Dominance Diagnostic Horizons in the Soil Under Various Vegetation Covers in Duhok, Iraq

Hamdiya Abd-Asattar Ahmed[1] Mohammed A. Fayyadh[2]

[1, 2] Soil and Water Sciences Dept., College of Agricultural Engineering Sciences, University of Duhok, Kurdistan, Iraq.

*Corresponding author's email: mohammed.fayyadh@uod.ac

Email addresses of coauthors: hamdiyaduhoki01@gmail.com

Abstract

Soils in different parts of Iraq vary in development. This study was conducted in three locations in Duhok province of the Kurdistan Region of Iraq. Two pedons were dug at each location, with 19 soil samples collected, and the horizons were specified. The dominant soil texture in the Semeel location was fine, which normally contains a clay fraction (402- 652 g. kg^{-1}), and the soil texture in the pedons of the Badi location was similar to that of the Zawita location, which was generally clay loam. Soil bulk density was low in the surface horizons and increased downward in the soil pedons (1.06- 1.69 Mg kg^{-1}). The EC had low values and a non-saline soil (0.10- 1.34 dS.m^{-1}), the soils were slightly alkaline (7.48 and 8.55) and had high CEC values (27.7 and 44.6 Cmol$_c$. Kg^{-1}). Organic matter content of the studied pedons was relatively low, and in semeel area, organic matter (3.1- 14 g. kg^{-1}) was less than its content in Zawita (9- 25g. kg^{-1}) and Badi (0.5- 35 g. kg^{-1}). High content of total carbonate (66.4- 377.7g. kg^{-1}) indicates that the study soils were calcareous and active carbonate was more effect on the soil properties. The most dominant of the exchangeable cations in the studied pedons are calcium, followed by magnesium, then sodium and potassium. Concluded from this study that the diagnostic horizons that are specified in the studied pedons include Mollic, Ochric, Calcic, Petrocalcic, Cambic, Duripan, and Argillic. The objective of this study is to specify diagnostic soil horizons in Duhok Province of the Kurdistan Region, Iraq.

Keywords: Clay content, Calcic horizon, Calcareous soil, Organic matter, Mollic epipedon

Introduction

Soils in different parts of Iraq vary in development due to differences in parent material, geomorphology, climate, and vegetation. The soils are classified into Aridisols, Inceptisols, Entisols, Mollisols, and Vertisols. Inceptisols have varying degrees of development and contain diagnostic horizons such as ochric epipedons over cambic horizons. Mollisols are dark, high-base soils with a mollic epipedon rich in organic matter and often feature diagnostic horizons like argillic and calcic horizons. Organic matter inputs and nutrient cycling from the forests enhance pedogenic processes of soil formation. Pine and oak forests are dominant in regions with Mediterranean and semi-arid climates. Carbonates are a significant component of calcareous soils in the Kurdistan Region of Iraq, where both primary and secondary carbonates are present [1, 2]. On the other hand, Asghari Hafshejani and Jafari [3] noted that primary carbonates originate from the parent material, while secondary carbonates form pedogenetically through reprecipitation of dissolved calcium carbonate. Primary carbonates are associated with sand and have coarse textures, whereas secondary carbonates are finer, silty, and clayey. Relief, temperature, and soil moisture regimes influence the distribution and transformation of carbonates. In semi-arid regions, pedogenic carbonate accumulations form through evaporative and transpiration mechanisms, involving calcium and bicarbonate [4]. The mollic, umbric, histic, ochric, and melanic epipedons are all defined by different morphological and chemical attributes. The mollic epipedon represents fertile grassland soils characterized by a dark color, high organic matter, a thickness of at least 25 cm, and a base saturation of over 50% [5]. The umbric epipedon has a similar colour and organic content to the mollic epipedon but shows lower base saturation (<50%), due to leaching in humid, forested regions [6]. In wetlands under saturated conditions, an organic-rich horizon more than 20 cm thick forms, with organic matter accumulating and decomposing slowly [7]. The presence of active carbonates and total carbonates in the soil indicated the downward vertical distribution in the profile [8]. Weathering of parent materials and the composition and degree of soil development regulate the formation and variation of soil carbonates [9]. In cultivated soils, and especially under continuous tillage with less organic matter and litter, there is a prolonged decrease in biological activity, which in turn influences the redistribution of soil carbonates. Cultivation also leads to the disruption of soil aggregates and enhances the total and active carbonates to understand the various pedogenic processes and the influence of vegetation cover and land use patterns on soil development [10]. The objective of this study was to specify diagnostic soil horizons in Duhok Province of the Kurdistan Region of Iraq.

Materials and Methods

Site Description and Sampling:

This study was conducted in three locations, Zawita, Badi, and Semeel, in Duhok province of the Kurdistan Region, Iraq (Figure 1), which were selected based on distinct land uses. For each of the three locations, two pedons were dug, and the horizons were specified (Table 1). Nineteen soil samples were collected from horizons in the studied pedons, air-dried, crushed and sieved with a 2 mm sieve and then stored in plastic containers in the lab for physical and chemical analyses. The climate of the studied area is hot and dry in summer, cold and rainy in winter. The topography is a mountainous area in both Zawita and Badi locations, with undulating to flat and semi-flat in Semeel location. Based on data from 2013-2024, the average annual precipitation in Semeel was 656.9 mm, and in Duhok (Zawita and Badi), 790.13 mm. Duhok receives rainfall more uniformly than Semeel. The average temperature in Semeel (between 2010 and 2022) was 20.03°C, and in Duhok (between 2011 and 2024) was 20.24°C. This uniform climate of rainfall and moderate temperature supports the growth of a diverse plant community, especially in the forest ecosystems [11].

Laboratory Analysis

Soil pH and EC were measured in soil suspension (1:3) (soil: water) using a pH meter and an EC meter, as adopted by [12]. Soil organic matter was determined by the oxidation method an oxidizing agent [13]. A calcimeter apparatus was utilized to determine total carbonate ($CaCO_3$) content [14]. Active carbonate was estimated using Kozhekov and Yakovleva method [15]. CEC was measured by a flame photometer [16]. Particle size distribution of soil was calculated using the hydrometer method to separate sand, silt, and clay particles [17]. and the bulk density was determined using the wax method as described by [18].

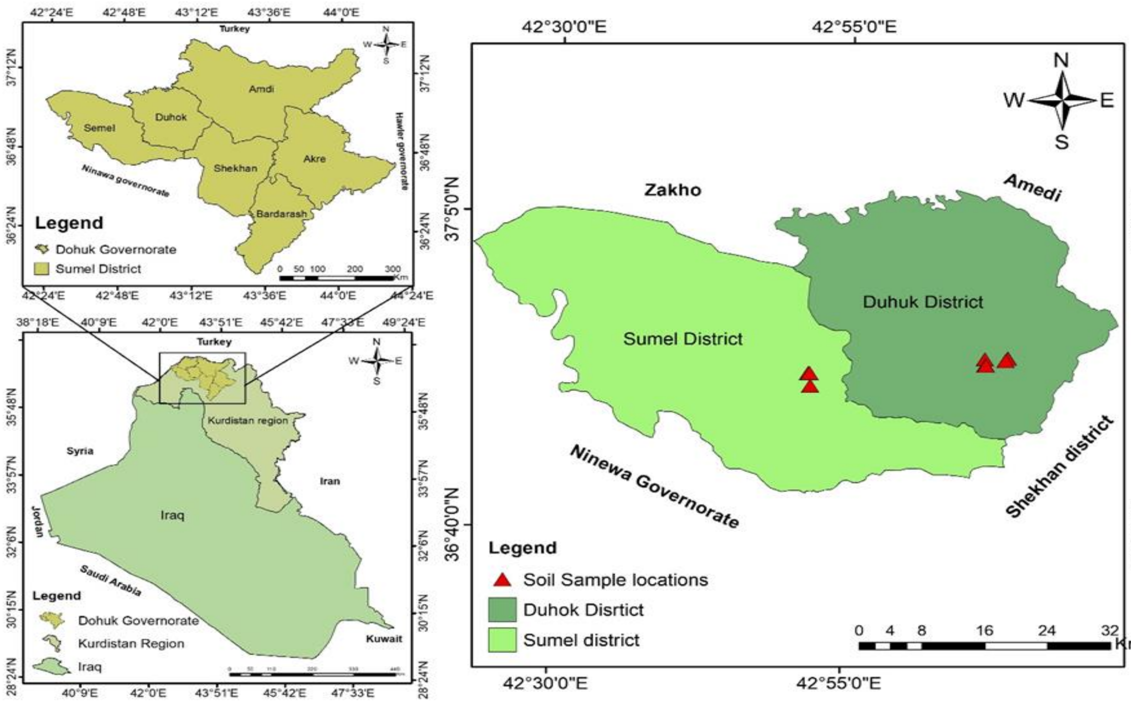


Figure 1: Map of Iraq showing the Kurdistan Region and the study locations.

Table 1: GPS Reading for Studied Pedons

Location	Pedon No.	Latitude (N)	Longitude (E)	Elevation (m)
Zawita	2	4085362	0334867	957
	3	4085097	0334425	925
Badi	4	4085349	0331918	972
	6	4084311	0332084	948
Semeel	7	4083260	0309465	495
	8	4083308	0309612	490

Results and Discussion

Physical properties

The particle size distribution of the studied soils showed that the soil texture in the Zawita location was generally clay loam across all soil samples, except for samples ZP1S2 and ZP1S3, which had a clay texture. This may be due to climatic conditions and rainfall amounts in the twelve years, which were 790.13 mm, increasing weathering and the formation of fine soil texture. The soil texture in the pedons of the Badi location was similar to that of the Zawita location, as both are under the same climatic conditions and have the same calcareous parent material. In contrast, at the Semeel location, the texture tends to be finer, ranging between silty clay and clay, except for sample SP6S3, which has a clay loam texture. The rainfall amount during 12 years was 656.9

mm. The dominance of fine texture in this location is due to the soil following the Vertisols order, which normally contains a considerable amount of clay fraction that ranged between (402- 652gkg^{-1}). Soil bulk density in the studied soil samples was generally low in the surface soil horizons (1.06 Mg kg^{-1}) and increased downward in the soil pedons (1.69 Mg kg^{-1}), as a result of an increase in the organic matter content in surface horizons and a decrease towards the bottom of pedon. The soil moisture percentage in the study pedons was relatively low due to the high temperatures during the summer when the soil samples were taken (Tables 2 and 3).

Table 2: Soil Master and Diagnostic Horizons with Some Physicochemical Properties of Studied Pedons

location	Samples	Master Horizon	Diagnostic Horizon	PSD (g kg^{-1})			Soil Texture	Bulk Density (Mg kg^{-1})	Ca++	Mg++	Na+	K+
				Clay	Silt	Sand						
Zawita	ZP1S1	A	**Mollic**	386	400	214	Clay loam	1.25	20.2	10	1.02	1.93
	ZP1S2	Bk1	**Calcic**	461	350	189	Clay	1.53	20	7.4	2.33	1.12
	ZP1S3	Bw2	**Cambic**	436	350	214	Clay	1.62	17	15	1.46	0.94
	ZP1S4	Cm	**Duripan**	336	250	414	Clay loam	1.3	16.6	7.6	1.02	0.45
	ZP2S1	A	**Mollic**	286	300	339	Clay loam	1.56	21	12	0.87	1.26
	ZP2S2	Bw	**Cambic**	311	350	339	Clay loam	1.54	17	7.2	0.87	0.99
	ZP2S3	Ck	**Calcic**	286	409	305	Clay loam	1.23	16.6	10.2	0.95	0.45
Badi	BP3S1	A	**Mollic**	327	343	330	Clay loam	1.06	17	15	2.1	2.57
	BP3S2	Bk	**Petrocalcic**	277	368	355	Clay loam	1.59	19.8	12.4	1.97	0.54
	BP3S3	Cm	**Duripan**	168	377	455	Loam	1.46	10.3	9.2	1.60	0.54
	BP4S1	A	**Mollic**	393	318	280	Clay	1.16	14.3	11.3	2.92	0.81
	BP4S2	Bw1	**Cambic**	652	227	380	Clay loam	1.45	15	10.1	2.12	0.63
	BP4S3	Bk2	**Calcic**	427	227	455	Sandy clay loam	1.58	10.1	8.5	2.12	0.63
Semeel	SP5S1	A	**Ochric**	402	543	55	Silty clay	1.26	12.3	11.3	1.68	2.02
	SP5S2	Bt1	**Argillic**	627	343	30	Clay	1.29	12.0	9.8	2.42	1.08
	SP5S3	Bk2	**Calcic**	652	318	30	Clay	1.69	14.3	9.0	2.26	1.17
	SP6S1	A	**Ochric**	427	518	55	Silty clay	1.53	9.0	7.6	1.68	3.28
	SP6S2	Bk1	**Calcic**	402	493	105	Silty clay	1.55	13.9	8.3	1,75	1.80
	SP6S3	Bt2	**Argillic**	527	343	130	Clay loam	1.37	12.5	8.1	1.90	1.12

Chemical Properties

The electrical conductivity of the studied soils had a low value; it was considered a non-saline soil (0.10- 1.34 dS.m^{-1}), as the groundwater table was relatively deep. Despite some of the studied soil samples being taken in the forests, the pH values of the studied soil samples ranged between 7.48 and 8.55; these soils were slightly alkaline, and the alkalinity of the studied soils was attributed to being derived from calcareous parent material (limestone). The cation exchange capacity of the soils in the studied pedon ranged between 27.7 and 44.6 Cmole$_c$.Kg^{-1} and is commonly considered to have high CEC values because of derived from limestone and has a high content of bases. Organic matter content in soil samples of the studied pedons was relatively low. Even though in both Zawita and Badi locations, the soil samples were taken from forest soils, because these forests were dominated by pine trees, which have needle leaves and low decomposition in

Zawita location and even though in Badi location, the forest cover includes oak trees, but the organic matter is low as a result of low tree density and mountains of topography, whereas in semeel area organic matter was less than it in both previous locations as mentioned above because of the soil in this location followed vertisols that contain cracks and existing in the flat area in turn organic matter can be removal through cracks and by wind. The total calcium carbonate content in the study soil samples ranged from 66.4 to 377.7 g. kg^{-1}. This range of carbonate indicates that the study soils were calcareous, as they derive from limestone parent material, which is a major source of carbonate. The minimum active carbonate in the soil samples of the studied pedons was 65 g kg^{-1}, and the maximum was 265 g kg^{-1}. Active carbonate occurs in the clay and fine silt fractions and has a greater influence on soil properties than total carbonate. The high carbonate content is due to the weathering of limestone rocks (Table 3).

The most dominant of the exchangeable cations in the studied pedons are calcium (9-20.2 Cmolc.Kg^{-1}), followed by magnesium (7.2-15 Cmolc.Kg^{-1}), then sodium (0.87-2.92 Cmolc.Kg^{-1}) and potassium (0.45-3.2 Cmol$_c$.Kg^{-1}). This distribution pathway is attributed to the influence of calcareous parent material and the dominance of calcite, magnesite, and dolomite carbonate minerals in the study soils, which resulted in an increase in Ca^{++} and Mg^{++} concentrations, respectively, through the weathering process (Table 2).

Table3: Some chemical properties of the studied soils

Location	Samples	Master Horizon	Diagnost Horizon	Total Carbonte (g kg^{-1})	Active Carbonte (g kg^{-1})	pH	EC (dS.m^{-1})	CEC Cmol.Kg^{-1}	O.M. (g kg^{-1})
Zawita	ZP1S1	A	Mollic	151.9	140	7.67	0.45	40.6	21
	ZP1S2	Bk1	Calcic	234	180	8.2	0.12	33.7	16
	ZP1S3	Bw2	Cambic	139.6	125	8.28	0.12	38.6	10
	ZP1S4	Cm	Duripan	287.4	240	8.46	0.10	27.7	9
	ZP2S1	A	Mollic	102.6	90	7.61	0.44	36.6	25
	ZP2S2	Bw	Cambic	131.3	140	8.17	0.13	34.6	5.3
	ZP2S3	Ck	Calcic	205.3	175	8.41	0.11	30.7	2.7
Badi	BP3S1	A	Mollic	66.4	65	7.73	1.34	44.6	35
	BP3S2	Bk	Petrocalcic	312	240	7.9	0.97	36.7	7.4
	BP3S3	Cm	Duripan	377.7	225	8.32	0.98	31.4	6.4
	BP4S1	A	Mollic	157.8	130	7.48	0.73	40.6	18
	BP4S2	Bw1	Cambic	221.7	210	7.94	0.10	36.6	5.3
	BP4S3	Bk2	Calcic	361.3	180	8.02	0.19	32.7	0.5
Semeel	SP5S1	A	Ochric	229.9	170	8.14	0.19	38.6	10
	SP5S2	Bt1	Argillic	290.8	240	8.6	0.11	30.7	3.1
	SP5S3	Bk2	Calcic	274.1	265	8.55	0.13	31.7	9
	SP6S1	A	Ochric	164.2	155	7.92	0.75	34.6	13
	SP6S2	Bk1	Calcic	229.9	220	7.94	0.73	34.6	14
	SP6S3	Bt2	Argillic	262.7	220	7.99	0.79	29.7	7.4

Diagnostic soil horizons

The soil diagnostic horizons are specified according to the criteria adopted by the USDA-NRCS, as determined by the soil survey staff. [19].

Mollic Diagnostic Horizon (Epipedon)

Is the surface mineral diagnostic horizon that exists in the studied pedons 1 and 2 at Zawita location, with pedons 3 and 4 at Badi location, under pine and oak trees, respectively. This horizon formed in the studied pedons because it meets the requirements and conditions for its formation, including the presence of 20 g kg-1 or more organic matter. The base saturation percentage exceeds 50% in all the studied surface horizons. The soil colour is dark, and the soil depth is at least 10 cm in the studied soil, which contains a considerable amount of calcium carbonate. The studied pedons are characterized by the existence of a calcic, or petrocalcic, and duripan horizons below the mollic horizon in the subsurface layers as a condition of formation of this epipedon. The depth of this horizon corresponds to the requirement of standards for mollic epipedon formation, 10 cm or more, because the soil texture is fine (clay and clay loam) (Tables 2 and 3) (Figures 2 and 3). On the other hand, the n value, which was dependent on the relationship of soil moisture under field conditions with organic matter and soil particle size percentage of the mollic epipedon, was less than 0.7 (Table 4). This result proved the existence of mollic epipedon as a surface horizon in pedons of Zawita and Badi locations.

Ochric Diagnostic Horizon (Epipedon)

It is a pale eluvial horizon that has a high colour value and chroma in both moist and dry cases (Figure 3), and this horizon does not meet the requirements of the formation mollic epipedon or any other horizons. This horizon formed under arid and semi-arid climatic conditions and contains low organic matter content (Table 3). It is the initial diagnostic horizon and may be converted to another horizon depending on the environmental conditions of the soil and the pedogenic processes that are responsible for soil formation and development. This horizon is relatively hard and has a thin thickness (Figure 3). Despite a low n value in the ochric horizon in both pedons 5 and 6 (Table 4), this horizon meets all the other requirements for its formation

Calcic Subsurface Diagnostic Horizon

Is the illuviation a subsurface horizon that indicates the accumulation of carbonates in (Bk) master horizon, and sometimes due to in situ formation in the (Ck) horizon by the weathering process. Generally, this diagnostic horizon is found in arid and semi-arid regions, as well as in semi-humid areas. The studied soils were derived from limestone, a calcareous parent material, with suitable soil moisture content and a sufficient availability of carbon dioxide. These conditions assist in the dissolution and movement of carbonate minerals such as calcite, dolomite, and magnesite, which are low-dissolution minerals; therefore, the depth of carbonate accumulation and calcic horizon formation in sub-surface horizons by the calcification process due to the decalcification in surface soil horizons depends on the factors as mentioned above to assist dissolution and translocation of carbonates in solum, this was correlated with environmental conditions, and both above pedogenic processes (calcification and decalcification) led to the formation of a calcic diagnostic horizon. Ordinarily, carbonate accumulation occurs at the surface horizon in arid regions, and in the subsurface horizon in semi-humid climates, and the form of carbonates mostly appears as powder or nodules. The studied soils contain considerable carbonates and within the range that is required for the formation of a calcic diagnostic horizon (more than 15%) (Table 3), and the thickness of the horizon is more than 15 cm, which is in agreement with the criteria of calcic horizon formation, in addition to the existence of carbonates as nodules and powder (Figure 2 and 3). These conditions indicate the formation of the calcic diagnostic horizon in all studied pedons except pedon 3, which contains a petrocalcic horizon.

Petrocalcic Subsurface Horizon

An illuvial subsurface diagnostic horizon exists in pedon 3, which contains secondary carbonates (Total carbonates, 312 g. Kg^{-1}) (Active carbonates, 240 g. Kg^{-1}), and has accumulated and cemented (indurated) (Table 3). The thickness of this subsurface horizon is 21 cm, which corresponds to the requirements of the petrocalcic horizon formation that should be 10 cm or more, and below it exists an indurated pan layer (Figure 2).

Cambic Subsurface Horizon

This horizon formed as a result of physical alteration and chemical modification when removals or a combination of two or more of these processes occurred. This horizon exists in pedons 1, 2, and 4. There is an unstable critical subsurface mineral horizon that may change to another horizon under suitable environmental conditions and depending on the intensity of pedogenic processes. This horizon depends on the development of soil structure and color properties as an important condition for it, and is concerned with the presence of (Bw) master horizon. The cambic horizon formation of the studied pedons agrees with the requirements of clay content, which is higher than that of the upper and lower horizons. The soil colour has a higher chroma, value, and redder hue. In addition, this horizon is never considered part of (Ap) master horizon and is characterized by high carbonate content; the thickness of cambic horizon in the studied pedons is more than (25) cm as an index of the existence of this horizon. Accordingly, the soil horizon in the above studied pedons was classified as a cambic diagnostic horizon (Table 2 and 3) (Figure 2 and 3).

Duripan Subsurface Horizon

This diagnostic horizon was dominant in the soil of semi-humid and arid regions (Xeric and Aridic soil moisture regimes); therefore, it was identified in pedons 1 and 3 (Figure 2), which have xeric soil moisture regimes and contain a significant amount of sand particles (414 and 455 g kg^{-1}), respectively (Table 2). This silica (sand fraction) was cemented due to the high carbonate content (287.4 and 377.7 g kg^{-1}) (Table 3) in the previous pedons and may be associated with a petrocalcic horizon, as in pedon 3. It is an indurated and hard pan horizon resulting from carbonate acting as a cementing agent for the silica. Additionally, there is no evidence of plant root penetration in this diagnostic horizon of the studied pedons because it shows no fractures and is an indurated layer.

Argillic Subsurface Horizon

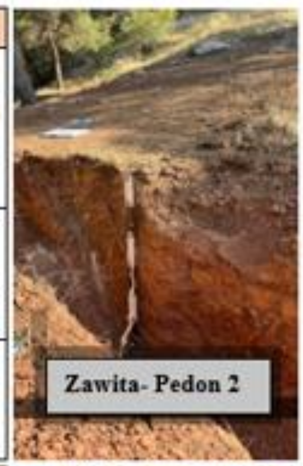
Is the mineral subsurface horizon formed as a result of Eluviation and Illuviation pedogenic processes simultaneously, when the translocation of mineral components -particularly the silicate clay minerals- from epipedon to subsurface horizon (Bt), as observed in pedons 5 and 6, with clay contents of 627 and 527 g. Kg^{-1}, respectively (Table 2), which take place under subhumid conditions. Additionally, due to the semi-arid conditions of the study area over the last few decades, the formation of the argillic horizon may be attributed to in situ formation, and the clay content in the epipedon was less than in subsurface horizon. The ratio of fine clay to total clay in (Bt) horizon (0.4 and 0.5) was more than that in the surface eluviation horizon (A) (0.2 and 0.4) in both pedons (5 and 6), respectively (Table 4). Furthermore, the thickness of (Bt) horizon exceeds 15 cm more than that of the (A) horizon (Figure 3).

Table 4: Ratio of fine to total clay, soil moisture percentage, and n value of the studied soils

Location	Samples	Master Horizon	Diagnostic Horizon	Fine clay/ Total clay	Soil Moisture %	n Value
Zawita	ZP1S1	A	Mollic	0.6	4.51	0.002
	ZP1S2	Bk1	Calcic	0.1	4.13	--------
	ZP1S3	Bw2	Cambic	0.3	5.11	--------
	ZP1S4	Cm	Duripan	0.5	4.68	--------
	ZP2S1	A	Mollic	0.7	4.93	0.003
	ZP2S2	Bw	Cambic	0.4	4.61	--------
	ZP2S3	Ck	Calcic	0.05	4.03	--------
Badi	BP3S1	A	Mollic	0.8	6.56	0.003
	BP3S2	Bk	Petrocalcic	0.6	1.45	--------
	BP3S3	Cm	Duripan	0.1	1.75	--------
	BP4S1	A	Mollic	0.6	5.06	0.02
	BP4S2	Bw1	Cambic	0.2	4.11	--------
	BP4S3	Bk2	Calcic	0.3	4.72	--------
Semeel	SP5S1	A	Ochric	0.2	4.29	0.001
	SP5S2	Bt1	Argillic	0.4	4.17	--------
	SP5S3	Bk2	Calcic	0.3	4.33	--------
	SP6S1	A	Ochric	0.4	4.54	0.001
	SP6S2	Bk1	Calcic	0.3	3.32	--------
	SP6S3	Bt2	Argillic	0.5	3.68	--------

orizon	Depth(cm)	Description of soil pedon 1
A Mollic	0- 25	Structure: Weak, fine, granular; contains dark humus, moderate amount of $CaCO_3$, few root hairs; abrupt regular boundary, 7.5YR 3/2 (Dark brown) (Dry);10YR 6/8 (Brownish yellow) (Moist).
B_k1 Calcic	25- 60	Structure: Moderate, medium, sub-angular blocky; high content of $CaCo_3$, white color layer with some dark color mottles. Existing of a large tree root, diffuse irregular boundary, 7.5YR 6/4 (Light brown) (Dry); 10YR 2/2 (Very dark brown) (Moist).
$B2_w$ Cambic	60- 85	Structure: Moderate, coarse, sub-angular blocky; existing nodules and powder of $CaCo_3$, tend to clay loam texture, some medium-sized roots, diffuse irregular boundary, 7.5YR 6/4 (Light brown) (Dry); 7.5YR 6/6 (Reddish yellow) (Moist).
C_m Duripan	85- 130	Structure: Strong, very coarse, massive; hardpan layer light color, high $CaCo_3$ content as large nodules, 7.5YR 8/4 (Pink) (Dry); 7.5YR 6/4 (Light brown) (Moist)

Horizon	Depth (cm)	Description of soil pedon 2
A Mollic	0- 10	Structure: Moderate, medium, granular; high amount of humus in the surface layer; contains a medium amount of $CaCo_3$, with the presence of root hairs, abrupt smooth boundary, 7.5YR 4/4 (Brown) (Dry); 5YR 3/3 (Dark reddish brown) (Moist).
B_w Cambic	10- 50	Stracture: Weak, fine, granular, existing large and medium tree roots, high $CaCo_3$ content, clay loamy texture, diffuse irregular boundary, 5YR 6/4 (Light reddish brown) (Dry); 5YR 5/4 (Reddish brown) (Moist).
C_k Calcic	50-140	Structure: Weak, medium, angular blocky; existence of medium and large tree roots less than the upper layer, containing a high $CaCo_3$ amount, 10R 5/6 (red) (Dry); 10R 3/4 (Dusky red) (Moist).



Horizon	Depth(cm)	Description of soil pedon 3
A Mollic	0- 60	Structure: weak, very fine, granular; the high amount of organic matter, presence of large stones, large tree roots of oak, and low $CaCo_3$ levels, activity of some organisms, and an abrupt, smooth boundary, 7.5YR 3/2 (Dark brown) (Dry); 7.5YR 3/0 (Black) (Moist)
B_k Petrocalcic	60- 81	Structure: Strong, very coarse, massive; containing large and medium roots of Oak trees, very high $CaCo_3$, Presence of white color layer, abrupt, irregular boundary,10YR 8/2 (White) (Dry); 10YR 6/4 (Light yellowish brown) (Moist).
C_m Duripan	81- 140	Structure: Strong, very coarse, massive; very hardpan layer, very high $CaCo_3$ content, more consolidated than upper layer, 7.5YR 8/2 (Pinkish white) (Dry); 7.5YR 8/2 (Pinkish white) (Moist).

Figure 2: Description of studied pedons (1, 2, and 3)

Horizon	Depth(cm)	Description of soil pedon 4
A Mollic	0- 34	Structure: strong, medium, granular; presence of organism channels; medium $Caco_3$ content and was powder in its form; this layer is dark in color and exhibits organism activity; clear, wavy boundary, 10YR 2/2 (Very dark brown) (Dry); 10YR 2/1 (Black) (Moist).
B_w1 Cambic	34- 90	Structure: Weak, coarse, sub-angular blocky; presence of more channels than in the upper layer, high $CaCo_3$ content, some white to grey mottles and light green mottles, clay loam texture, presence of large tree roots, diffuse, irregular boundary, 7.5YR 7/4 (Pink) (Dry); 7.5YR 4/4 (Dark brown) (Moist).
B_k2 Calcic	90- 150	Structure: Structureless (Weak structure), very high $CaCo_3$ content appears as nodules, some green areas may be iron oxide, presence of a few tree roots, 7.5YR 7/4 (Pink) (Dry); 7.5YR 5/6 (Strong brown) (Moist).

Horizon	Depth(cm)	Description of soil pedon 5
A Ochric	0- 20	Structure: Strong, very coarse, subangular blocky; high $CaCo_3$ content, existing organism channels, fine root hairs, activity of organisms, medium cracks in this layer, abrupt smooth boundary, 7.2YR 6/4 (Light brown) (Dry); 7.2YR 5/4 (Brown) (Moist).
B_t1 Argillic	20- 53	Structure: Weak, medium subangular blocky; channels formed by large wooden roots, some small nodules of $CaCo_3$, very high $CaCo_3$ content, few channels of organisms, cracks in different sizes, diffuse irregular boundary, 7.5YR 7/4 (Pink) (Dry); 7.5YR 5/4 (Brown) (Moist).
B_k2 Calcic	53- 130	Structure: Weak, medium, crumb; large nodules of $CaCo_3$, excessively high $CaCo_3$, and existing channels in this layer, 10YR 7/4 (Very pale brown) (Dry); 10YR 5/6 (Yellowish brown) (Moist).

Horizon	Depth(cm)	Description of soil pedon 6
A Ochric	0- 15	Structure: Moderate, coarse, angular blocky; few fine roots of plant, organism's activities as ant, high $CaCo_3$ content, channels of organisms, accumulation of wheat straw on the soil surface, small cracks in this layer, abrupt smooth boundary, 10YR 6/3 (Pale brown) (Dry); 10YR 6/4 (Light yellowish brown) (Moist).
B_k1 Calcic	15 -85	Structure: weak, coarse crumb; existing $CaCo_3$ as nodules, very high $CaCo_3$ content, existence of large channels, gradual wavy boundary, 10YR 7/4 (Very pale brown) (Dry); 10YR 5/4 (Yellowish brown) (Moist).
B_t2 Argillic	85- 130	Stracture: Weak, medium, crumb; few channels in this layer, very high CaC03 content, nodules and powder of calcium carbonate, 10YR 6/6 (Brownish yellow) (Dry); 10YR 5/6 (Yellowish brown) (Moist).

Figure 3: Description of soil pedons (4, 5, and 6)

Conclusions

The Mollic epipedon and Cambic subsurface diagnostic horizon were dominant in the Mollisols pedons of forest soils under pine and oak trees with good fertility. The Ochric epipedon and Argillic subsurface diagnostic horizon were dominant in the Vertisols under crop vegetation cover (Wheat) with the existence of cracks. The calcic subsurface diagnostic horizon existed in all pedons under forest trees and crop vegetation cover, as the soil was derived from calcareous parent material. Duripan formed as hard pan (Cm) in the deep layers of the pedons under pine and oak forest trees.

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