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The study of particle size distribution of calcium carbonate and its effects on some soil properties in khuzestan province

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ABSTRACT-This experiment was carried out to study particle size distribution (PSD) of carbonates in soils and its effect on some calcareous soil properties in Khuzestan Province, Iran. Soil samples (n=72) were collected from different regions. To evaluate the effect of carbonates on water contents at pressure head of -1500 kPa and PSD of soil samples, these properties were determined before and after removing their calcium carbonate. Based on the results, removal of $CaCO_3$ led to a change in PSD in all the samples and 70% of those changed textural class. Carbonates were most accumulated in clay and sand size in Abadan region while they were accumulated in silt and sand fractions in other areas. Also, evaluation of moisture retention at permanent wilting point (PWP) showed that this feature has been reduced in all samples after removal of carbonates. Following these changes, verification of key to soil taxonomy equation [Clay%= 2.5(% water retained at -1500 kPa tension-%organic carbon)] in calcareous soils of Khuzestan Province showed that this equation can be used with high reliability in calcareous soils of Abadan, Karoon, Haft-Tape agro-industries. However, this equation is not valid in Amir-Kabir and Debal-Khozaiea gro-industries. Our fitted equation [Clay % = (4.35*% water retained at -1500 kPa tension +35.3* % organic carbon)] has high reliability in predicting clay content in non-carbonate samples. This result suggests that the presence of carbonates and its distribution in soil particle size is an important factor in the variability of soil properties at arid and semiarid areas.

INTRODUCTION

Calcareous soils have 5% content or more inorganic carbon or carbonate calcium equivalent (Soil Survey Staff, 2014). These soils are dominant in many areas, particularly in arid and semiarid regions and generally where precipitation is too low to leach these minerals from the soil. According to the FAO, around 12% of world soils and 65% of Iran's soils are calcareous (FAO.UNDP, 1972).

Calcareous soils often contain carbonates of the alkaline earth metal including calcium (Ca) and magnesium (Mg). The carbonate minerals may be either primary carbonates originating from carbonate-rich parent material, or secondary carbonates formed by partial re-precipitation of dissolved carbonates. Calcareous soils are sometimes referred to as alkaline soils with high pH. The pH range (in water) is from 7.0 to 8.5 in calcareous soils. Calcareous soils have a high buffering capacity to changes in pH. Carbonates influence the physical and chemical soil properties of horizons and soil aggregates (Kishchuk, 2000).

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 (2000-50μm), silt (50-2μm), and clay (<2μm) soil fractions. Carbonates are very active in the clay and fine silt (2-5μm) fraction (Moore et al., 1990). Particle size distribution, surface area and activity are important properties of soil carbonates which influence soil pedogenesis, chemical and rhizosphere processes. The results of Francis and Aguilar (1994) 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, Sabbah et al.'s results (1999) showed a significant decrease in clay content after removal of carbonates from the main soil series of Qazvin plains.

Carbonates can affect soil properties by in fluencing soil pH, structure, water holding capacity (WHC) and hydraulic conductivity. Carbonates can change soil structure by affecting soil texture and promoting aggregation formation or stability. On the other hand, carbonates as a cementing agent, affect the soil physical properties by secondary sand formation and silt-sized granules that mimic primary particles, which not only affect PSD, but also affects soil structure and pedogenic development by controling the infiltration and aeration rates (Kishchuk, 2000).

Additionally, Ca^{2+} and Mg^{2+} in soil cause soil particles to flocculate, or clump together, thus promoting the aggregates formation or stabilities. 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 PSD and subsequent textural classification. Carbonates can influence soil structure leading to having different water relation properties than non-calcareous soils. Soil water holding capacity depends on the texture and pore size distribution. Water retention was influenced by particles adsorption and specific surface area of soil particles, and less affected by soil structure. According to Gardner et al. (1970), soil moisture at -1500 kPa tension has a relatively good correlation with specific area of soils. Water adsorbed on the soil surface approximately equals10 layers of water molecules. Therefore, it seems that the soil moisture characteristic curve is strongly influenced by soil texture. The effects of carbonates on soil moisture characteristics also depended on the type and origin of these compounds. Primary carbonates that are usually put in sand particle size component of soils have less adsorption energy and lower moisture holding capacity (Khodaverdiloo and Homaee, 2002). In spite of it, the secondary carbonates, which mostly are in silt and clay size, have a great ability to absorb and hold water, especially at high tension (Motallebi et al., 2011). In some studies, negative effects of carbonates were reported on the amount of moisture at varying tensions. The results of these studies revealed that increasing the amount of carbonates leads to a decrease in the amount of moisture at different tensions (Rajkai et al. 1996; Khodaverdiloo et al., 2011). Aryanpour et al. (2012) also reported carbonates have a negative effect on soils water holding capacity, especially at high tensions. However, the positive effect of carbonates on water holding capacity and soil moisture characteristics was shown in some other studies. Therefore, with increasing the amount of carbonates in the soil, the amount of water increased at saturation, field capacity and permanent wilting point (Keshavarzi et al., 2011; Motallebi et al., 2011). Furthermore, water holding capacity (WHC) can be affected by the size and concentration of carbonates. Very fine carbonate particles can coat clay and silt particles and reduce their surface tension with water, and when a high $CaCO_3$ percentage is present in the clay fraction (30% or higher), the soil's WHC can be reduced (Kishchuk, 2000).

Although there are lots of calcareous soils in Iran and especially Khuzestan Province, a comprehensive study on the distribution of carbonates in soil size fraction and its effects on soil properties is not available in these soils. Moreover, studying the relationship between these characteristics with soil properties can be used in land management and accurate application of this relationship. Also, the amount of clay particles without carbonates is needed for soil classification in many cases. Therefore, carbonate particles distribution can be used to classify and understand the behavior of these soils such as cation exchange, water holding capacity, and etc. We have to determine the amount of silicate clay (clay carbonate free) for soil classification especially at the family category. In the soil taxonomy, carbonate-free clay estimating equation [Clay % = 2.5(% water retained at -1500 kPa tension - % organic carbon)] is used for determining soil family class or also great groups of many soils. Therefore, clay size carbonates are treated as silt (Soil Survey Staff, 2014). Validation of this formula in calcareous soils of Khuzestan Province with high amounts of carbonates can be effective in the application of this equation in these soils or others of Iran. The main objectives of this research were to determine the particle size distribution of carbonates in Khuzestan's soil and its effects on some soil properties of these calcareous soils.

MATERIALS AND METHODS

Khuzestan Province is located between latitudes of 46° 58′ and 50° 39′ E and between longitude of 29° 58′ and 33° 4′ N in southwestern Iran. The soil moisture and temperature regime of the region are Aridic Ustic and Hyperthermic, respectively. The climate is semiarid, and the mean annual precipitation is 233 mm.

The 72 disturbed samples were collected from 0-30 and 30-60 cm depths from four sugarcane-Agro-Industry and Abadan region (Fig. 1). With the North-southern aspect slope of Khuzestan plain, soil texture gradually changes to fine from northern parts of plain to the southern parts. Due to the fact that Abadan is located in the southern part of Khuzestan plain, itssoil texture is very fine and heavy. The soils were classified as Calcic Haploustepts in sugarcane Agro-Industries and Typic Haplosalids in Abadan (Soil Survey Staff, 2014).

Soil samples were analyzed for several physical and chemical properties including carbonate calcium equivalent (CCE) by back-titration method with hydrochloric acid 2N (Allison and Moodie, 1965) and PSD by the hydrometer method (Gee and Bauder, 1986). The samples were air-dried and then sieved through a 2 mm sieve. Particle size distributions of less than 2 mm were determined by the hydrometer method. The soil cores were slowly saturated by water to determine their water retention for 24-48 hours. Then, cores were subjected to consecutive -1500 kPa pressure to allow desaturation of the samples and determine their water content.

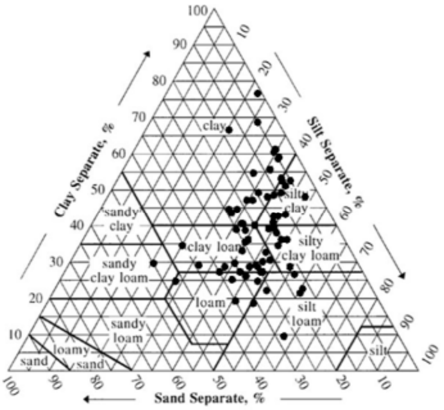

Fig. 1. Particle size distribution of soil samples with $CaCO_3$

In the second step, particle size distributions were determined after calcium carbonate removal from soil samples. Calcium carbonate was removed by diluted HCl (10%) following procedures proposed by Kroetsch and Wang (2006) for removal of carbonates prior to determining particle size distributions. The carbonate free soil samples were air-dried and particle size distributions and water retention values were determined in the same way as that of carbonate samples. Paired t-tests were used to determine the statistical significance of carbonate free and carbonate samples for retained water and the soil particle size distributions.

In this study, validation of key to soil taxonomy's equation for estimating the amount of non-carbonated clay was conducted. Following that, the rate of soil samples from the limited established for this equation (the ratio of the percentage of water retained at -1500 kPa tension to the percentage of measured clay is 0.25 or less or 0.6 or more in half or more of the particle-size control sections or part of the particle-size control sections in strongly contrasting classes) evaluated and fitted the new equation fits in calcareous soils of Khuzestan Province.

RESULTS AND DISCUSSION

Soil properties are shown in Table 1 from two depths (i.e. 0-30 and 30-60 cm) in sugarcane Agro-Industries (including: Haft Tapeh, Karun, Amir-Kabir and Debal-Khozaie) and Abadan region (Fig. 1). The soil textures are moderate to heavy in most soils and generally are silty clay, silty clay loam, clay loam, and clay textural class. Calcium carbonate equivalent amount is very high (at mean value 40%) in these soils. Parent material was from calcareous rocks. Geological formations were included from Fars group that consisted of Gachsaran, Mishan and Aghajari formation. Therefore, soil carbonates were inherited from this formation in soils (Jafari and Nadian, 2012).

Table 1. Ranges in some physical and chemical soil properties

Region	Land use	Depthcm	clay	silt	sand	CCE*	PWP	OC	ECdS.m
			%						
Abadan	Data palm orchard	0-30	8.56	3.35	8.7	3.38	4.12	12.0	3.78
		30-60	0.60	6.34	6.4	1.38	6.13	09.0	8.54
	uncultivated	0-30	9.61	3.33	3.8	5.41	3.16	09.0	0.130
		30-60	0.67	3.27	3.6	8.41	4.16	05.0	7.63
Haft Tapeh	sugarcane	0-30	5.47	5.39	6.25	7.38	3.15	64.0	9.0
		30-60	9.34	4.37	3.31	5.39	0.14	47.0	7.0
	rotation cropping	0-30	2.28	0.46	7.25	0.37	0.10	32.0	5.5
		30-60	2.28	0.47	7.24	4.37	1.7	16.0	5.4
	uncultivated	0-30	2.23	0.49	7.27	3.41	7.7	13.0	5.12
		30-60	2.37	2.38	5.24	9.41	9.8	06.0	8.8
Karoon	Sugarcane	0-30	2.41	5.44	2.14	1.39	5.15	44.0	8.1
		30-60	7.41	7.44	3.15	3.39	5.18	28.0	6.1
	rotation cropping	0-30	3.28	0.38	6.33	4.39	4.7	30.0	3.1
		30-60	6.31	0.50	0.52	2.41	2.6	27.0	0.1
	uncultivated	0-30	5.41	8.42	0.11	6.41	6.10	13.0	5.33
		30-60	8.46	1.42	0.11	0.42	86.8	08.0	1.26
Amir-Kabir	sugarcane	0-30	3.33	1.35	5.31	1.40	3.20	87.0	3.4
		30-60	6.33	8.38	5.27	0.41	0.25	70.0	0.4
DebaiKhozaie	sugarcane	0-30	2.35	8.41	8.25	7.39	6.20	57.0	58.2
		30-60	3.25	0.50	6.24	9.39	1.20	45.0	9.2

CCE*: calcium carbonate equivalent

As regards, parent material has high carbonates content in this region. Therefore, the soils formed from this material havehigh carbonates content. Also, carbonates were added from dust storms that happen very much in this arid region (Jafari, 2005). The organic carbon is low in most samples and electrical conductivity is high in southern soils. Electrical conductivity of uncultivated lands is more than that of the cultivated lands, which is probably due to leaching by irrigation water. Figures 2 and 3 show particle size distribution of soil samples before and after $CaCO_3$ removal, respectively.

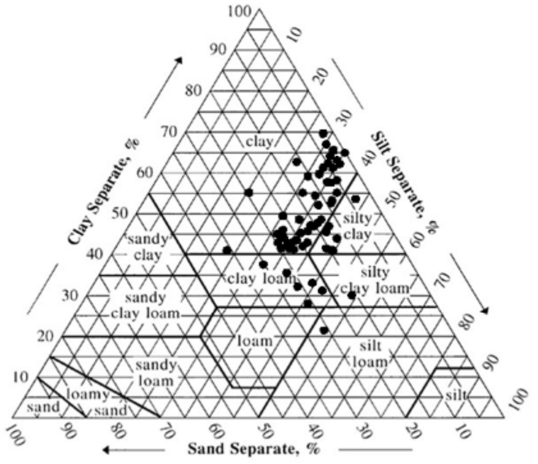

Fig. 2. Particle size distribution of soil samples for $CaCO_3$ free

As shown in fig. 2 and 3, after carbonates removal, PSD has changed in all samples. Also, textural classes changed in 70% (n=48) of these samples. Additionally, the comparison of particle size distributions before and after carbonate removal indicates that distribution of soils were limited in soil textural triangle and were located centrally to each other in textural triangle. In the majority of carbonate free samples, mean particle size increased. On the other hand, coarser particles diameter decreased in carbonate free samples and moved to smaller components. Therefore, it increased the amount of clay in 83% of samples (n=60). Conversely, the amount of silt declined in 83% of samples (n=60). Also, sand content decreased after carbonate removal in all samples. These results showed that carbonates can generally flocculate many clay particles and consequently they appear as silt or 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 that will be discussed in the next section.

Carbonates can bind clay particles into larger units as an effective cementing agent (Zhang and Norton, 2002). Therefore, following the carbonates removal from soils, and the destruction of carbonates coating layer or removal of cementing agents in aggregates, the amount of silt and sand particles decreased and clay content increased. Fig. 4 shows the relationship between soil particles before and after carbonates removal.

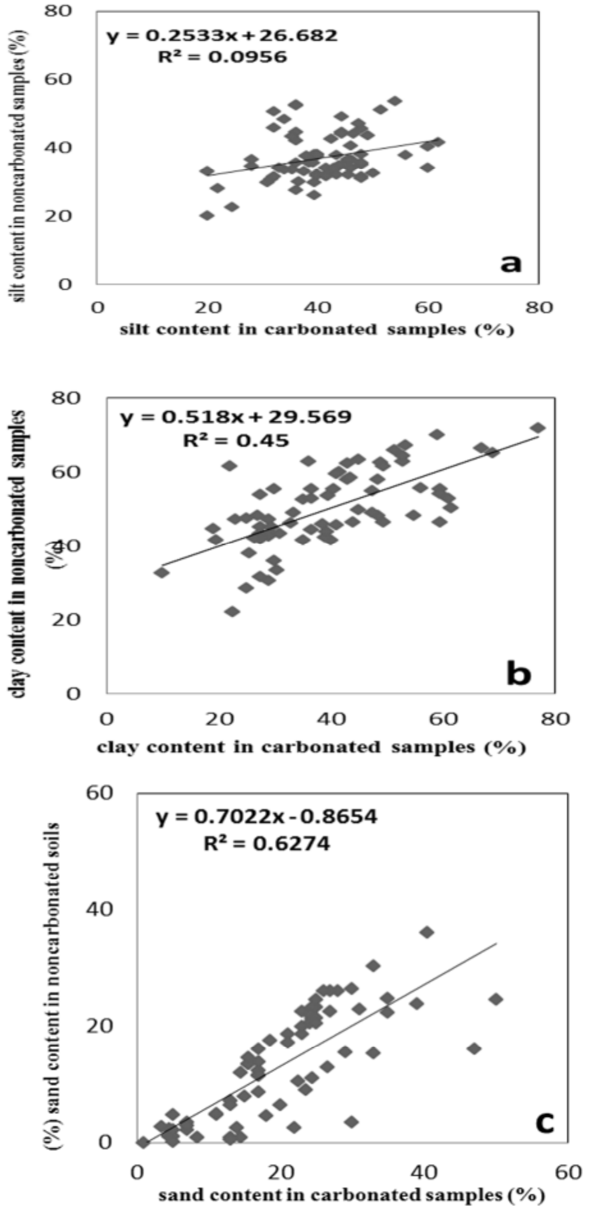

Fig. 3. Relationship between particle size distribution (a: clay, b: silt and c: sand) of soil samples before and after $CaCO_3$ removal

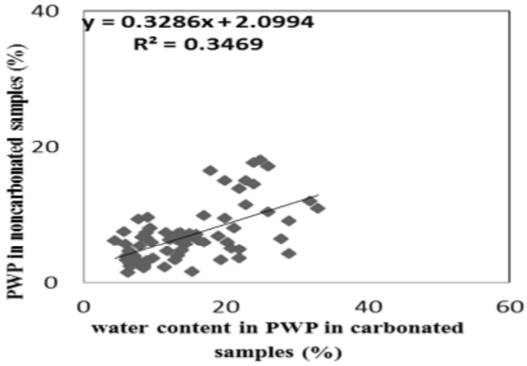

Fig. 4. Relationship between water holding capacity at PWP before and after carbonates removal

The maximum correlation between particle size distribution before and after carbonates removal was related to sand particles, and the next step belonged to clay particles which was related to silt components at the minimum level. This 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 0.7 and the minimum was 0.09 for silt particles. These results are not unexpected in the calcareous parent material in most Iran's soils. Large crystals of calcite or dolomite have often primary sources (Kishchuk, 2000). The high amount of sand size carbonates can be related to physical weathering of calcareous parent material in these soils. The Khuzestan plain had been formed from alluvial materials, particle size distribution is sorted in the north (coarse particles) to south (fine particles) pattern in 150 kilometer distance. Suspension particles were trans located through Karoon River and, fine particles were deposited when they were in contact with Persian Gulf's saline water. The correlation between water holding capacity in PWP before and after removal of carbonates is shown in Fig. 5.

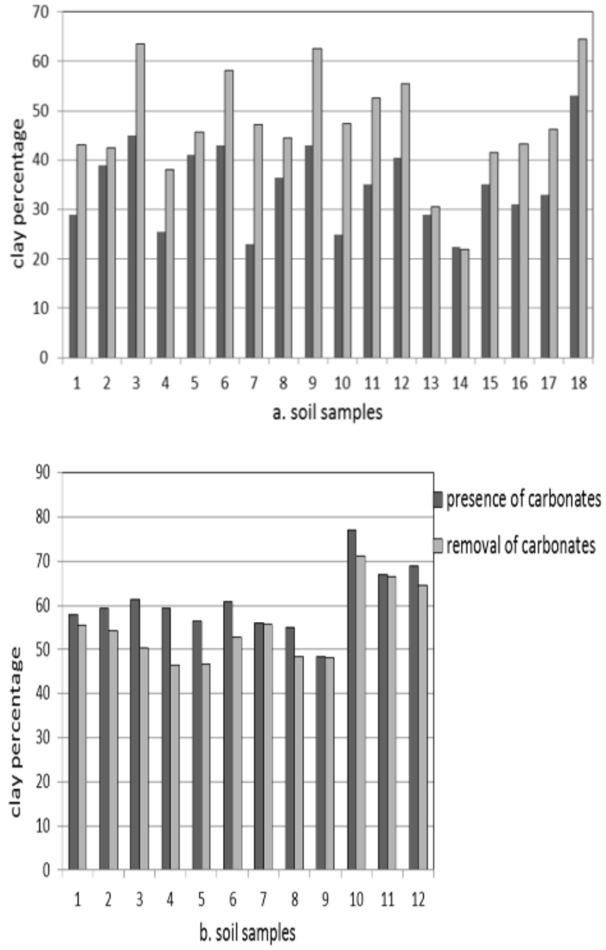

Fig. 5. Carbonates effect on clay content in some soil samples of (a) sugarcane-Agro-Industries and (b) Abadan region

As shown in Fig. 5, there is a low correlation betweenwater holding capacity at PWP before and after carbonates removal, which could be due to multiplicity of affecting factors on this moisture point. Moradi (2012) studied the most important factors affecting moisture retention of four sugarcane-Agro-Industries (i.e. Amir-Kabir, Haft Tapeh, Karoon and Debal-Khozaie) in Khuzestan Province. He reported that particle size and total carbonate content are the most important factors which determine soil moisture retention curve. Also, it was found that due to low organic matter and high clay content, the organic matter role is not considered on water retention in these soils. Moreover, high carbonates content have been introduced as an effective agent on water retention in these soils. Furthermore, bulk density is a key parameter to be considered. Soil particle size is considered as the most important factor which influence soil moisture retention curve in most studies (Haverkamp and Parlange, 1986; Bruand et al., 2003).

Soil water retention is related to surface adsorption and soil texture at high tension and is less affected by soil structure (Hillel, 1998). Thus, due to the effect of soil structure on bulk density, this parameter role is negligible in water retention at PWP. On the other hand, soil organic matter role especially in surface soil and organic soils is very practical (Rawls et al., 2003); low OM content reduces this factor role in water retention at PWP. Therefore, particle size distribution and carbonates content are the most important factors affecting water retention at PWP in these soils. With regard to particle size distribution changes in all samples after carbonates removal, changes in water retention at PWP following the change in particle size and surface adsorption properties are inevitable. In addition, carbonates removal and particle size changes can lead to change in micro pores which influence water retention at PWP. Also, carbonates were introduced as the main independent parameters that influence water retention curve at PWP (Motallebi et al., 2011).

Tables 2 and 3 show the results of soil textural analysis, carbonates content and water holding capacity at PWP of soil samples before and after carbonate removal in four sugarcane-Agro-Industries and Abadan region, respectively.

The results show that generally clay content increased significantly after carbonates removal and sand and silt content decreased in soil samples of sugarcane-Agro-Industries (Table 2).

Table 2. Mean of soil properties before and after $CaCO_3$ removal for soil samples in sugarcane- Agro-Industries

Soil property	Mean before $CaCO_3$ removal	Mean after $CaCO_3$removal
clay	35.4	49.0
silt	42.5	35.7
sand	22.1	15.4
PWP	15.7	7.1
CCE	39.9	-

Table 3. Mean of soil properties before and after CaCO3 removal for soil samples in Abadan region

Soil property	Mean before $CaCO_3$ removal	Mean after $CaCO_3$removal
clay	60.25	55.20
silt	32.60	43.70
sand	6.80	1.05
PWP	14.70	6.35
CCE	39.80	-

As previously mentioned, carbonates mainly flocculate clay particles and consequently they will appeare as silt or sand particles. Clay content significantly increased after coated carbonates removal around aggregates in these soils. Water retention decreased after carbonates removal at PWP due to the role of carbonates in clay and silt size in water retention especially at high tension (Motallebi et al., 2011). However, carbonates accumulated in clay and sand in Abadan's soil and carbonates removal lead to increasing the silt; consequently, PWP decreased. These results disagree with Khodaverdilloo et al.'s (2011) results. They reported an increase in PWP after carbonates removal. From north to south in the studied area, texture will gradually be heavier. Abadan is located in southern part plain; therefore, soil texture is heavier and carbonates are mainly accumulated in clay size (Jafari and Nadian, 2012).

Table 4 shows the particle size distribution average and water retention at PWP of paired samples (i.e., samples before and after calcium carbonate removal) in two depths (i.e., 0-30 and 30-60 cm).

Table 4. Comparison of mean of soil properties in studied depths in Haft Tapeh

Treatments*	parameter	df	MS	F	condense level
1	Clay silt Sand PWP	1	85.5	1.22	0.29^{ns}
		1	68.3	3.60	0.07^{ns}
		1	0.5	0.01	0.90^{ns}
		1	4.2	0.07	0.79^{ns}
2	Clay Silts and PWP	1	22.2	0.32	0.58^{ns}
		1	9.5	0.18	0.53^{ns}
		1	0.17	0.00	0.96^{ns}
		1	3.45	0.28	0.60^{ns}

treatments 1 and 2: presence of carbonates and removal of carbonates, respectively
ns: no statistical significance

Table 4 shows that none of the properties show significant differences in surface and subsurface depths. It is greatly influenced by the presence or absence of carbonates for evolution and development of most soils in Iran, including Khuzestan plain soils. Clay movement is prevented by high carbonate content. On the other hand, the presence of high content carbonates and also bivalent Ca^{2+} and Mg^{2+} cations can flocculate clay particles (as plasma fraction) and then these particles act as larger particles in soils that do not move easily. Carbonates precipitate in secondary form that coated and bind primary soil particles to gather and can inhibit clay dispersion. This is associated with disruption of aggregates by replacing Na^+ and Mg^{2+}in clay and aggregates, thereby adding to aggregate stability and preventing them from dispersion. Thus, soil texture and water retention did not change much between soil depths. Furthermore, due to negligible effects of pathogenic factors, these soils are young and soil properties in soil profile do not change. Also, soil properties do not show a significant difference between two mentioned depths (i.e., 0-30 and 30-60 cm) in studied areas.

Carbonates can bind clay particles together and create bigger particles; hence, these compounds removal leads to a reduction in the amount of clay in Abadan region and an increase of these particles in other areas (Fig. 6a). Also, it is shown in Fig. 6 that before and after carbonates removal in Abadan region, clay has a more uniform pattern than that of silt and sand particles.

Also, as a result of carbonates removal, water retention reduced at PWP in all studied areas (Fig. 6b). This reduction is uniform in Abadan region but PWP has less uniform changes in other regions due to different effects of clay content on soil.

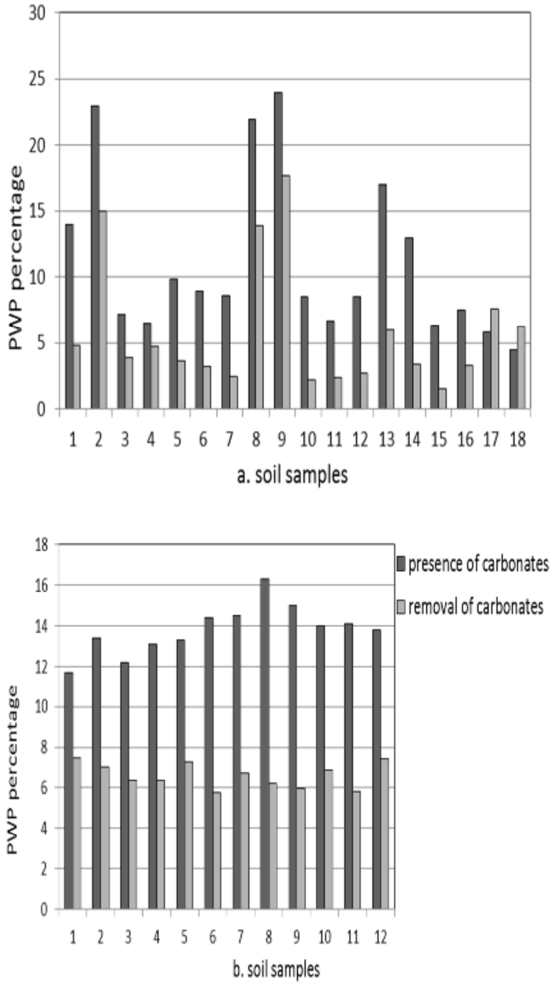

Fig. 6. Carbonates effect on PWP content in (a) some soil samples of four sugarcane-Agro-Industries and (b) Abadan region

The effect of carbonates was confirmed on these soil properties following the change in the particle size distribution after removal of carbonates and the decrease in the PWP in all studied samples. Therefore, validation of the equation between the clay content and water retention at PWP was used to estimate the amount of free carbonate clay [Clay % = 2.5(% water retained at -1500 kPa tension- % organic carbon)]. Carbonate-Free clay was used to determine the soil family class and also great groups of many soil orders. These validations were conducted in paired samples (i.e., samples before and after calcium carbonate removal). The results showed that compliance rates for key to soil taxonomy equation [the ratio of the percentage of water retained at PWP to the percentage of measured clay is ≤0.25 or ≥0.6 in half or more of the particle-size control sections or part of the particle-size control sections in strongly contrasting classes] in carbonate samples of the Abadan area, Haft-Tapeh, Karoon, Debal-Khozaie and Amir-Kabir were 58, 45, 57, 25 and 16%, respectively and in non-carbonated samples were 100, 90, 70, 75 and 100%.

According to the results, it seems that following the change in PSD, there is a decrease in water retention at PWP after carbonates removal in all samples. In most cases, the ratio of the percentage of water retained at -1500 kPa tension to the percentage of measured clay reduced and was placed at the range of 0.25 or less. Therefore, most of non-carbonate samples compared to carbonate samples are at valid range specified for the key equation to estimate the amount of clay. Also, the difference at compliance rates of samples from valid range specified for the equation of key to soil taxonomy, especially in samples containing carbonate, could be related to the different sample location and non-uniform distribution of carbonates in the soil particle size.

Validation of this equation expresses that in the Abadan region, and also Karoon and Haft Tapeh Agro-Industries, this equation can be reliably applied in order to estimate free carbonate clay in soils containing carbonate. However, given that this correlation was very low in non-carbonate soils, this equation is not valid in these soils.

Also, the clay content estimated by fitted equation [Clay % = (4.35*% water retained at -1500 kPa tension +35.3* % organic carbon)] has acceptable correlation with the amount of clay in the samples containing carbonate and this correlation is very low in non-carbonate samples. Therefore, application of these two equations for estimation of the amount of clay in Abadan, Karoon and Haft-Tapeh regions, in carbonate samples was greater than that of the non-carbonate samples. However, the correlation between estimated clay from key to soil taxonomy's equation and clay in carbonate samples is more than that of clay estimated from fitted equation. Therefore, key to soil taxonomy's equation can be used with greater confidence in carbonate soils.

Comparing the mean characteristics studied before and after carbonates removal illustrates the effect of carbonates on PSD and specific surface area changes (refer to particle size). As mentioned before, soil texture is the most important factor affecting moisture retention capacity at PWP. Therefore, carbonates removal can lead to variability and various correlations between the amounts of clay obtained from the equations in the presence or absence of carbonates. On the other hand, according to this study, positive effects can lead carbonate on moisture retention capacity at PWP to a higher correlation at clay obtained from the equations compared with measured clay content in the presence of carbonates.

Key to soil taxonomy's equation cannot be applied for Amir-Kabir and Debal-Khozaie due to low compliance of carbonate samples from valid range specified for this equation. However, clay content is higher in non-carbonate samples and PWP is lower compared to carbonate samples and, the water retained at -1500 kPa tension to the measured clay percentage ratio is lower in non-carbonate samples. Khattab and Al-Taie (2006) reported that the water holding capacity increased due to an increase in lime percentage. According to Keshavarzi et al. (2011) and Motallebi et al. (2011), by increasing the amount of carbonates in the soil, the amount of water increased at saturation, field capacity and permanent wilting. Therefore, non-carbonate samples were placed at valid range specified for the key to soil taxonomy's equation [the ratio of the percentage of water retained at -1500 kPa tension to the percentage of measured clay is 0.25 or less or 0.6 or more]. Comparing the estimated clay from these equations in non-carbonate samples showed that estimated clay from both of these equations has an acceptable correlation with clay in non-carbonate samples. Thus, according to these results, in Amir-Kabir and Debal-Khozaie Agro-Industries, the performance of these two equations is higher in non-carbonate samples. Despite the high correlation between estimated clay from these equations and clay content in non-carbonate samples, correlation between estimated clay from fitted equation and clay content in non-carbonate samples is higher than that of the key to soil taxonomy's equation. Therefore, fitted equation can be used with reasonable confidence for predicting non-carbonate clay in Amir-Kabir and Debal-Khozaie Agro-Industries. Organic carbon content is one of the important factors in key to soil taxonomy's equation which, due to low content of organic carbon in Khuzestan Province, has a negligible role in clay estimated from key to soil taxonomy's equation. Therefore, by assigning a higher coefficient to this factor, it is possible that the fitted equation in Khuzestan calcareous soils (especially in Amir-Kabir and Debal-Khozaie Agro-Industries with higher organic carbon content than that of other studied areas (Table 1)) improve its value in estimating clay content and therefore, is causing the higher correlation compared with key to soil taxonomy's equation.

CONCLUSIONS

According to the results, it seems that the presence of carbonate and its distribution in soil particle size will be able to explain the variability of soil properties; i.e., soil texture and water retained at PWP. Thus, its removal leads to a change in PSD in all the samples. Following the $CaCO_3$ removal, sand contents and textural class of 70% of samples were changed. Soil textures were finer than bulk samples in all samples.

Also, the results showed that the carbonates impacted on the obtained amount of clay in key to soil taxonomy's equation [Clay % = 2.5(% water retained at -1500 kP a tension - % organic carbon)] by affecting the amount of clay content and water retained at -1500 kP a tension. This equation has high reliability in carbonate samples of Abadan and Karoon and Haft-Tape Agro-Industries but, it is not valid in non-carbonate samples in these areas. Based on these results, the new equation was fitted [Clay % = (4.35*% water retained at -1500 kPa tension +35.3* % organic carbon)] so that it has high reliability for carbonate samples in these areas but it is not valid in non-carbonate samples. However, key to soil taxonomy's equation and our fitted equation in this study were invalid, in the prediction of clay content in carbonate samples in Amir-Kabir and Debal-Khozaie Agro-Industries. But, predicted clay content has high reliability from these two equations in non-carbonate samples. The correlation was higher between clay content predicted by the fitted equation and clay content in non-carbonate samples compared with clay obtained from key to soil taxonomy's equation. Thus, the fitted equation application to estimate non- carbonate clay content in soil family class and lots of groups of many soil orders was recommended.

Therefore, the presence of carbonate in soils not only impacted on particle size distribution but also, due to water retention control and water infiltration, influenced hydraulic properties, soil structure and soil expansion. The $CaCO_3$ affects soil properties, directly or indirectly, as a consequence of ecological interpretation, classification, and management decisions. We recommend that soil samples in calcareous soils analyzed for PSD be pretreated for $CaCO_3$, because in the presence of CaCO3, soil classification may be compromised.

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تحقیقات کشاورزی ایران (۱۳۹۶) ۳۶(۲) ۷۱-۸۰

مطالعه توزیع اندازه‌ای ذرات کربنات کلسیم و اثرات آن بر برخی ویژگی‌های خاک‌های استان خوزستان

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واژه های کلیدی:
رس بدون کربنات
رده‌بندی خاک
نگهداشت آب

چکیده- این مطالعه با هدف مطالعه توزیع اندازه‌ای کربنات‌ها (PSD) در خاک‌ها و اثرات آن بر برخی ویژگی‌های خاک‌های آهکی استان خوزستان انجام شده است. نمونه‌های خاک (۷۲ نمونه) از مناطق مختلف جمع‌آوری شد. به منظور ارزیابی اثر کربنات‌ها بر میزان نگهداشت آب در فشار ۱۵۰۰- کیلوپاسکال و توزیع اندازه‌ای ذرات، این ویژگی‌ها قبل و بعد از حذف کربنات کلسیم تعیین، اندازه‌گیری شدند. بر اساس نتایج، حذف کربنات کلسیم منجر به تغییراتی در توزیع اندازه‌ای ذرات در تمامی نمونه‌های مورد مطالعه و همچنین تغییر کلاس بافتی ۷۰ درصد از این نمونه‌ها شد. در منطقه آبادان کربنات‌ها بیشتر در اندازه‌ی رس و سیلت و در سایر مناطق در اندازه‌ی سیلت و شن تجمع داشتند. همچنین، ارزیابی نگهداری رطوبت در نقطه پژمردگی دائم (PWP) نشان داد که این ویژگی پس از حذف کربنات‌ها در تمامی نمونه‌ها کاهش یافته است. به دنبال این تغییرات، صحت‌سنجی رابطه‌ی کلید رده‌بندی خاک [درصد رس=۲/۵(درصد نگهداشت آب در مکش ۱۵۰۰- کیلوپاسکال- درصد کربن آلی)]، در خاک‌های آهکی استان خوزستان نشان داد که این رابطه می توان را با اطمینان بالایی در خاک‌های آهکی مناطق آبادان و کشت و صنعت‌های نیشکر کارون و هفت تپه به کار برد. با وجود این، این رابطه در کشت و صنعت‌های امیرکبیر و دعبل خزاعی معتبر نیست. رابطه‌ی برازش داده شده‌ی ما[درصد رس=۲/۵(۴/۳۵×درصد نگهداشت آب در مکش ۱۵۰۰- کیلوپاسکال-۳۵/۳×درصد کربن آلی)] در پیش‌بینی میزان رس در نمونه‌های غیرکربناته صحت بالایی نشان داد. نتایج فوق نشان می‌دهد که حضور کربنات‌ها و توزیع آن در اجزای اندازه‌ای خاک‌ها عامل مهمی در تغییرپذیری ویژگی‌های خاک در مناطق خشک و نیمه خشک است.