to Soil Survey Staff (1993) and ,soil samples were taken for physical and chemical properties determinations. According to the Keys to Soil Taxonomy Soil Survey Staff (2006) the soil were classified.

Physical properties:

Soil particle size was determined by using the International Pipette Method as described in Kilmer and Alexander (1949). The silt and clay were separated from the sand by washing the dispersed samples through a

50 μ sieve, as described in Jackson (1956). The various clay fractions were thus obtained by pipette method as described in Jackson (1979). Fine clay was determined according to Avery and Bascomb (1982). Bulk density was measured by clod method using Paraffin Wax, as described by Blake (1965_b), that cited in Black (1965). Particle density was measured by pycnometer method, as described by Blake (1965_a), which cited in Black (1965). The porosity was calculated using the equation [1] according to Vomocil (1965), which cited in Black (1965) as follows:

$$\% \text{ Porosity} = \{1 - (\text{bulk density} / \text{particle density})\} \times 100 \text{ -----}[1]$$

Chemical properties:

Organic carbon (OC) was determined by wet oxidation method using chromic acid according to the method of Walkley-Black (1934), which was described by Hesse (1972). The organic carbon can be converted to organic matter by the equation below:

$$\text{Organic matter} = \text{Organic carbon} \times 1.72 \text{}[2] \text{ (Jackson, 1958 and Nelson and Sommer, 1982)}$$

Total carbonate was measured by equilibrium with (1N) of hydrochloric acid, depending upon Piper (1950), as described by Hesse (1972). Active carbonate was measured after precipitation as a calcium oxalate, by using (0.1 M) of ammonium oxalate according to Galet (1972). Soil reaction (pH) was measured in a saturated soil paste extract which described by Richards (1954) using pH meter device, model-pH 211-Microprocessor pH meter-HANNA Com.-Italy. Electric conductivity (EC_e) of extract was measured according to the 4b method, as described by (Richards, 1954), using EC meter- Lovibond – con 200 - Germany. Cation exchangeable (CEC) capacity was measured by using calcium chloride as saturated solution (0.5M at pH = 7), followed by removing calcium chloride with sodium nitrate (1M) and the removed calcium measured according to Papanicolaou (1976).

Exchangeable cations:

Exchangeable calcium measured in soil paste extract treated with sodium acetates as described in Chapman and Pratt (1961), then the exchangeable calcium titrated with E.D.T.A. (Ethyl diamine tetra acetic acid) as a chelating substance, to take off calcium ions, at pH = 12 by using sodium hydroxide (4M) and murexide indicator as vercenite titration method which described in Yoseef (1999). Exchangeable magnesium was measured in the soil paste extract which treated with sodium acetate, as mentioned in Chapman and Pratt (1961), whereas exchangeable calcium and magnesium were measured, then the amount of exchangeable magnesium was calculated by subtracting the amount of exchangeable calcium from the amount of exchangeable calcium plus magnesium, as described by Yoseef (1999). Exchangeable sodium and potassium were measured by taken, five grams of the soil samples were saturated by ammonium acetate (1M) as described in (Kelley, 1948), the exchangeable sodium and potassium were measured by Compact ion meter device, model-HORIBA Kyoto 60 – 8510. Japan Cod K⁺ C - 131, Na⁺ C - 122. Base saturation percentage (B.S.P.) was calculated by using the following equation:

$$\text{B. S. P} = \frac{\text{Total Exchangeable Cations}}{\text{Cation Exchangeable capacity}} \times 100 \text{}[3]$$

III. Results and Discussion

According to the results of the morphological description of the studied pedons (Table 1) all the pedons represent developed soils with A-Bt-C profiles. All pedons have dark color and deep surface horizons meet the criteria of Mollic epipedon Soil Survey Staff (2010). The studied soil profile macromorphology show the following features: clear and abrupt transition becomes diffuse and clear or gradual among the horizons when the soil evolution increases. Granular macrostructure on the surface horizons and sub angular blocky on the subsurface horizons. The degree of development of these soils is reflected by the horizon number and thickness on soil profiles depth. The color is brown to dark brown indicating good drainage, and intense surface darkening, due to high organic matter contents, which make the soil more friable when moistened. The surface horizons of studied soils are deep, dark brown with chroma and value less than 5.5 for dry soil samples with more than 2.5 % organic matter to more than 50 cm soil depth. These properties meet the criteria of Pachic condition Soil Survey Staff (2010). The presence of Pachic conditions are due to the interaction of environmental conditions and vegetation factors causing high activity of the melanization process represented by the accumulation organic, decomposition and mixing of organic matter with mineral soil components leading to the formation of deep dark surface horizon rich with organic matter content. According to the results of soil properties and the environmental conditions allowed to conclude that surface horizons were developed from interactions among climate and vegetation that induces the leaf fall and their decomposition and mixing with the mineral soil components.

Table 1: Morphological characteristics of the studied pedons.

Site	Pedon	Horizon	Depth (cm)	Color (D)	Structure*	Consistence (D)	Boundary
Banzamen	1	Ap	0-25	(10YR 5/3)	1 med. gr	Soft	Clear Smooth
		Btk ₁	25-90	(10YR 5/4)	3 med. bk	Hard	Clear Smooth
		Ck ₁	90-117	(10YR 7/3)	2 fine sbk	Slightly Hard	Clear Smooth
		Ck ₂	117-150	(10YR 7/4)	2 fine sbk	Soft	Clear Smooth
	2	Ap	0-30	(10YR 5/3)	2med.sgr	Soft	Diffused Smooth
		Btk ₁	30-95	(10YR 5/4)	2 fine sbk	Hard	Clear Smooth
		Btk ₂	95-125	(10YR 7/2)	2 med.sbk	Hard	Clear Smooth
		Ck	125-160	(10YR 7/3)	2 fine sbk	Soft	Clear Smooth
Qaracham	1	AP	0-30	(10 YR 5/1)	2 med.gr	Hard	Abrupt Smooth
		Btk ₁	30-50	(10YR4/2)	3 med.sbk	Hard	Clear Smooth
		Btk ₂	50-90	(7.5YR 6/3)	2 fine sbk	Slightly Hard	Diffused Smooth
		Ck ₁	90-130	(10YR 6/3)	2 med.sbk	Hard	Diffused Smooth
	2	Ck ₂	130-150+	(7.5YR6/3)	2 fine sbk	Slightly Hard	Clear Smooth
		Ap	0-25	(10YR 5/2)	2 med.gr	Hard	Clear Smooth
		Btk ₁	25-100	(10YR 5/3)	2 med.sbk	Hard	Diffused Smooth
		Btk ₂	100-140	(10YR 5/4)	3 med.sbk	Slightly Hard	Diffused Smooth
Ck	140-170	(10YR 6/4)	2 fine sbk	Slightly Hard	Clear Smooth		

* 1= weak 2= moderate 3= strong gr= granular sbk= sub angular blocky med.= medium

The results of soil particle analysis (Table 2) indicated that silt content was the dominant fraction followed by clay and sand in the studied pedons due to the effect of parent material and to some extent to the geomorphic and climatic conditions. Amount of total clay and fine clay showed the same pattern of distribution with in all the studied pedons (Figure 2). They increase with depth at Bt horizons and decrease in C horizons. This type of distribution may be due to the effect of pedogenic processes and to some extent to the in situ clay formation. The main pedogenic processes are eluviation and illuviation causing clay translocation from the surface horizons to subsurface horizons (Bt). Movement of clay particles and colloids through the soil profile has been investigated extensively during the past decades. This movement has significant impacts environmentally and pedologically. This movement is important environmentally because heavy metals, pesticides, or fertilizers can be translocated to the ground water and contaminate it via their adsorption on mobile clay particles Ryan et al., (1998) and Sprague et al., (2000). This movement is also important pedologically because formation of some soil diagnostic horizons, such as the Albic, Argillic and Spodic horizons, is concomitant with clay particle movement Soil Survey Staff (1999). McKeague and St. Arnaud (1969) and Dixit (1978) stated that clay particles can move downward from the upper horizons and deposit in the lower horizons. The process of clay particles translocation in suspension downwards is known as lessivage Schaeztl and Anderson (2005).

Factors affecting clay movement were suggested by different researchers. Zhuang et al., (2007) and Sharma et al., (2008) attributed the colloidal movement in soils to the moving air-water interface. Michel et al., (2010) suggested that colloid movement is affected by gravitational water drainage, water evaporation from the soil and water profile redistribution from preferential flow paths toward the soil pores. Clay translocation by lessivage, is generally described as beginning with chemical or physical dispersion of fine clays along a macro pore, followed by downward movement as suspended load in leaching pore water and ending with deposition Eswaran and Sys (1979), Miller (1983) and Phillips (2007).

Table (2): Some physical properties of the study pedons.

Site	Pedon	Horizon	Depth (cm)	Total Sand (g/kg)	Total Silt (g/kg)	Total Clay (g/kg)	Fin Clay (g/kg)	Fin Clay/ Total Clay	Bulk Density (Mg/m ³)	Particle Density (Mg/m ³)	Porosity (%)
Banzameen	1	Ap	0-25	288.1	497.7	214.2	48.56	0.23	1.42	2.47	42.57
		Btk ₁	25-90	242.3	476.6	281.1	62.86	0.22	1.46	2.55	43.02
		Ck ₁	90-117	306.3	474.9	218.8	2.11	0.010	1.5	2.81	47.02
		Ck ₂	117-150	359.4	425.2	215.4	1.8	0.008	1.51	2.71	44.69
	2	Ap	0-30	291.6	480.4	228	37.4	0.16	1.4	2.5	44.00
		Btk ₁	30-95	255.5	471.9	272.6	57	0.21	1.47	2.57	42.80
		Btk ₂	95-125	301.7	441.3	257	8.8	0.034	1.52	2.79	45.52
		Ck	125-160	370.1	390.5	239.4	7.6	0.032	1.57	2.7	41.85
Qaracham	3	Ap	0-30	195.5	563.5	241	100.22	0.416	1.53	2.52	39.29
		Btk ₁	30-50	180.4	538.2	281.4	118.33	0.421	1.59	2.55	37.65
		Btk ₂	50-90	252.6	439.2	308.2	111.87	0.363	1.62	2.56	36.72
		Ck ₁	90-130	280.3	471.3	248.4	89.56	0.361	1.66	2.6	36.15
	4	Ck ₂	130-150+	689	196.1	114.9	50.73	0.44	1.67	2.7	38.15
		Ap	0-25	320.3	470.1	209.6	28.4	0.14	1.33	2.51	47.01
		Btk ₁	25-100	185.4	524.6	290	64	0.22	1.47	2.53	41.90
		Btk ₂	100-140	310.7	435.2	254.1	129.6	0.51	1.51	2.57	41.25
Ck	140-170	463.2	333	203.8	32.9	0.16	1.55	2.62	40.84		

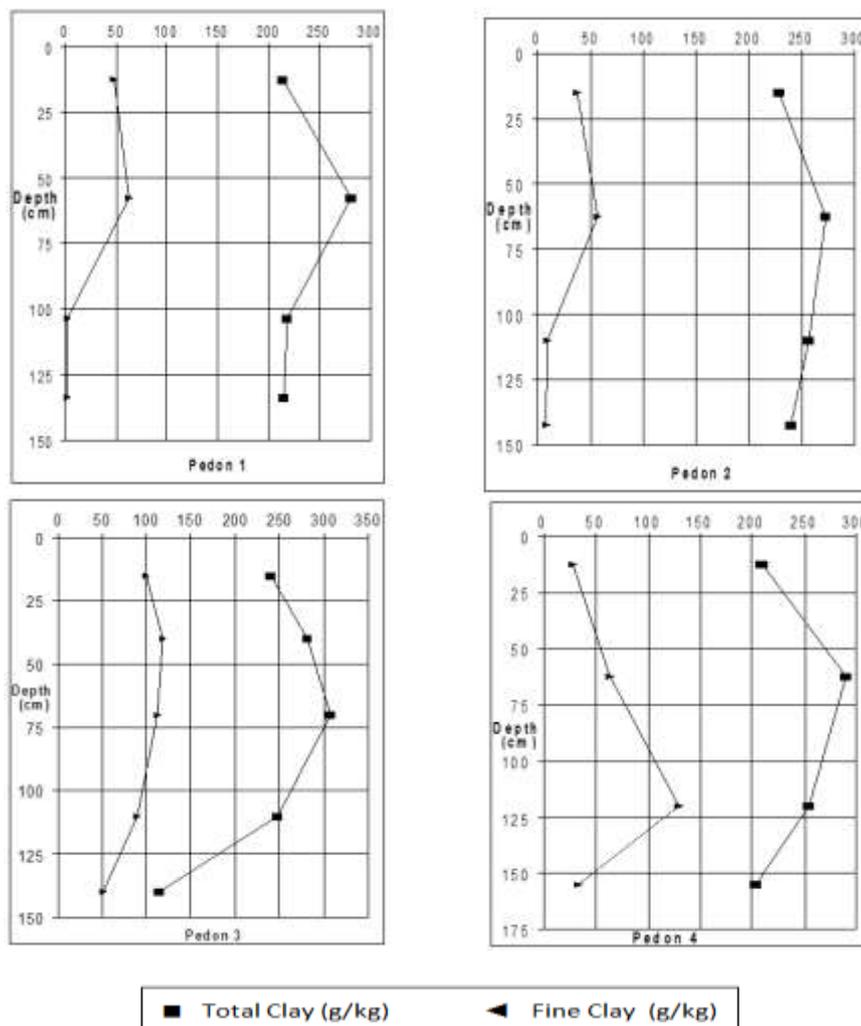


Figure 2 : Distribution of total and fine clay in the study pedons.

The depth of clay deposition in the solum is thought to be controlled by wherever pore size becomes so small as to constrict water flow, a pore is partially plugged by illuviated clays from prior episodes of translocation, or, pore water is pulled into side pores via capillarity which leaves the clays lining the original macro pore Thorp and Smith (1949), or, by flocculation as the clays encounter increased soil pH and ionic strength in the lower solum.

Distribution pattern of total and fine clay in all studied pedons indicates significant differences between the eluvial and illuvial horizons. The value of the average clay content in B horizons to the average value of clay content in A horizon is more than 1.2, which meets the criteria required for the formation of Argillic horizon Soil Survey Staff (1999). Total clay, fine clay contents and the percentage of fine clay to total clay are at their maximum in Btk horizons and decrease with depth in all pedons of the study region (Figures 2 and 3).

The increment of clay content in illuvial horizons comparison to eluvial horizons seems to be sufficient to meet the criteria for Argillic horizon formation. However, the presence of Argillic horizons in all pedons can not be related to semiarid climatic conditions of the study area, but may be greatly related to the effect of the paleo-climatic conditions, which were more humid than the dominant conditions of the present days. This fact reflected by the presence of Calcic horizons within the depth of Argillic horizons within these pedons which may be caused by the new addition of calcareous materials to these pedons from the upland area by erosion and sedimentation processes during the dry period Muhaimed et al., (2013).

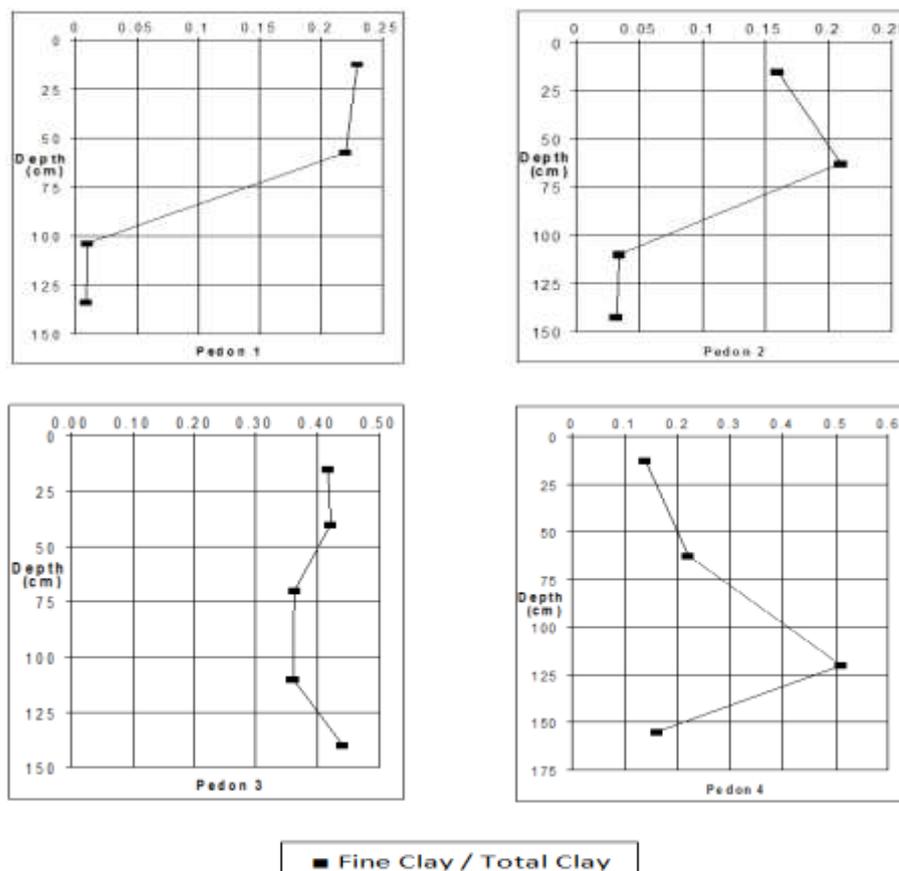


Figure 3 : Distribution of fine clay / total clay in the study pedons.

The results of some chemical properties (Table 3 and Figure 4) show that the amount of both total and active carbonate increase with depth at Bk then decrease at lower horizons in all of the studied pedons. The amount of carbonate in all pedons increased in the subsurface horizons to the level required for Calcic horizon formation, for example, in the depth of 20 to 65 cm (Btk₁ and Btk₂) in Pedon 4 with the identification of the presence of >5% masses and small nodules of identifiable secondary carbonates in these horizons Soil Survey Staff (2010). The presence of Calcic horizons reflect the effects of calcareous parent material and climatic condition and the activity of some pedogenic processes mainly decalcification and calcification. According to the morphological ,physical and chemical properties of the studied pedons, soils were classified as Typic Argixerolls as the have Mollic surface horizons with more than 50% base saturation for more than 180 cm depth. They have Argillic and Calcic subsurface horizons.

Table (3) : Some chemical properties of the study pedons.

site	Pe.*	Ho.*	Depth (cm)	O.C.	Total Lime	Active Lime	pH (ex.*)	ECe (ds/m)	Exchangeable Cations (cmol _c /kg soil)				CEC (cmol _c /kg soil)	BSP
									Ca ⁺²	Mg ⁺²	Na ⁺	K ⁺		
Banzameen	1	Ap	0-25	7.74	280	110	7.69	0.65	23.88	1.25	1.26	0.28	29.8	89.50
		Btk	25-90	3.32	290	105	6.97	1.79	22.21	1.25	1.17	0.19	27.4	90.58
		Ck ₁	90-117	0.52	220	100	7.4	2.23	19.08	1.24	1.33	0.18	24.35	89.65
		Ck ₂	117-150	0.39	260	80	6.91	2.25	18.71	1.23	1.24	0.17	22.86	93.39
	2	Ap	0-30	7.67	305	100	7.74	0.57	20.81	1.1	1.2	0.23	25.9	90.12
		Btk ₁	30-95	3.26	325	105	7	1.65	20.02	1.08	1.09	0.11	25.41	87.76
		Btk ₂	95-125	0.41	260	85	7.32	2.36	17.34	1.06	1.22	0.07	23.55	83.61
		Ck	125-160	0.29	280	75	7.1	2.28	18.71	1.01	1.2	0.06	24.71	84.90
Qurachan	3	Ap	0-30	9.31	165	100	7.33	0.85	24.41	0.49	1.87	0.67	29.62	92.64
		Btk ₁	30-50	5.72	175	100	7.32	0.55	23.14	0.39	1.85	0.54	28.57	90.72
		Btk ₂	50-90	3.51	295	110	7.21	0.51	24.35	0.28	1.63	0.41	29.7	89.80
		Ck ₁	90-130	0.77	380	60	7.27	0.48	20.01	0.19	1.74	0.33	25.97	85.75
	4	Ck ₂	130-150+	0.6	320	110	7.19	0.59	17.17	0.14	1.79	0.38	22.99	84.73
		Ap	0-25	8.02	240	75	7.72	0.65	20.44	4.96	1.26	0.1	30.09	88.93
		Btk ₁	25-100	5.29	330	115	7.15	0.58	17.1	3.87	1.05	0.08	25.99	85.03
		Btk ₂	100-140	0.58	315	105	7.1	0.5	15.08	3	0.99	0.06	22.45	85.21
Ck	140-170	0.29	255	90	7.69	0.45	14.12	3.01	1.03	0.04	21.78	83.56		

* Pe= Pedon * Ho= Horizon * ex= extract

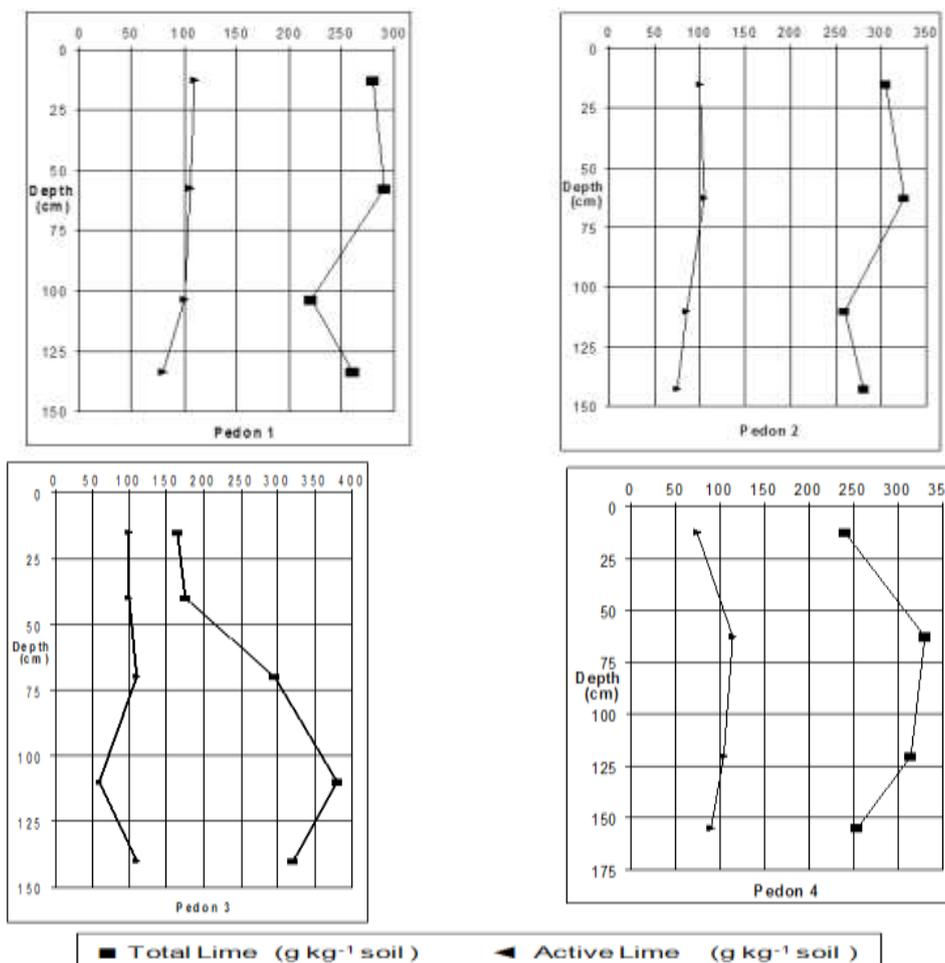


Figure 4 :Distribution of total and active lime in the study pedons.

IV. Conclusions

The development of a dark, usually brownish colour, surface horizons in the study pedons was due to the effects of melanisation process as related to interactions among climate and vegetation that induces the leaf fall and their decomposition and mixing with the mineral soil components. Also, the genesis of the subsurface horizons was initially characterized by sequences of eluviation, illuviation and lessivage processes and to some extent to in situ formation of clay minerals.

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