

Effect of Topography and Slope on Formation and Development of Calcareous Soils in North-Eastern Part of Lattakia Governorate, Syria

Samar Ghanem⁽¹⁾ Alaa Khallouf^{*(2,3)} Ahmad Majar⁽²⁾ and Adel Rukia⁽¹⁾

(1). Soil and Water Department, Faculty of Agriculture, Tishreen University, Lattakia, Syria.

(2). General Commission for scientific Agricultural Research (GCSAR), Damascus, Syria.

(3). Department of soil and Land Reclamation, Faculty of Agriculture, Al-Baath University, Homs, Syria.

(*Corresponding author: Alaa Khallouf. E-Mail: alaakhallouf@gmail.com).

Received: 16/08/2020

Accepted: 05/09/2020

Abstract

This study aimed to highlight on soil genesis and some diagnostic characteristics and its relation with topographic location in the north-eastern part of Lattakia governorate. Three soil profiles (P27, P10 and P09) were dug on various calcareous parent materials in April 2018, and were chosen as a topographic Catena: P27 was on the upper slope (summit), P10 was on the middle (back slope), while P09 was on the bottom (foot slope). Soil profiles were prepared and described based on the referenced methods. Samples were collected from each pedogenic horizon and some physical and chemical analyses were performed, in addition, the mineral composition analysis was carried out using X-Ray Diffraction. The topographic factor showed direct and indirect effects on some diagnostic characteristics of studied soils, including soil depth, color, structure, organic matter percentage, distribution of carbonates, and development of some surface and subsurface diagnostic horizons, whereas the clay distribution was not affected by topographic factor. It was concluded that the topographic factor and slope gradient had an important impact on some soils characteristics and development, thus, according to USDA Soil Taxonomy the classification of soils were as following: Entisols represented by p27, Mollisols which represented by p10, and Inceptisols which represented by p09.

Key words: Formation processes, Mineral composition, Slope gradient, Diagnostic characteristics, Topographic factor.

Introduction:

The term terrain indicates the arrangement of the Earth's surface, i.e., the differences in the slope of the local site, while topography shows the height of the Earth's surface at a large scale (Singh and Chandran, 2015). Terrain considers as a dynamic system that changes in a long time, since these changes rate varies from place to another based on environmental factors particularly climate and parent material type (Al-Khatib, 1998). Terrain effects are usually presented by slope (degree and

Aspect), that due to change in the amount of percolated water through the soil profile, and the amount of surface runoff (Kovda and Rozonova, 1988). In sequence, the different types of soils are developed; despite the similarity of some soil formation factors especially parent material (Al-Hinnawi, 2012). The topography effects are also clear on young soils than on mature (Fisher and Binkley, 2000; Birkeland, 1999). Several studies were conducted to study the relationship between topography and soil characteristics (Lin *et al.*, 2005; Seibert *et al.*, 2007), these studies examined the effect of topography on soil genesis and its development (Nejad and Nejad, 1997). It is concluded that the slope and its length have direct and indirect effects on mineralization processes, and also on the physical and chemical of soil properties. These changes can be explained by the movement and sedimentation of soil materials. Increasing the slope gradient due to increasing the surface runoff velocity and thus increases the amount of eroded soil (Dengiz *et al.*, 2009), and this leads to changes in soil properties along the slope (Tsui *et al.*, 2004). The aspect of the slope also effects on the amount and intensity of solar radiation and the thermal system, which in turn effects on the soil biological and chemical processes (Miller *et al.*, 1988; Bhatti *et al.*, 1991). Accordingly, the soil located on the top of the slope is less developed and less deep, and has a good drainage, unlike the soil in the bottom of the slope. The aspect direction effects on the local climate, natural vegetation and distributes heat and light. As a result, the northern aspects are usually with a thicker and darker color surface horizon in comparison to southern aspects. The intensity of erosion increases in the aspects facing the sunshine due to the decrease of soil aggregates percentage (Jebari *et al.*, 2008). Ruhe and walker (1968) reported that the slope in two-dimensional consists of the summit, shoulder, back slope, foot slope, and toe slope components. Limestone rocks are widespread in the coastal region of Syria (Lattakia governorate) (GORS, 1991). The genesis and development of soils on calcareous parent materials relate to two factors: the carbonates percolation speed and the passed water amount through the soil profile (Fanning, 1978). The process of carbonates percolation is one of the important processes that affect clearly by terrain, especially in humid and sub-humid areas (Nettleton, 1991). The main goal of the study is presenting the topography and slope impacts on pedogenic processes and its reflections on soil classification.

Materials and methods:

1- Study area description:

The study was conducted in Lattakia governorate, particularly in the north-eastern part (Fig.1). Three soil profiles (P09, P10 and P27) were dug on various calcareous materials, selected based on the geological map of Lattakia governorate at a scale of 1/50000 (MPMR,1999). The profiles distributed on the summit, back slope and foot slope as a topo-sequence (catena) (Fig.2). The climate of studied area described as a Mediterranean climate which is characterized by moderate temperatures, high humidity throughout the whole year, and with relatively high precipitation rates which may excess 100 mm/day, however the soil moisture regime is Xeric, while mesic is the soil temperature regime (ACSAD,1980; Khallouf, 2017). Vegetation cover differs based on topographic location and altitude. Since P10 is developed under oak forest, P9 and P27 are developed under succulent plants, *Calicotome villosa*, citrus, and sumac trees.

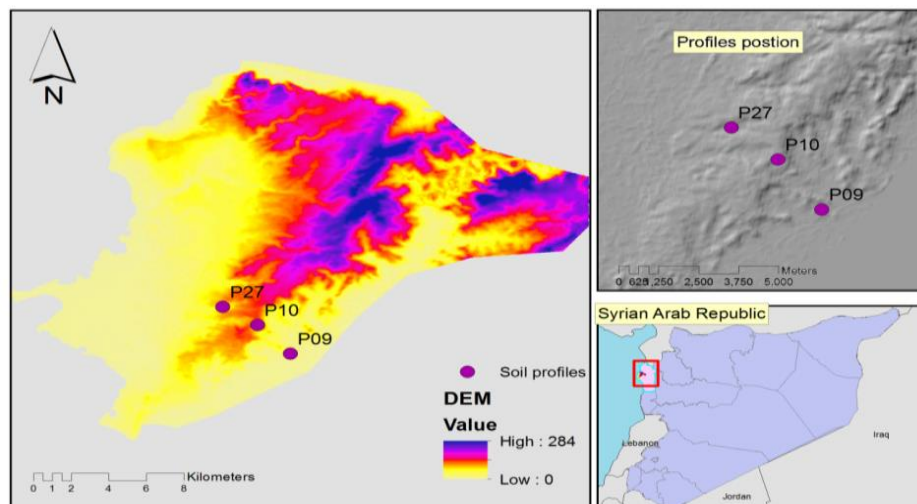


Fig. 1. Study area location and distribution of soil profiles

2- Soil profile description and soil sampling:

The three soil profiles were prepared and Global Positioning System (GPS, Garmin, accuracy $\pm 5\text{m}$) was used to record the altitude, and their geographic locations. The slope degree was determined using the geological compass (Table 1, Fig. 2), then the profiles were described according to USDA, (2012) in terms of total profile depth, depth of each horizon, the presence of stones, the abundance of roots and their depth, the presence of molting, biological activity and the soil structure type for each horizon, in addition, determining the color of the soil on each horizon using (Munsell, 1954). Carbonate was detected in the field by HCl solution (10%). After all that, samples were taken from each horizon to soil properties analysis at Lattakia Research Center, General Commission for Scientific Agricultural Research.

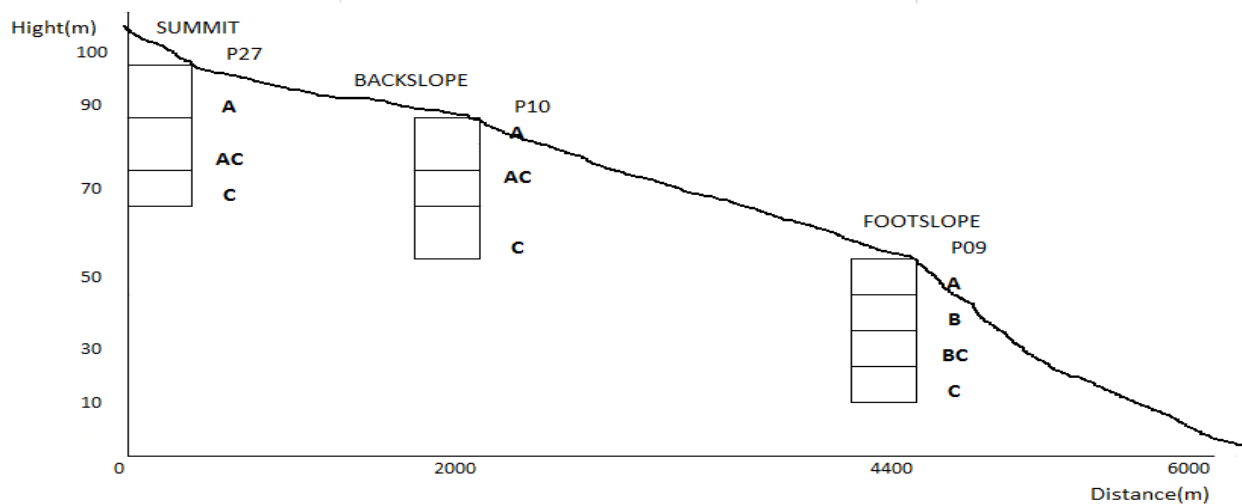


Fig. 2. Topographic section of studied area

Table 1. Soil profiles geographic locations and altitude in the study area

Profile Code	Parent Material	Altitude (m)	Slope Degree	Coordinates	
P09	Calcareous rock	50	30	35° 32' 55.000" N	35° 51' 15.000" E
P10	Calcareous rock	90	40	35° 33' 56.000" N	35° 50' 18.000" E
P27	Marl	100	30	35° 34' 34.410" N	35° 49' 18.174" E

3-Soil samples analysis:

Soil samples were air dried, grinded, sieved through a 2 mm sieve, and the totally dried weight was determined. Physical and chemical analyses were carried out including: soil particles distribution by Hydrometer Method (FAO, 1974), soil reaction (pH) was measured by a pH –meter of 1: 5 suspension (Melean, 1982), total carbonates was measured by using volumetric titration (Drouineau, 1942), organic matter (OM) was determined by wet combustion method (FAO, 1974). Cation Exchange Capacity (CEC) was estimated by Sodium Acetate Method (Rhoades and Polemio, 1977).

4-Mineral composition analysis:

The XRD (X-Ray Diffraction) was used to determine the mineral composition of both soil and parent material samples, where samples were very smoothly grinded as powder, and set on aluminium slides (Karimeldin, 1996), then measured by the XRD device using PC-APD Diffraction Software. (The curves were read and the mineral composition of each horizon was determined).

Results and discussion:**1-Morphologic characteristics:**

Morphological characteristics varied from profile to another due to their topographic location. The main horizons of (P27) and (P10) were distinguished as (A-AC-C) (Tables 2 and 3), with some rock fragments presence in the horizons of (P10), while the main horizons of profile (P09) differed as follows (Table 4): A-(B)-BC-C, which referred to alluvial accumulation of silicate clay, iron, aluminum. The surface diagnostic horizons are Ochric Epipedon in (P27), Mollic Epipedon in (P10), whereas Cambic subsurface diagnostic horizon for P09. The carbonate field test showed a strong reaction with the 10% HCl due to their calcareous nature. The biological activity was also reported with a variety of abundance of roots which intensively concentrated in the surface horizons particularly in (p27) while the roots were found along the horizons in (P10). All studied profiles have a strong structure especially in the surface horizons, as a result of the high content of clay and organic matter. The granular structure was distinguished in all surface horizons of three profiles, whereas it was blocky in subsurface horizons of P09, P10 and rocky structure in P27. The color often reflects many of the soil characteristics including the compounds and its formation process (Ali, 2015), besides, the percentage of calcium carbonate and organic matter content play a vital role in the color differences, the soil color varied in all three profiles despite their origin from the same parent material (limestone), and this was related to the profile development degree and weathering processes.

Table 2. Morphological description of soil profile p27

Entisols- -Orthents -Xerorthents- Lithic xerorthents		profile (P27)
A	0-25cm	Light brownish gray (10YR 6/2D), grayish brown (10YR 5/2M), clay, granular structure, common fine roots, , strongly calcreous, common biological features, gradual wavy boundary.
AC	25-45cm	Light brownish gray (10YR 6/2D), grayish brown (10YR 5/2M), clay, stratified rocky structure , few very fine roots, strongly calcreous, gradual wavy boundary.
C	45-100cm	Gray (5Y 6/1D), light olive gray (5Y6/2M), rock structure, none roots, strongly calcreous.




The soil color of profile (P09) was distinguished from the rest where the color of the soil was affected by the oxidation conditions of the present minerals, and this relates to soil moisture and solar radiation conditions (Brady *et al.*, 2002; Ghanem, 2019). Cracks in the surface soil were obviously reported as a result of wetting and drying alternation, but these cracks did not reach to the diagnostic characteristics of Vertisol. The soil depth was inversely increasing with the altitude, where the profile P27 was the shallowest comparing to P09 and P10 which were relatively deeper.

Table 3. Morphological description of soil profile p10

Haploxerolls Typic - Haploxerolls Mollisols-Xerolls		profile (P10)
A	0-20cm	Very dark grayish brown (10YR 3/2D), very dark gray (10YR 3/1M), clay, granular structure, common coarse roots, high poeosity,none stones, strongly calcreous, smooth boundary.
AC	20-60cm	Dark grayish brown (10YR 4/2D,M), clay, granular structure, common coarse roots, high poeosity, insects pores, few rock fregments 2-5 cm, strongly calcreous, gradual smooth boundary.
C	60-100cm	Light brownish gray (10YR 6/2D,M) blocky structure, few fine roots, few rock fregments 2-5 cm, strongly calcreous.



Table 4. Morphological description of soil profile p09

Haploxerepts -Typic Haploxerepts		profile (P09)	xerepts – Inceptisols
A	0-10cm	Pale brown (10YR 6/3D), brown (10YR 5/3M), silt clay, granular structure, few fine roots, none stones, strongly calcareous, clear gradual wavy boundary.	
(B)	10-55cm	Pale brown (10YR 6/3D), brown (10YR 5/3M), clay, stratified structure, few moderate roots, insects pores, none stones, strongly calcareous, gradual smooth boundary.	
BC	55-80cm	Very pale brown (10YR 7/3D), grayish brown (10YR 5/2M), silt clay, stratified blocky structure, few fine roots, strongly calcareous, clear gradual wavy boundary.	
C	80-110cm	Light brownish gray (10YR 6/2D), grayish brown (10YR 5/2M), silt clay, blocky structure, very few moderate roots, strongly calcareous.	

2- Mineral composition:

Soil mineral composition is the most important indication of weathering processes, soil formation and soil development (Douglas, 1990). Mineral composition results in Table (5) shows that calcite is the dominant mineral in all horizons of the studied profiles, as it is the main component of calcareous rocks. However, the its presence indicates the weak effect of the climate on the leaching process of carbonates (Carroli and Hathaway, 1954). In the study area the terrain situation and the nature of precipitation have played an important role in reducing the amount of percolated water through the soil profile, moreover the relatively absolute short age of the soil. In addition to calcite, all horizons contained several primary minerals such as enstatite, leucite, quartz, and forsterite, indicating the impurities of limestone. Furthermore, a presence of some secondary minerals such as clay minerals (Kaolinite, Montmorillonite, and Illite), since the medium conditions prevent their formulation (Lamouroux, 1973), so their presence in the horizons could be caused by some inherited minerals associated to impurities of limestone, moreover minerals immigrated from adjacent zones due to the different transport conditions.

Table 5. The mineral composition of studied soil profiles

Profile code	Horizon symbol	Mineral composition
P27	A	Calcite > Enstatite > Saponite > Montmorillonite
	AC	Calcite > Leucite > Illite > Montmorillonite
	C	Calcite > Saponite > Kaolinite
P10	A	Calcite > Quartz > Gismondine > Montmorillonite
	AC	Calcite > Forsterite > Illite
	C	Calcite > Quartz > Leucite > Gismondine-
P09	A	Calcite > Quartz > Enstatite > Montmorillonite
	(B)	Calcite > Kaolinite > Philipsite > Enstatite
	BC	Calcite > Enstatite > Leucite > Illite
	C	Calcite > Philipsite > perialite > Illite

3 - Physical and chemical properties:

3-1-Total carbonates:

The depth of carbonate is considered as an essential diagnostic characteristic, since it is vital for classification of these soils at lower levels, moreover it also reflects the status of the terrain and its differences at the local scale (Monger *et al.*, 2001). The study showed that due to the nature of the calcareous parent material a high content of carbonate were obtained, furthermore it was also distributed in all horizons of studied profiles and ranged between 46.87 and 86.27% (Fig.3; Table 6). The most obvious carbonate characteristic is its transportation with leaching water from upper to lower layers, which is usually affected by the topographic features (slope degree, slope position, etc.) where the lateral and vertical movement of water, in addition to surface runoff, play an crucial role in the carbonates distribution and their content in the soil profile. for instance, in profile (p10) the partial leaching of carbonates was observed and the percentages of total carbonates was recorded from upper to the lower horizons as following 69.04, 73.1, 86.27% respectively (Fig. 3). However the location of the profile (P10), where the soil is located on a back slope with 40%, in addition to the contribution of the vegetation and the biological activity affected the soil solution movement, which was directed inside of it particularly in the surface horizons. It is also worth noting that the Decalcification process is the main process of forming the soil placed over limestone rocks. Conversely in (p27) where the topographic location: Summit, and slope of 30%, it was noticed that the topography has a limited role in the process of carbonates transmission and accumulation. In this case, the main reason for carbonate accumulation was due to the high biological activity in the surface horizon (A). All of these factors lead to an increase in the carbonates dissolving and their transfer with the soil solution. On the other hand, the topographic position of P09 (foot slope) played a vital role in facilitating the water movement, dissolving materials through the horizons moreover carbonates leaching. In the absence of the factors, carbonates return to accumulate again. However, the high level of carbonates in the surface horizons is related to transport and mixing of the soil which was caused by the slope and the lateral water movement furthermore because of human activity (Ghanem, 2019) Theoretically, it is assumed that the carbonate percentage will increase towards the bottom of the slope as a result of the transfer of carbonate, beside the surface and lateral runoff from the summit (p27) to be accumulated in the foot slope (p09) (Chen *et al.*, 1997), so, as previously mentioned, the type of the limestone in addition to the poor leaching processes have the key role in defining the percentage of carbonates and their spatial distribution within a limited area.

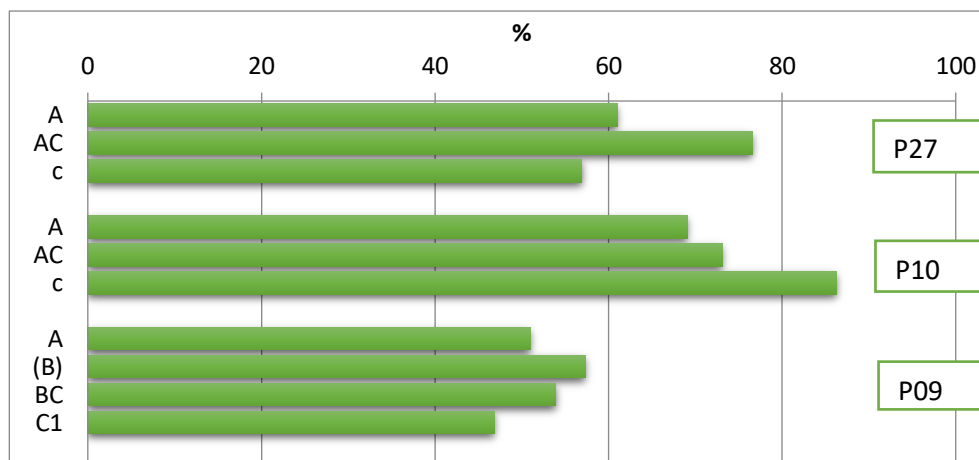


Fig. 3. Total carbonates distribution through studied soil profiles

3-2- clay:

A very high clay content was observed in all studied soil profiles (Fig.4: Table 6), this might be mainly linked to the parent material nature (Sys, 1979), moreover it was also clear that the soil texture was mainly clay. Based on the results of the textures analysis, the absence of clay immigration process in both (p27) and (p10) was reported, although the high content of clay in the horizon (B) of (P09). However, it was formed locally in-situ. It is well-known that clay immigration takes place in the soil when some preliminary pedogenic processes such as removing preventing clay dispersion materials by desalination, decalcification, and others, which required a sufficient amount of water enabling these processes. In the studied profiles, the topographic location, in addition to the calcium parent material, moreover the relatively short absolute age of these soil prevent its development and the movement of plasma and dissolved colloids of both $Al(OH)_3$ and $Fe(OH)_3$. Accordingly the clay immigration through the soil profile decreases and consequently the formation of Eluvial and Illuvial horizons was prevented (Buol *et al.*, 1980). All of these factors, as one or combined affected the development and materials movement through the soil profile. Although profiles (p09) and (p27) are similar in slope degree, but they differed in the topographic location that indirectly affected the soil properties including the clay content. The excessive amount of water in p09 (foot Slope) accelerated the internal weathering processes led to formation of the (B) horizon (Cambic horizon) with formed in-situ clay content of 70.95% .

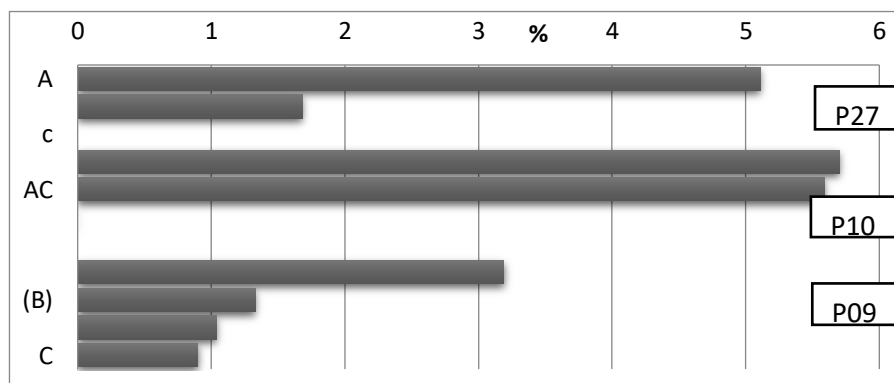


Fig. 4. The clay percentage in studied soil profiles

3-3 Organic matter (OM):

The organic matter content was high, especially in the surface horizons where it ranged between 0.5 - 5.11 % (Fig.5: Table 6). In p27 the high rates of organic matter of 5.11% in upper horizon may be explained by the abundance of natural vegetation(Oak forests), as a primary source of organic material in the soil; in addition to the soil richness of calcium carbonate and clay assisting to preserve the organic matter by forming calcium humates, moreover as higher the clay fraction in the soil as greater the organic content is (Soil Survey Staff, 2014). Due to the penetration of roots and to the lateral movement of soil materials with the land slope (Rukia, 2012), humus in P10 was distributed relatively to more than 100 cm depth with value more than 5 %, however it was rationally distributed in (P09) with gradual decrease going deeper and 3.19 % was recorded in the surface horizon.

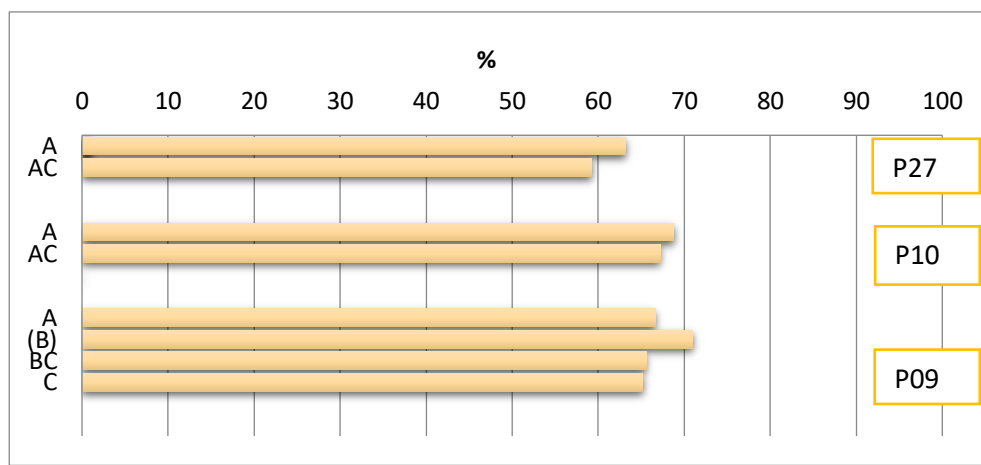


Fig. 5 The percentage of organic matter in studied profiles

3-4 Cation Exchange Capacity (CEC):

Soil clay content, its type and organic matter content can be proximately reflected by the cation exchange capacity (CEC), which is considered as an essential criterion for soil fertility (Al-Hinnawi, 2012). CEC ranged from moderate to high levels in all profiles and varied between 22.5 - 52.6 mq/100 g soil (Table 6), where due to the high organic matter content and the clay mineral type of Montmorillonite, the highest CEC value was observed in the surface horizon (A) of P10 with the value of 52.6 6 mq/100 g soil; however even if the clay content was high with the value of 70.95 %, the CEC decreased in the B horizon of P09 to 34.3 mq/100g soil with the domination of kaolinite mineral (Table 5), in addition low organic matter content in it. Besides, due to the high carbonates content of 57.32 % ,the clay in this horizon might considered to be lime-clay.

4- Soil Pedogenic characteristics and its relationship with topography and slope gradient:

Due to the weak weathering processes related to low soil moisture, which is essential for the majority of pedogenic processes such as chemical weathering of primary minerals, and to the high solar radiation, the soil in P27 was immature, skeletal, moreover low level of pedogenic processes; hence the Ochric horizon was recognized with the absence of the subsurface diagnostic horizons; additionally the speared general pedogenic processes such as organic matter adding and its decomposition were dominant, while the parent materials still Eluvium. Classification requirements were absent for all soils orders where there were no diagnostic horizons. Therefore the soil in P27 is classified as Entisols.

Soil formation processes in (p10), which is situated on mixed parent materials (Eluvium and Diluvium), took another tendency of pedogenic process development, where the Mollic Epipedon was developed as a result of the combination of the topographic location, the slope degree, and the vegetation density factors. Since the progression of decalcification process has direct relationship to the soil profile development, furthermore to the partial carbonate leaching, it was concluded that the profile (p10) has reached an advanced stage of soil formation on calcareous materials compared to the rest of the profiles. Therefor based on (USDA, 2012) P10 was classified as Mollisols.

Table. 6 Soil physical and chemical properties of studied profiles

Profile code	Clay %	Silt %	Sand %	Soil texture	Total carbonate %	CEC mq/100g soil	OM %	PH	% Carbonate of parent material
P27									
A	63.21	20.93	15.86	Clay	61	30	5.11	7.9	107.24
AC	59.27	27.15	13.58	Clay	76.54	24.4	1.68	8	134.5
C	-	-	-	-	56.88	-	-	-	100
P10									
A	68.81	21.89	9.3	Clay	69.04	52.6	5.7	7.2	80
AC	67.2	26.7	6.1	Clay	73.1	30.1	5.59	7.8	84.7
C	-	-	-	-	86.27	-	-	-	100
P09									
A	66.7	26.51	6.79	Silty clay	50.99	40.4	3.19	7.8	108.7
(B)	70.95	17.82	11.23	Clay	57.32	34.3	1.33	8	122.2
BC	65.6	21.2	13.2	Silty clay	53.92	22.6	1.04	8	115
C	65.19	22.64	12.17	Silty clay	46.87	22.6	0.9	7.9	100

Mollisols is usually affected by the presence of organic matter mixed with the mineral substances (Humification), the optimal temperature and humidity conditions, in addition to the biological activity. It is also well-known that the Mollic Epipedon may be developed on different parent materials and the rich organic matter with calcium is the base of forming it (Soil Survey Staff, 1975). Whereas in P09, the high soil moisture content is reflected by the morphological characteristics such as color, oxidation process and the internal weathering processes of primary minerals. As a result Cambic horizon (B) has developed. Generally, the weathering processes are activate in whole soil profile, particularly in the middle part, where the lowest fluctuation of temperature and soil moisture was observed (Barshad, 1988), as well as the high clay content with relativity low organic matter affected the soil structure and decreased the porosity with the following prevention of the water and soluble substances movement, especially carbonates, across soil profile. Therefor soil in P09 was classified as Inceptisol, taking in consideration that it was Automorphic, developed far of the effect of groundwater conditions (Table 7).

Table. 7 Soil classification of studied profiles at Sub-great group level (USDA, 2012)

Profile code	Order	Suborder	Great group	Sub-great group
p27	Entisols	Orthents	Xerorthents	Lithic Xerorthents
P10	Mollisols	Xerolls	Haploxerolls	Typic Haploxerolls
P09	Inceptisols	Xerepts	Haploxerepts	Typic Haploxerepts

Conclusion:

The three studied soil profiles were developed on one type of parent material and affected by the same climatic conditions, therefor the results of the physical and chemical analyses of soil properties and morphological features concluded that differences in the soil formation processes, morphological and genesis characteristics are basically caused by the variation in the topographic and terrain location. Soil

can also develop even on a high slope degree lands as in profile (P10) in the presence of some factors, such as vegetation.

References:

- ACSAD (The Arab Centre for the Studies of Arid zones and Dry lands) (1980). USDA soil taxonomy and the soil map of Syria and Lebanon. Damascus. 3.
- Al-Hinnawi, S. (2012). Characterization and Evaluation of Some Soils from Swaida Province Using Remote Sensing Techniques. Ph.D. thesis, soil sciences Department, Faculty of Agriculture. Damascus University.
- Ali, Y.H. (2015). The study of some soil formation in Hauran plateau and it's classification and evaluation. Ph.D. thesis. soil sciences Department, Faculty of Agriculture, Damascus University. Damascus, Syria. Pp 107.
- Al-Khatib, S.A. (1988). Principles of soil sciences. Al-Maaref institution. Alexandria, Egypt.
- Barshad, I. (1988). Chemistry of soils development in. Bear, F.E (Ed) Chemistry of The Soil Rein Hold, New York, Pp. 1-70.
- Brady, N.C.; and R.R. Weil (2002). The Nature and Properties of Soils 13th ed. Pearson Education, Upper Saddle River, NJ.
- Birkeland, P.W. (1999). Soils and geomorphology. Oxford University Press, New York, Pp. 430.
- Boul, S.W.; F.D. Hole; and R.J. Mccrackens (1980). Soil genesis and classification. 2nd Edition, Iowa. Iowa State University Press, Ames.
- Carroli, D.; and J. Hathaway (1954). Clay Minerals in Alimestone soil profile. U.S. Geological survey, Washington.
- Chen, Z.S.; C.F. Hsieh; F.Y. Jiang; T.H. Hsieh; and I.F. Sun (1997). Relations of soil properties to topography and vegetation in a subtropical rain forest insouthern Taiwan. Plant Ecology. 132 (2): 229–241.
- Dengiz, O.; T. Yakupoglu; and O. Baskan (2009). Soil erosion assessment using geographical information system (GIS) and remote sensing (RS) study from Ankara- guvenc basin, Turkey, Journal of Environmental Biology. 30(3): 339-344.
- Douglas, L.A. (1990). Soil micromorphology a basic and applied science. Elsevier science publisher B.V., The Netherland.
- Drouineau, G. (1942). Dosage rapid du calcire actif du sol, nouvelles donnies sur la reportation de la nature des fraction calcaires. Ann. Agron., 12: 441-450.
- Fanning, D.C. (1978). Soil morphology genesis, classification and geography published by the author. Department of agronomy .university of Maryland, college park.
- FAO (Food and Agriculture Organization)(1974). The Euphrates pilot irrigation project, Methods of soil analysis, Gadeb soil laboratory (a laboratory manual). Food and Agriculture Organization, Rome, Italy.
- Fisher, R.F.; and D. Binkley (2000). Ecology and management of forest soils, John Wiley and Sons, New York.
- Ghanem, S. (2019). Study of the diagnostic properties of the pedological cover of the northern- eastern area of Lattakia and the participation in its classification. Ph.D thesis. Department of soil and water, Faculty of Agriculture, Tishreen University. Lattakia, Syria.
- Jebari, S.; R. Berndtsson; A. Bahri; and M. Boufaroua (2008). Exceptional rainfall characteristics related to erosion risk in Semiarid Tunisia. The Open Hydrology Journal. 1(3): 1-9.
- GORS (General Organization of Remote Sensing) (1991). Study on lands and forests of the coastal region using remote sensing techniques, Lattakia District. Damascus University press. Agriculture Faculty- Damascus university.

- Karimeldin, Y.A. (1996). X-ray diffraction of mineralogical composition of Mudstone from eastern Gadaref area, Sudan, Department of Physics, Faculty of sciences, University of Khartoum, Sudan.
- Khallouf, A. (2017). Land use planning using remote sensing and geographic information systems in Lattakia governorate. Faculty of Agriculture. Master theses, soil sciences Department, Faculty of Agriculture, Damascus University. Damascus, Syria.
- Kovda, B.K.; and B.K. Rozonova, (1988). Pedology soil types and Geographic, Eds high school Moscow.
- Lamouroux, M.; H. Paquet; and G. Millot (1973). Evolution des minéraux argileux dans les sols du Liban. *Pédologie, Gand.*, 23:53-71.
- Melean, E.O. (1982). Soil pH and lime requirement. *Methods of Soil. Analysis. Part 2*, 2nd. Ed. A.L. Page, R.; H. Miller; and D.R. Keeny (eds), American. Society of Agronomy, Madison W.I., USA.
- Miller, P.M.; M. Singer; and D. Nielsen (1988). Spatial Variability of Wheat Yield and Soil Properties on Complex Hills, *Soil science society of America Journal*. 5 (4): 1133-1141.
- MPMR (Ministry of Petroleum and Mineral Resources) (1999). The geologic map of Lattakia (1/50000), Damascus, Syria.
- Monger, H.C.; R. J. Southard; and J.L. Boettinger (2011). Classification of soils, Aridisols. In: Huang PM, Li Y, Sumner ME (eds) *Handbook of Soil Science*, 2nd Edn, Boca Raton, CRC Press.
- Munsell color charts (1954). Munsell color company .USA.
- Nejad, A.A.A.; and M.B. Nejad (1997). The effects of topography on genesis and development of soils in Kermansha area. *Iran Journal of Science*. 28(3):99-111.
- Nettleton, W.D. (1991). Occurrence, Characteristics, and Genesis of Carbonate, Gypsum, and Silica Accumulations in Soils, *SSSA Special Publication*, Madison, WI .Volume 26.
- Rhoades, J.D.; and M. Polemio (1977). Determining cation exchange capacity: Anew procedure for calcareous and gypsiferous soils, *Soil Sci. Soc., Am. J.*, 41:524 – 300.
- Ruhe, R.V.; and P.H. Walker (1968). Hillslope models and soil formation, I. Open systems. *Transactions Ninth International Congress of Soil Science*. 4:551–560.
- Rukia, A. (2012). The structure of pedologic cover in the coastal region of Syria. *Tishreen University Journal for Research and Scientific Studies, Biological Sciences Series*. 34 (2): 43-55.
- Seibert, J.; J. Stendahl; and R. Sorensen (2007). Topographical influences on soil properties in boreal forests. *Geoderma*.141: 139—148.
- Singh, S.K.; and S.K. Chandran (2015). Soil genesis and classification ,Chapter: 3, Publisher: Indian Society of Soil Science, Editors: R.K. Rattan, J.C. Katyal, B.S. Dwivedi State Univ. of Ghent, Belgium.
- Soil survey staff (2014). *Illustrated guide to soil taxonomy*, U.S. Department of Agriculture, Natural Resources Conservation Service. National Soil Survey Centre. Lincoln, Nebraska.
- Sys, C. (1979). *Regional Pedology, Tropical soils II*. I. T.C. course, State Univ. of Ghent, Belgium. 125 Pp.
- Tsui, C.C.; Z.S. Chen; and C.F. Hsieh (2004). Relationships between soil properties and slope position in a lowland rain forest of southern Taiwan. *Geoderma.*, 1(123):131-142.
- USDA (U.S. Department of Agriculture) (2012). *Field book for describing and sampling soils*. Version 3.0, National Soil Survey Centre Natural Resources Conservation Service.