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CALCIUM CARBONATES EFFECT ON PARTICLE SIZE DISTRIBUTION AND TEXTURE CLASSES IN CALCAREOUS SOILS IN SULAIMANI GOVERNORATE

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Abstract

This experiment was carried out to study the effect of removal of $CaCO_3$ on particle size distribution (PSD) and texture classes in some soils in Sulaimani Governorate, Kurdistan region, Iraq. Thirty-four soil samples were collected from different calcareous soil horizons. These soils were analyzed for $CaCO_3$ and the carbonates were ranged from 51.9 and 42.63 g kg^{-1}. The three weighted soil textures (sand, silt and clay) were determined before any removal of the $CaCO_3$ and after the removal of $CaCO_3$. The sand fraction ranged from 87.6 to 316.0 g gk^{-1} while the clay fraction ranged from 237.7 to 614.7 g kg^{-1} and the silt fraction was slightly higher than clay fraction. The results showed that removal of $CaCO_3$ led to a change in PSD in all the samples and 85% of those changed textural class. The carbonates did not show a uniform distribution in soil particle size and generally carbonates were most accumulated in sand and silt size. The soil had the most prevalent PSA change in the silt and sand fractions following $CaCO_3$ removal. The maximum significant correlation between particle size distribution before and after carbonates removal was related to clay particles ($P < 0.01$) but the correlation was not significant between the silt components. Therefore, we recommend that all calcareous soil samples from the semiarid be pretreated for $CaCO_3$ removal prior to particle-size analysis and subsequent textural classification.

Keywords: Calcium Carbonate, Particle Size Distribution, Calcareous Soil,

تأثير كربونات الكالسيوم على التوزيع الحجمي لدقائق التربة وصنف النسجة في الترب لكلسية في محافظة السليمانية

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الخلاصة

أجريت هذه التجربة لدراسة تأثير إزالة كربونات الكالسيوم على توزيع حجم لدقائق (PSD) واصناف النسجة التربة في بعض الترب في محافظة السليمانية، إقليم كردستان العراق. جمعت أربعة وثلاثون عينة تربة من آفاق تربة كلسية مختلفة. تم تحليل عينات التربة من أجل كربونات الكالسيوم وتراوحت الكربونات بين 51.9 و42.63 غم كغم$^{-1}$. تم تحديد نسجة التربة الموزونة (الرمل والغرين والطين) قبل إزالة كربونات الكالسيوم وبعد إزالة كربونات الكالسيوم. تراوح مفصول الرمل من 87.6 إلى 316.0 غم كغم$^{-1}$ بينما تراوح كذلك الطين من 237.7 إلى 614.7 غم كغم$^{-1}$ وكان كذلك الطين أعلى قليلاً من كسر الطين. ظهرت النتائج أن إزالة كربونات الكالسيوم أدت إلى تغير في PSD في جميع العينات و85٪ من تلك تغيرت صنف النسجة التربة. لم تُظهِر الكربونات توزيعًا موحدًا في حجم لدقائق التربة، وتراكمت الكربونات عمومًا في حجم الرمل والغرين. كانت التربة أكثر تغيرات PSA انتشارًا في أجزاء الطين والرمل بعد إزالة كربونات الكالسيوم $CaCO_3$. كان الارتباط الأقصى المعنوي بين توزيع حجم لدقائق قبل وبعد إزالة الكربونات مرتبطًا بجزيئات الطين ($P< 0.01$) ولكن الارتباط لم يكن معنويًا بين مكونات الطين. لذلك، نوصي بمعالجة جميع عينات التربة الكلسية من شبه الجافة مسبقًا لإزالة كربونات الكالسيوم قبل تحليل حجم ا لدقائق وتصنيف النسجة اللاحق.

كلمات مفتاحية: كربونات الكالسيوم، التوزيع الحجمي لدقائق التربة، الترب الكلسية.

Introduction

Calcareous soils are common in the arid areas of the earth (9), occupying 30% of the earth surface, and their $CaCO_3$ content vary widely from a few percent to 95% (18). Calcareous soils occur naturally in arid and semi-arid regions because of relatively little leaching. They also occur in humid and semi-humid zones if their parent material is rich in $CaCO_3$, such as limestone, shells or calcareous glacial tills, and the parent material is relatively young and has undergone little weathering. Some soils that develop from calcareous parent material can be calcareous throughout their profile. This will generally occur in the arid regions where precipitation is scarce. Calcareous soils are characterized by the presence of calcium carbonate in the parent material and by a calcic horizon, a layer of secondary accumulation of carbonates (usually Ca or Mg) in excess of 15% calcium carbonate equivalent and at least 5% more carbonate than an underlying layer (24).

Soil texture represents the relative proportion of soil particles distribution. It is a fundamental physical property of soils, correlated to just any other soil property. The particle-size distribution (PSD) of a soil is calculated by the sand, silt and clay content. Soil carbonates size can be varied from very fine clay-like powder to coarser, silt-like particles, which can influence soil texture. The carbonate particle size is very different from one calcareous soil to another. Carbonates are distributed in the sand (2000-50 µm), silt (50-2µm), and clay (< 2 µm). Particle size distribution (PSD), surface area and reactivity are important properties of soil carbonates which influence soil pedogenic, chemical, and rhizosphere processes (19). Carbonates influence the physical and chemical soil properties of horizons and soil aggregates (17) and carbonates are very active in clay and silt fractions (20). The presence of carbonate in soils not only impacted on particle size distribution but also, influenced hydraulic properties, soil structure and soil expansion. Carbonate minerals are among the most important basic components of the soil and one of the most important carbon salts common, especially in the soils of arid and semi-arid regions (14). The $CaCO_3$ affects soil properties, directly or indirectly, as a consequence of ecological interpretation, classification, and management decisions (6).

Calcium carbonate bonds to clay and /or silt particles, which affects particle-size analysis. Highly aggregated, stable clay soils may behave like coarse sands. They may be mistakenly identified in the field as sands or coarse loams. However, an important step in PSA, based upon Stoke's law, is the treatment of samples to enhance separation or dispersion of aggregates (12). Carbonate is commonly precipitated as silt crystals (2-50 µm) in the soil but also occurs in indurated forms as nodules and/or as hard calcareous layers (10) Soils may contain aggregates, such as secondary $CaCO_3$, that are not readily dispersed and bind particles together. Therefore, chemical pretreatment should be used to remove carbonate coatings and secondary $CaCO_3$ aggregates for accurate particle-size distribution (PSDs) and subsequent textural classification (4). The objective of our study was to determine the quantitative effects of $CaCO_3$ on soil particle size analysis and how this relates to soil textural classification of semiarid soils found in different calcareous soils collected from different climatic area from Kurdistan region, Iraq.

Materials and Methods

Sulaimani Province is located between latitudes 45.62444E and between longitudes 35.35472 N in northeast Iraq. The soil moisture and temperature regime of the region are Aridic Ustic and Hyperthermic, respectively. The climate is semiarid, and the mean annual precipitation ranged from 593 to 738 mm (Table 1) .

Soil samples were collected from different soil horizons on the basis of present different amount of carbonates from the Sulaimani Governorate. Soil samples were air dried ground by hand and sieved through a 2 mm sieve. The soils were analyzed for same physical and chemical properties, including calcium carbonates equivalent content, pH and particle size distribution (PSD). PSD was carried out with and without $CaCO_3$ removal to determine the effects on resulting PSD and subsequent textural classification of the samples. In the second step, PSD were determined after calcium carbonate removal from soil samples. Calcium carbonate was removed by diluted HCl (10%) following procedures proposed by (18) for removal of carbonates prior to determining PSD. The carbonate free soil samples were air-dried and PSD was determined using the pipette method, which is considered to be an exact and precise method suitable for routine analyses (13), following the destruction of soil organic matter and dispersion of the sample. The sand was separated from the sample by sieving it through a 53 µm mesh and quantified gravimetrically.

The $CaCO_3$ equivalent of the soils was determined by the acid neutralization method (21). Selection of samples for pretreatment (removal of $CaCO_3$) prior to PSA was set at the >5% $CaCO_3$ equivalent based on the taxonomic definition of a calcic horizon (24).

Results and Discussion

The result in Table 2 shows some physical and chemical properties of selected soils. It indicates that all the soils are calcareous. The results of total carbonates equivalent in soil samples showed in Table 2 and the values ranged between 51.9 and 42.63 g kg^{-1} soil with an average of 291.4 g kg^{-1}. The lowest value of carbonate equivalent found in soil sample from Goezha (A1) cultivated with olive trees, while the highest value 426.3 g kg^{-1} of carbonate were found in soil samples from Goezha (Bk2). The carbonates content was lower in the surface horizons and gradually increased with soil depth as indicated by the accumulation of carbonated in Bk horizons from the surface horizons. The results of total $CaCO_3$ showed that all soils were contained a high amount of total $CaCO_3$ equivalent. Most carbonate minerals found in local soils are calcite and account 90% of total soil carbonate (3). According to the USDA classification, these soils considered as a calcareous reaction because it indicated that the thrush old is 50 g $CaCO_3$ kg_{-1} soil (24) and all the studied soils had more carbonate equivalent than this value.

Soil pH of the studied soils shown in the Table 2, and the pH values ranged from 7.42 to 7.95 with the average value 7.05. The soil reactions were neutral to slightly alkaline and this may be due to effect of high carbonates content which were inherited from portent materials. In spite of high calcium carbonate relatively present in most of soil horizons, the pH was not very high which may be due presence of calcite and dolomite minerals (8). Generally, the soil pH value was lower at the surface than sub-surface. This may be due to leaching processes were happened by precipitations on Ca^{2+} ions in alkaline soils from the surface to subsurface soils. These values were in agreement with the results found by (2) that carbonate mineral content was 59-313 g kg^{-1} in some soils from northern Iraq. Generally, it had been reported that carbonate equivalent in samples selected from different part of Iraq was ranged from 30 to 496.7 g kg^{-1} soil (16).

The distribution of soil particles was shown in Table 2 and the results indicated that the sand fraction ranged from 87.6 to 316.0 g gk^{-1} with an average value 149.6 g kg^{-1} while the clay fraction ranged from 237.7 to 614.7 g kg^{-1} and the silt fraction was slightly higher than clay fraction and the value ranged from 287.0 to 658.6 g kg^{-1} with an average 469.8 g kg^{-1}. The soil had heavy texture classes for most of the soils and they were silty clay loam to clay classes.

The effect of $CaCO_3$ on distribution of soil particles was shown in Fig 1 the result indicated that after carbonates removal, PSD has changed in all samples. Also, textural classes changed in 85% (n=34) of these samples. Additionally, the comparison of particle size distributions before and after carbonate removal indicated that distribution of soils were differed in soil textural triangle to each other in textural triangle. The results in Fig 1 showed that most of the removal of carbonate changed soil texture classes from sandy clay loam to fine texture classes, clay, clay loam, silty clay and silty clay loam in free carbonate samples. These results were in agreement with the results found for local area (15). They found that the distribution of soil carbonate for different soils from Iraq and it has been found that the majority of calcium carbonate mineral was within the silt fraction. Also (1) found that the most leached and weathered soils have the largest fraction of total carbonate in silt size fraction. On the other hand, (7) reported that carbonate exists in all size fractions with the least fraction of carbonate in clay size. The results of (6) in the study of the carbonates impact on soil textural class in semi-arid region of Wild land in New Mexico indicated a significant increase in clay particles content after $CaCO_3$ removal of soils. Carbonates were accumulated in clay size fraction in these soils. Also results (23) showed a significant decrease in clay content after removal of carbonates from the main soil series of Qazvin plains. (6) Found that the removal of $CaCO_3$ led to a change in PSD in all the samples and 70% of those changed textural class .

The soil had the most prevalent PSA change in the silt and sand fractions following $CaCO_3$ removal. The results in Fig 2 indicated that the majority of carbonate free samples, mean particle size increased in silt and clay while the sand decreased. The sand measurements with presences of carbonates made overestimated the sand fraction in all soil samples. Silt content increased in all 32 horizons upon $CaCO_3$ removal, with a corresponding change in textural class in 29 of these soils. The amount of silt increased in 94% of samples. Conversely, the amount of sand decreased in all of soil samples. On the other hand, clay content slightly increased or nearly remain constant after carbonate removal in all samples. These results showed that carbonates can generally flocculate many clay or silt particles and consequently they appear as sand particles. This trend may be in soil particle size as the result of carbonate elimination that coated soil particles following the removal of this part, and particles diameter have decreased. The other part of this change can be related to coarse particles elimination of soils carbonates. Carbonates can bind silt particles into larger units as an effective cementing agent (25). Therefore, following the carbonates removal from soils, and the destruction of carbonates coating layer or removal of cementing agents in aggregates, the amount of sand particles decreased and silt content increased. The results show that generally mean silt content increased significantly after carbonates removal and mean sand content decreased in soil samples (Fig 3).

The result in Fig 4 shows the relationship between soil particles before and after carbonates removal. The maximum significant correlation between particle size distribution before and after carbonates removal was related to clay particles ($P< 0.001$), and the next step belonged to sand particles ($P< 0.05$) but there was not significant correlation between the silt components and at the minimum level. These results show that carbonates did not show a uniform distribution in soil particle size. The maximum carbonates proportion was related to sand particles with a rate of 1.52 and the minimum was 0.009 for clay particles. Most carbonate minerals found in local soils were large calcite had often primary source and account 90% of total soil carbonate (3). The high amount of sand size carbonates can be related to physical weathering of calcareous parent material in this foot hill soils .

Carbonates can bind clay particles together and create bigger particles; hence, these compounds removal leads to a reduction in the amount of sand in soil samples and an increase of silt and clay particles (Fig 2). Also, it is shown that before and after carbonates removal clay has a more uniform pattern than that of silt and sand particles. Removal of carbonate from soil in fact reduced the weight of sand fraction which means that carbonate is highly distributed in sand fraction compared to silt and clay fractions. Therefore, the increase in silt and clay fraction could attributed not only to the release of carbonate cemented and clay fraction from the larger size fraction after carbonate removal, but also to the higher reduction in the weight of sand fraction compared to diminution in clay fraction (5). The removal of $CaCO_3$ caused change in texture of 29/34 (i.e., change in texture 85% of the soil samples). The change was from sandy clay loam to clay loam to silty clay loam. This agreed with the results of (22) who analyzed some soils from New Mexico for particle size distribution and classified them into 1 of 12 textural classes before and after calcium carbonate removal. They found that all of the samples having $CaCO_3$ changed particle size distribution, and 60% of those samples changed textural class following the pretreatment for $CaCO_3$ removal. Therefore, they recommend that all wild land soil samples from the semiarid Southwest New Mexico be pretreated for $CaCO_3$ removal prior to particle size analysis and subsequent textural classification. On the other hand, lack of significant difference among the clay fractions could be explained by the fact that the contribution of the clay sized to the total $CaCO_3$ was minimal among the 3 soil separates. Therefore, the % clay was not significantly affected by the pretreatment of the soil samples with HCl.

Table 1. soil samples location, classification according to USDA and precipitation for the studied soils.

Soil location	Soil classification	Climatic precipitation (mm)
Goezha 1,2,3		624
Dukan 1	Typical Calcixerolls	621
Baxy Baxtyari		585
Khalakan	Typical Hploxerolls	675
Dukan 2	Calcic Agrixerolls	593
Mawat	Typical Hpioxerolls	644
Penjween		738
Kuna Masi	Calcic Agrixerolls	703
Bakrajo	Chronic Haploxerts	562

Table 2. Some physical and chemical properties of studied soils.

No	Soil samples	Horizons	depth (cm)	pH	Sand	Silt g kg^{-1}	Clay	Texture class	Total carbonate
1	Dukan 1	Bk1	20-30	7.72	13.87	39.25	46.88	Clay	198.9
2		Bk2	30-49	7.77	17.98	42.77	39.25	Silty Clay Loam	359.0
3		Ck1	49-70	7.70	18.22	44.19	37.59	Silty Clay Loam	368.8
4	Goezha 1	Bk1	33-52	7.68	12.00	59.07	28.93	Silty Clay Loam	294.7
5		Bk2	52-80	7.79	11.89	62.91	25.20	Silty Loam	314.9
6		A	0-17	7.70	9.83	28.70	61.47	Clay	416.4
7	Baxy	Bk1	17-30	7.87	11.28	33.63	55.09	Clay	311.2
8	baxtyari	Bk2	30.65	7.83	15.05	38.78	46.17	Clay	354.8
9		Bk3	65-93	7.42	14.48	47.23	38.29	Silty Clay Loam	418.9
10		A1	0-15	7.87	8.76	39.75	51.49	Silty Clay	51.9
11	Goezha 2	A2	47-62	7.74	13.59	55.35	31.06	Silty Clay Loam	229.8
12		Bk1	62-89	7.65	12.88	58.27	28.85	Silty Clay Loam	285.7
13		Ck1	89-115	7.76	11.79	62.73	25.48	Silty Loam	281.6
14	Goezha 3	Bk2	53-83	7.72	11.07	46.74	42.19	Silty Clay	402.4
15		Bk3	83-110	7.69	9.89	50.88	39.23	Silty Clay Loam	426.3
16		Ck1	110+	7.95	11.78	49.52	38.70	Slty Clay Loam	394.4
17		A1	0-17	7.42	31.60	28.81	39.59	Clay Loam	359.9
18	Khalakan	Bk1	17-34	7.76	21.66	30.77	47.57	Clay	236.8
19		Bk2	34-55	7.75	20.47	30.56	48.97	Clay	196.3
20		Bk3	55-78	7.60	21.06	37.08	41.86	Clay	167.2
21		Bk4	78-89	7.51	28.19	35.33	36.48	Clay Loam	191.6
22	Dukan 2	A	0-25	7.61	11.77	44.02	44.21	Silty Clay	115.6
23		Bk1	25-40	7.68	11.34	39.56	49.10	Silty Clay	282.6
24		Bk2	40-56	7.45	10.39	45.00	44.61	Silty Clay	286.8
25		Bk3	56-83	7.67	10.58	46.13	43.29	Silty Clay	402.9
26	Mawat	A1	0-30	7.75	24.65	32.55	42.80	Loam	315.3
27	Penjween 1	Ap	0-30	7.65	22.00	45.72	32.28	Clay Loam	166.9
28		A1	0-30	7.74	23.79	52.28	23.93	Silty Loam	271.4
29	Kuna masi	Ap	0-30	7.65	15.41	51.99	32.60	Silty Clay Loam	235.6
30		AB	30-50	7.78	10.90	65.31	23.79	Silty Loam	322.3
31		AB	30-50	7.77	10.37	65.86	23.77	Silty Loam	306.8
32	Bakrajo	AB	30-50	7.87	10.15	62.17	27.68	Silty Clay Loam	319.8
33		Ap	0-30	7.76	10.04	61.47	28.49	Silty Clay Loam	304.7
34		A1	0-30	7.75	9.89	63.01	27.10	Silty Loam	316.4

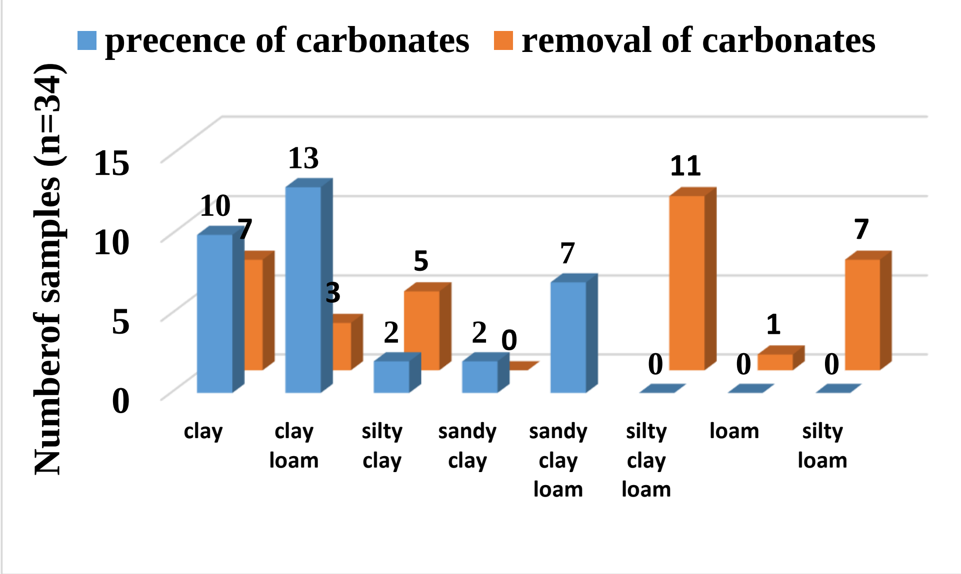


Fig.1. Carbonates effect on soil texture classes in the studied soils.

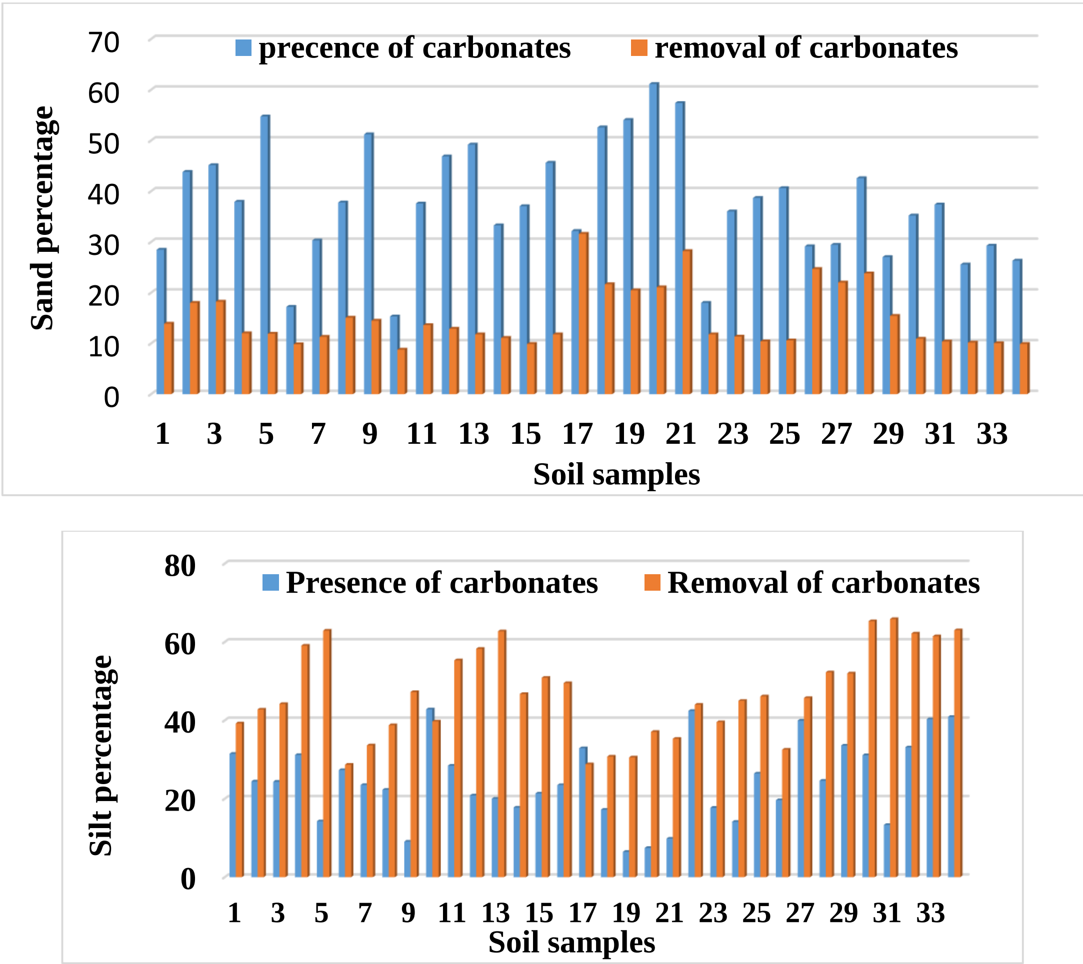


Fig 2. Carbonate effect on (a) sand (b) silt content in the soil samples.

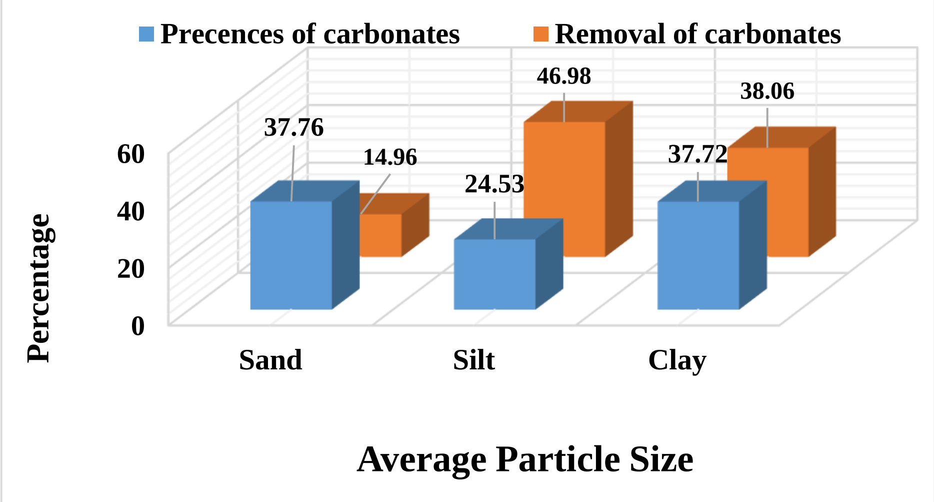
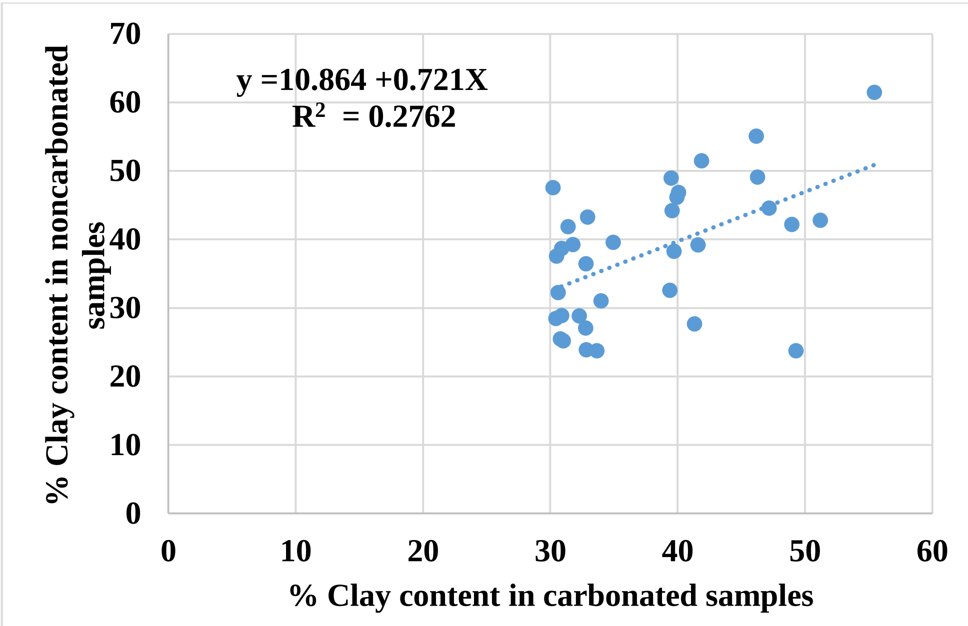
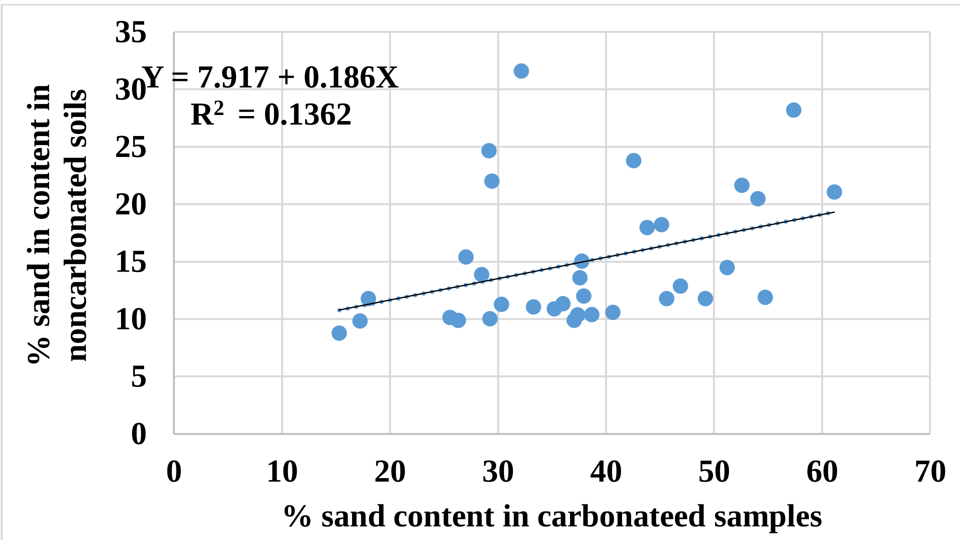


Fig 3. Carbonates effect on average sand, silt and clay content in studied soil samples.





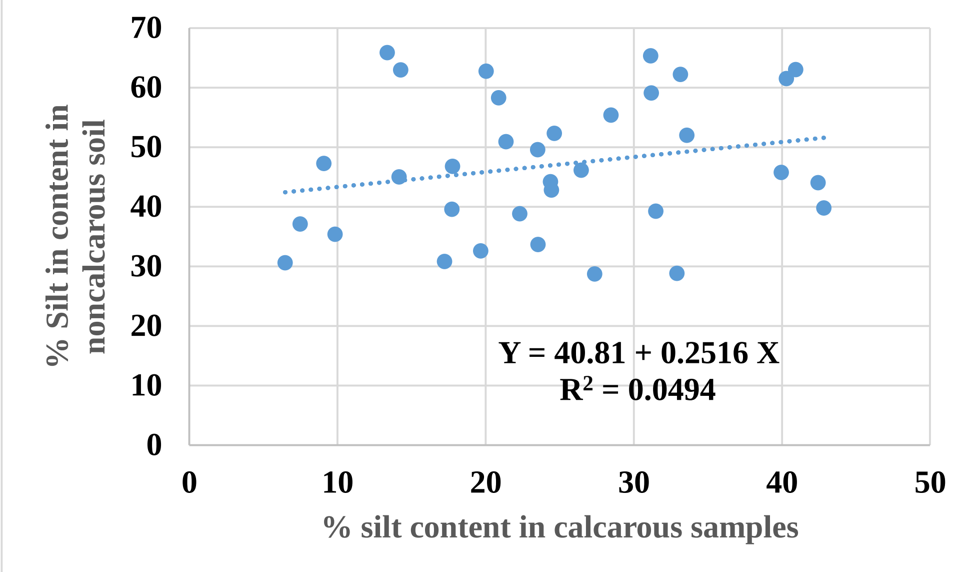


Fig. 4. Relationship between, particle size distribution (a: clay, b: sand, c: silt), of soil samples before and after carbonate removal).

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