Intrinsic Problems In Determination Of Soil Texture In Calcareous Soils Of Arid Zones

Mozna A. Ahmed, Ibrahim M.M.M, Suleiman, H. Nasser, Dafalla, M. S, Ibrahim S. Ibrahim

Abstract: This study aimed at studying the effect of removal of $CaCO_3$ on the texture of the soil profile and that of the control section in some Aridisols of the Sudan. Sixty soil profiles were sampled from Shendi area (latitude16º36' and longitude 33º 48'), River Nile State, Sudan. These soils were analyzed for $CaCO_3$ and 20 of these profiles were found to be of relatively appreciable calcareousness and were, therefore, selected for this study. The following three weighted soil textures were determined: (1) before any removal of the $CaCO_3$ (Texture1); (2) after the removal of $CaCO_3$ (Texture2); (3) after amending the texture by adding the clay sized CaCO3 to the silt fraction (Texture 3). Statistical analysis revealed significant differences among soil separates in the three textures except between clay of T2 and clay of T3 and among sand fractions in the three textures. That was not unexpected because the first texture included both mineral separates plus their equivalent size of $CaCO_3$, the second texture included only the mineral separates in complete absence of $CaCO_3$ while texture 3 was an amended texture. The change in the textural class amounted to 72% of the profiles. Statistical analysis in the weighted texture of the control section revealed that this texture was not affected except in two profiles. That could be attributed to the fact that the clay content of the soils of the study area did not fall at or near the boundary between any two major textural classes used in the Soil Taxonomy. The size of the $CaCO_3$ was found in the order of clay size> silt size >sand size.

Index words: calcareous soils, soil texture, arid zones, weighted texture, control section, $CaCO_3$, Soil Taxonomy

1 INTRODUCTION

Soil texture is an important soil property that relates soil physical properties to chemical reactions, structure of the plant community, ecological potential and management of resources. It also, greatly influences soil hydraulic properties, water movement and retention through the profile [10]. Soil texture is used to describe the relative proportion of different grain sizes of mineral particles in a soil. Particles are grouped according to their size into what are called soil separates. These separates are typically named clay, silt, and sand [8] [7]. Soil texture classification is based on the fractions of soil separates present in a soil. The USDA soil texture triangle is a diagram often used to figure out a soil textural class of the soil. Soil separates are specific ranges of particle sizes. In the United States, the smallest particles are clay particles and are classified by the USDA as having diameters of less than 0.002 mm. The next smallest particles are silt particles and have diameters between 0.002 mm and 0.05 mm. The largest particles are sand particles and are larger than 0.05 mm in diameter. Furthermore, large sand particles can be described as very coarse to coarse, intermediate as medium, and the smaller as fine and very fine [9]. Other countries have their own particle size classifications. Soils of the arid and semi-arid are subjected to more physical weathering by insolation or freezing and sowing and less chemical weathering due to limited amount of water that causes chemical weathering. Therefore, these soils are likely to be related in their properties to the local rocks(parent materials) particularly at the early stages of soil formation in residual soils (non-transported soils). They are, as well, usually calcareous if they have developed (or still are developing) on calcareous parent material (e.g. limestone) [2] [1] and/or through precipitation of authigenic carbonates of calcium are only subjected to seasonal changes following moisture availability and moisture gradient according to the reaction:

$$CaCO_3 + H_2O + CO_2 \rightleftharpoons Ca(HCO_3)_2$$

When there is moisture in the soil profile (i.e. during the very short rainy season) the moisture gradient would be down the profile and the above reaction will proceed to the right i.e. towards the formation of the soluble $Ca(HCO_3)_2$. When temperatures get high during the long summers, for example and since the soil systems under arid climates are closed ones, the moisture gradient is reversed upwards and when water and/or CO2 are lost the above reaction will reverse to the left i.e. towards the precipitation of sparingly soluble $CaCO_3$[5] [6]. $CaCO_3$ is a cementing agent that binds the soil particles together. Therefore, in the determination of the soil texture clay particles could be cemented to form particles within the silt size fraction or conversely, clay sized $CaCO_3$ is present and will be counted as clay chemically and physically if $CaCO_3$ is not removed prior to the determination of soil texture. The NRCS of USDA recommended that the clay sized $CaCO_3$ should be estimated and added to the silt fraction if the proper and more realistic texture of the soil was to be determined. When $CaCO_3$ is removed the solubilized salts will increase the electrical conductivity of the soil suspension. If this salinity is not lowered this will cause flocculation of the soil when it is supposed to be highly dispersed. Therefore, this research aims at scanning the effect of removal of $CaCO_3$ and addition of the clay sized $CaCO_3$ to the silt fraction on soil texture. An equally important aim was to see the effect of the determination of the soil texture in this way on the classification of the soil at the family level according to the American System of Soil classification [4]

2 MATERIAL AND METHODS

Sixty soil profiles were sampled from soils around Shendi Area (Latitude16º36' and longitude 33º 48'), River Nile State, Sudan. These soils formed and still are forming under semi –desert conditions and are, therefore, classified as Aridisols according to the soil taxonomy [4]. Calcium

- *Mozna A. Ahmed, Ibrahim M.M.M, Suleiman, H. Nasser, Dafalla, M. S, Ibrahim S. Ibrahim*
- *Department of soil and Environment Sciences, Fac. of Agric. U of K, Sudan*

carbonate was determined in all soil samples usingcalcimeter (model ARE No. 08.53. Then the twenty (out of the 60) soil profiles - of appreciable calcareousness - were selected for this study. The soil texture was determined in each sample before removal of the calcium carbonate using the hydrometer method [3]. These values were used to calculate the weighted texture (texture of the top 100 cm) of each soil profile considering the thickness of the soil horizon and the percentage of the soil separates in that horizon. This texture will be referred to as texture 1 (T1). Then each soil sample was made into suspension with a little amount of distilled water. Then to each suspension a calculated amount of mille equivalent of HCl was added depending on the % $CaCO_3$ in the soil sample. An additional 10 me of HCl were added to each suspension to ensure complete destruction of CaCO3. Each soil: water suspension was transferred to 1.2 L sedimentation Jar, made to volume with distilled water and electrical conductivity of the suspension (EC susp.) was measured in dSm-1 using an EC meter (Model Con222). All soil suspensions were found to be saline. Therefore, the suspensions were left to settle and the clear supernatant liquids were decanted, otherwise centrifugation was done beforedecantation. This step of washing with water and siphoning off or decantationof the clear supernatant liquids was repeated until the EC of each suspension was brought down to values less than 4dSm-1. Finally the soil samples were dispersed chemically with calgon and mechanically by a dispersion machineand texture was determined in each sample using hydrometer method [3]. This gave texture 2 (T2) which contained only mineral fractions with no $CaCO_3$of the size of the different separates. Then subtracting the percent of each soil separates of texture 2 from percent of the corresponding separates of texture 1 gave the % $CaCO_3$ in the size of each of the three separates. Now calculating the percent of the clay sized $CaCO_3$ (clay of T1minus clay of T) and adding this value to % silt of texture 1 (with sand remaining more or less constant) gave texture 3 (T3). Then the weighted textural classes of all soil profiles were calculated taking into account the depth of the each horizon within the profile and the percent of each soil separate in that horizon. In the same way the texture of the control section (a diagnostic criterion used as a differentiating characteristic at the family level in the Soil Taxonomy) was also calculated. Statistical comparison was then made among soil separates of the soil samples in the three textures of all soil profiles. That was used to give an idea about the effect of removal of $CaCO_3$ in changing the textural class of the soil and/or the classification of the soil at the family level. Finally the contributions $CaCO_3$ in the size of each soil separate to the total $CaCO_3$ were calculated

3 RESULTS AND DISCUSSION

The three soil textures T1, T2 and T3 are presented in tables 1, 2 and 3, respectively. The three separates clay, silt and sand in the three textures are listed separately in Table 4.Figs (1a) to (1e) show the content of the three soil separates in the three soil textures in five soil profiles selected to represent the full range of $CaCO_3$ in the study area.

Table 1: *Soil texture before the removal of $CaCO_3$ (T1)*

Prof. No.	% Clay	% SILT	%VFS	%FS	%MS	%CS	%VCS	$CaCO_3$%	Textur Class
P21	25.82	8.54	10.38	17.02	16.36	15.98	5.81	7.7	SCL
P22	29.76	14.52	9.86	11.49	14.43	13.01	6.93	16	SCL
P23	33.06	11.15	8.68	14.24	13.69	13.37	4.86	15.15	SCL
P24	35.51	9.19	10.40	10.19	16.99	13.75	4.47	13	SC
P25	33.71	12.22	8.28	13.58	13.06	12.76	4.63	14.1	SCL
P26	37.01	11.80	8.71	15.84	8.57	15.51	3.07	10.08	SC
P27	29.43	14.73	4.25	6.97	6.70	6.55	31.37	6.94	SCL
P28	26.59	17.68	7.63	10.18	18.01	15.72	5.37	8.58	C
P29	30.84	14.74	8.62	14.14	13.58	13.28	4.82	7.77	C
P30	31.38	14.74	8.70	14.24	13.69	13.38	4.87	8.97	C
P31	30.54	12.47	9.06	14.85	14.28	13.95	5.07	9.19	SC
P32	30.23	11.38	9.29	15.23	14.64	14.29	5.19	8.99	SCL
P33	33.83	11.84	6.53	22.90	11.70	9.75	4.54	9.7	SCL
P34	31.26	16.00	8.50	13.92	13.38	13.08	4.75	8.48	SC
P35	30.30	14.68	8.71	14.29	13.74	13.42	4.87	6.88	SC
P36	31.18	12.19	9.13	14.97	14.38	14.05	5.10	6.98	SC
P37	33.96	12.08	8.70	14.25	13.70	13.39	4.86	7.57	SC
P38	30.15	14.74	8.74	14.31	13.75	13.44	4.88	7.53	SC
Total	**564.56**	**234.69**	**154.18**	**252.61**	**244.64**	**238.68**	**115.46**	**173.61**	
Average	**31.36**	**13.04**	**8.57**	**14.03**	**13.59**	**13.26**	**6.41**	**9.65**	
SE	**1.26**	**1.05**	**0.62**	**1.45**	**1.18**	**0.96**	**2.80**	**1.30**	

Table 2: *Soil texture after removal of $CaCO_3$ (T2)*

Prof. No.	% clay	% silt	%VFS	%FS	%MS	%CS	%VCS	$CaCO_3$%	Text.
P21	19.70	7.18	10.24	13.68	17.00	16.96	7.47	7.7	SL
P22	26.80	7.28	7.77	10.37	12.89	12.86	5.67	16	SCL
P23	19.73	8.69	9.16	12.23	15.19	15.16	6.68	15.15	SL
P24	25.70	6.76	8.19	11.30	14.50	13.56	5.97	13	SCL
P25	29.34	5.25	8.86	11.17	12.59	13.57	5.01	14.1	SCL
P26	30.99	8.60	10.22	11.08	12.53	11.51	5.51	10.08	SCl
P27	27.21	10.28	9.93	12.55	13.15	13.13	6.78	6.94	SCL
P28	24.22	11.12	9.69	12.27	14.76	12.74	6.61	8.58	SCL
P29	25.01	12.11	8.40	11.82	14.76	12.74	7.62	7.77	SCL
P30	26.68	10.13	9.00	10.90	13.80	14.20	6.30	8.97	SCL
P31	24.33	10.21	9.31	10.36	14.23	14.86	7.33	9.19	SCL
P32	25.01	9.33	7.76	12.45	15.10	13.00	8.66	8.99	SCL
P33	26.49	9.21	8.40	11.24	14.73	12.70	7.60	9.7	SCL
P34	27.34	11.09	7.98	10.40	15.29	12.89	6.53	8.48	SCL
P35	26.22	12.13	8.97	11.65	14.23	13.21	6.95	6.88	SCL
P36	25.56	11.01	8.00	13.68	13.70	15.25	5.84	6.98	SCL
P37	27.22	10.32	8.80	11.44	14.20	14.97	5.48	7.57	SCL
P38	24.87	12.54	7.83	11.46	15.04	13.97	6.04	7.53	SCL
Total	**462.42**	**173.24**	**158.51**	**210.04**	**257.69**	**247.28**	**118.05**	**173.61**	
Average	**25.69**	**9.62**	**8.81**	**11.67**	**14.32**	**13.74**	**6.56**	**9.65**	
SE	**1.23**	**0.90**	**0.37**	**0.44**	**0.49**	**0.58**	**0.42**	**1.30**	

Table 3: *Amended * soil texture (T3)*

Prof. No.	%Clay	%Silt	%VFS	%FS	%MS	%CS	%VCS	CaCO3%	Text.classs
P21	19.7	14.66	10.38	17.02	16.36	15.98	5.81	7.7	SL
P22	26.8	17.48	9.86	11.49	14.43	13.01	6.93	16	SCL
P23	19.73	24.48	8.68	14.24	13.69	13.37	4.86	15.15	SL
P24	25.7	19.005	10.4	10.19	16.99	13.75	4.47	13	SCL
P25	29.34	16.59	8.28	13.58	13.06	12.76	4.63	14.1	SCL
P26	30.99	17.82	8.71	15.84	8.57	15.51	3.07	10.08	SCL
P27	27.21	16.95	4.25	6.97	6.7	6.55	31.37	6.94	SCL
P28	24.22	20.05	7.63	10.18	18.01	15.72	5.37	8.58	SCL
P29	25.01	20.57	8.62	14.14	13.58	13.28	4.82	7.77	SCL
P30	26.68	19.44	8.7	14.24	13.69	13.38	4.87	8.97	SCL
P31	24.33	18.68	9.06	14.85	14.28	13.95	5.07	9.19	SCL
P32	25.01	18.35	9.29	15.23	14.64	14.29	5.19	8.99	SCL
P33	26.49	19.18	6.53	22.9	11.7	9.75	4.54	9.7	SCL
P34	27.34	19.92	8.5	13.92	13.38	13.08	4.75	8.48	SCL
P35	26.22	18.76	8.71	14.29	13.74	13.42	4.87	6.88	SCL
P36	25.56	17.81	9.13	14.97	14.38	14.05	5.1	6.98	SCL
P37	27.22	18.82	8.7	14.25	13.7	13.39	4.86	7.57	SCL
P38	24.87	20.02	8.74	14.31	13.75	13.44	4.88	7.53	SCL
Total	462.42	338.59		252.61	244.64	238.68	115.46	173.61	
Average	25.69	18.81		14.03	13.59	13.26	6.41	9.65	
SE	1.23	0.9	154.18	1.45	1.18	0.96	2.8	1.3	
			8.57						

Amended means addition of the clay sized $CaCO_3$ to the silt fraction

Table 4: *The three soil separates in the three textures in all soil profiles*

Prof No.	Clay T1	Clay T2	Clay T3	Silt T1	Silt T2	Silt T3	Sand T1	Sand T2	Sand T3
Prof. 21	25.82	19.7	19.7	8.54	7.18	14.66	65.54	65.35	65.54
Prof. 22	29.76	26.8	26.8	14.52	7.28	17.48	55.72	49.56	55.72
Prof. 23	33.06	19.73	19.73	11.15	8.69	24.48	55.84	55.43	54.84
Prof. 24	35.51	25.7	25.7	9.19	6.76	19	55.8	54.27	55.8
Prof. 25	33.71	29.34	29.34	12.22	5.25	16.59	55.23	51.2	52.3
Prof. 26	37.01	30.99	30.99	11.8	8.6	17.82	51.7	50.85	51.7
Prof. 27	29.43	27.21	27.21	14.73	10.28	16.95	55.84	55.57	55.84
Prof. 28	26.59	24.22	24.22	17.68	11.12	20.05	56.92	56.08	56.92
Prof. 29	30.84	25.01	25.01	14.74	12.11	20.57	54.45	55.22	54.45
Prof. 30	31.38	26.68	26.68	14.74	10.13	19.44	54.88	54.22	54.88
Prof. 31	30.54	24.33	24.33	12.47	10.21	18.68	57.2	56.27	57.2
Prof. 32	30.23	25.01	25.01	11.38	9.33	18.35	58.64	56.8	58.64
Prof. 33	33.83	26.49	26.49	11.84	9.21	19.18	55.41	54.78	55.41
Prof. 34	31.26	27.34	27.34	16	11.09	19.92	53.63	53.09	53.63
Prof. 35	30.3	26.22	26.22	14.68	12.13	18.76	55.03	55.01	55.03
Prof. 36	31.18	25.56	25.56	12.19	11.01	17.81	57.63	56.45	57.63
Prof. 37	33.96	27.22	27.22	12.08	10.32	18.82	54.9	54.89	54.9
Prof. 38	30.15	24.87	24.87	14.74	12.54	20.02	55.13	54.66	55.13
Total	**564.56**	**462.42**	**462.42**	**234.69**	**173.24**	**338.59**	**1009.49**	**989.7**	**1005.56**
Average	**31.36**	**25.69**	**25.69**	**13.04**	**9.62**	**18.81**	**56.08**	**54.98**	**55.86**
SE	**1.26**	**1.23**	**1.23**	**1.05**	**0.9**	**0.9**	**1.26**	**1.46**	**1.32**

Figure (1). *The three textures in some soil profiles:*

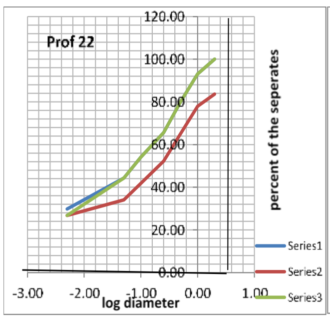


Fig. 1*(a) Profile2*

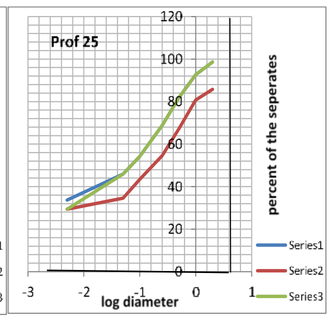


Fig. 1*(b) Profile 25*

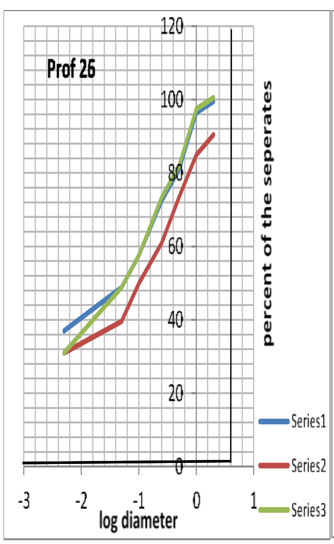


Fig. 1*(c) Profile 22*

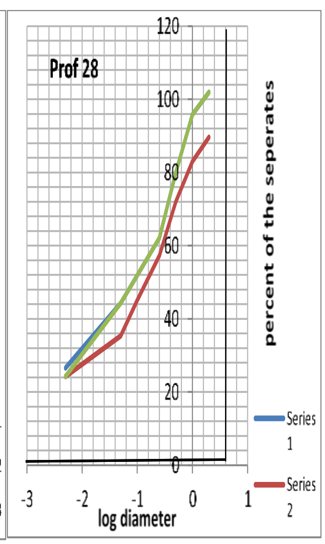
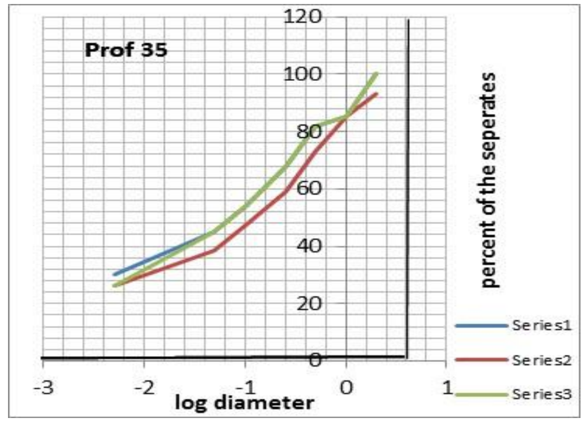


Fig. 1*(d) Profile 28*



It can be seen from tables 1, 2, 3, and 4 and figures 1a to 1e that the three soil separates are different in the three textures. When analysis of variance was performed in the data of each soil separate in three textures (presented in Table 4), differences among the separates in the three textures were found to be statistically significant ($p = 0.001$) except for differences between clay T2 and clay T3 which were not significant as well as those among sand separates in the three textures (see Table 4). Table 5 presents the textural class in the three textures in all profile. It can be seen from this result that from texture 1 to texture, there was a change in the textural class in 13 out of the 18 profile (72%). However texture 2 and texture 3 were the same.

Table 5: *The textural classes in the three textures in all profiles*

Profile number	Textural class		
	T1	T2	T3
P21	SCL	SL	SL
P22	SCL	SCL	SCL
P23	SCL	SL	SL
P24	SC	SCL	SCL
P25	SCL	SCL	SCL
P26	SC	SCL	SCL
P27	SCL	SCL	SCL
P28	C	SCL	SCL
P29	C	SCL	SCL
P30	C	SCL	SCL
P31	SC	SCL	SCL
P32	SCL	SCL	SCL
P33	SCL	SCL	SCL
P34	SC	SCL	SCL
P35	SC	SCL	SCL
P36	SC	SCL	SCL
P37	SC	SCL	SCL
P38	SC	SCL	SCL

The significant differences in the % of the different soil separates among the three textures were not unexpected since these textures consisted of: the mineral separates + the $CaCO_3$ falling within the size of those separates (T1), or only the mineral separates (T2) with no $CaCO_3$, or the different separates after addition of the % clay sized $CaCO_3$ to the % silt (T3). This is further supported by the change in the weighted textural class of the soil profiles (Table 5). Indeed, the removal of $CaCO_3$ caused change in texture of 13/18 (i.e. change in texture 72% of the profiles). The change was from SCL to SL; SC to SCL; C to SCL (see table 5). This agreed with [7] 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 ($CaCO_3$) 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. The lack of significance in clay 2 and clay 3 could be explained by the fact that they both estimated only the clay mineral in these soil samples (in the absence of $CaCO_3$).On the other hand lack of significant difference among the sand fractions in the three textures could be explained by the fact that the contribution of the sand sized to the total $CaCO_3$ was minimal among the 3 soil separates (see Table 8). Therefore, the % sand was not significantly affected by the pretreatment of the soil samples with HCl. The vertical gaps in the figures 1a - 1d between graph lines of texture 1 on one hand and that of texture 2 on the other hand represent the $CaCO_3$ in the size of the different soil separates. However, the difference between the last pints in the summation curve represents the % of the total $CaCO_3$ in the soil samples. The texture of the control section is a diagnostic characteristic at the family level of the American System of soil Classification (Soil Taxonomy). The texture of the control section in the study area can fall in any of five (of the eleven classes in the system) textures depending on % clay and whether the % fine sand or coarser fraction is greater or less than 15%. These five textures are fine, fine silty, coarse silty, fine loamy and coarse loamy according to Table 6 below[4].

Table 6: *Limits in percent clay and percent sand that determine the texture of the control section (1)*

Clay / Sand	% clay (for silty and loamy textures)		% Clay (for clayey textures)	
	< 18 %	>18 % - <35%	.35 – 59 %	>59
.> 15 % fine sand or coarser including gravel	Coarse loamy	Fine loamy	Fine	Very fine
<15 % fine sand or coarser including gravel	Coarse silty	Fine silty		

(1)This texture is used as a differentiating criterion among classes at the family level in theSoil Taxonomy. Accordingly the three weighted textures of the control section were calculated for all soil profiles in the same way as that of the whole soil profile. Table 7 presents these textural classes.

Table 7: *Textural classes of the control section in the three textures*

Textural classes of the control section for the three textures according to the Soil Taxonomy			
Profile Number	Texture 1	Texture 2	Texture3
P21	Fine loamy	Fine loamy	Fine loamy
P22	Fine loamy	Fine loamy	Fine loamy
P23	Fine loamy	Fine loamy	Fine loamy
P24	Fine	Fine loamy	Fine loamy
P25	Fine loamy	Fine loamy	Fine loamy
P26	Fine	Fine loamy	Fine loamy
P27	Fine loamy	Fine loamy	Fine loamy
P28	Fine loamy	Fine loamy	Fine loamy
P29	Fine loamy	Fine loamy	Fine loamy
P30	Fine loamy	Fine loamy	Fine loamy
P31	Fine loamy	Fine loamy	Fine loamy
P32	Fine loamy	Fine loamy	Fine loamy
P33	Fine loamy	Fine loamy	Fine loamy
P34	Fine loamy	Fine loamy	Fine loamy
P35	Fine loamy	Fine loamy	Fine loamy
P36	Fine loamy	Fine loamy	Fine loamy
P37	Fine loamy	Fine loamy	Fine loamy
P38	Fine loamy	Fine loamy	Fine loamy

It is clear from table (7) that the textural class of the control section was not affected much by the removal of $CaCO_3$. There was change in the texture of the control section in only 2 of the soil profiles (P24 and P26). The lack of difference in the texture classes of the control section could be due to the fact that clay content of the majority of the soils before removal of $CaCO_3$ was neither near nor at the border line between any two textural classes (i.e. clay content of 18%, 35% or 59% see Table 6). The difference in texture recorded for profiles 24 and 26 was possibly because the clay content of these profiles was 35% and 37%, respectively, both of which were at the border line (35%, in Table 6 above) between loamy and silty texture on one side and clayey texture on the other. Another reason could be due to the fact that all soil profiles had > 15% of fine sand or coarser (i.e. they were all loams) and that the clay content in all soil profiles (with exception of P24 and P26) ranged between > 18% and less than <35% i.e. 18% < clay content of all soil samples < 35% (i.e. they were in the majority fine). Therefore, they were in the majority fine loam. The order of contribution of the $CaCO_3$ was found in the following order clay > silt > sand. This disagreed with [7], who found a reverse order of contribution of the soil separates to the total$CaCO_3$ in the soil i.e. Sand > silt > clay. The result of this study could be explained by the fact that during the very short period of the rainy season (few showers) of the semi - desert climate of the study area the very limited moisture in the soil profile dissolves part of the $CaCO_3$, most likely the very fine particles, to form soluble $Ca(HCO_3)_2$. When the soil dries up the moisture gradient becomes upwards and the reaction is reversed in the direction of precipitation of $CaCO_3$, most likely, in the colloidal size (clay size) since the reaction is very swift and hence after a very long period of time the clay sized $CaCO_3$ will dominate the $CaCO_3$ fraction in the soil. Table 8 presents the difference in % weight (T2-T1) in each of the three soil separates due to treatment of the soil with HCl (removal $CaCO_3$). This difference represented the proportion of $CaCO_3$ in the size of eachsoil separate.When these values were expressed as a percent of the total

$CaCO_3$, they gave the contribution of size of each soil separate to the total $CaCO_3$.Statistical analysis revealed highly significant differences ($p = 0.001$) among contribution of these separates. The order of contribution was found in the following order Clay > silt > sand. This disagreed with [7], who found a reverse order of contribution of the soil separates to i.e. sand >silt >clay.

Table 8:*$CaCO_3$ in the size of the different soil separates and its contribution to the total $CaCO_3$ of the soil.*

Profile No.	C1 - C2*	% Cont. of clay sized $CaCO_3$ to total $CaCO_3$**	Z1 - Z2*	% Cont. of silt sized $CaCO_3$ to total $CaCO_3$**	S1 -S2*	% Cont. of sand sized $CaCO_3$ to the total $CaCO_3$**	%$CaCO_3$
Prof. 21	6.12	79.48	1.36	17.66	0.19	2.47	7.70
Prof. 22	2.96	18.49	7.24	45.26	6.16	38.51	16.00
Prof. 23	13.33	87.97	2.46	16.24	0.41	2.71	15.15
Prof. 24	9.81	75.48	2.43	18.69	1.53	11.77	13.00
Prof. 25	4.37	31.02	6.97	49.43	4.03	28.58	14.10
Prof. 26	6.02	59.72	3.20	31.75	0.85	8.43	10.08
Prof. 27	2.22	32.05	4.45	64.12	0.27	3.89	6.94
Prof. 28	2.37	27.62	6.56	76.42	0.84	9.79	8.58
Prof. 29	5.83	75.03	2.63	33.87	-0.77	-9.91	7.77
Prof. 30	4.70	52.40	4.61	51.42	0.66	7.36	8.97
Prof. 31	6.21	67.57	2.26	24.58	0.93	10.12	9.19
Prof. 32	5.22	58.06	2.05	22.80	1.84	20.47	8.99
Prof. 33	7.34	75.64	2.63	27.11	0.63	6.49	9.70
Prof. 34	3.92	46.23	4.91	57.90	0.54	6.37	8.48
Prof. 35	4.08	59.30	2.55	37.02	0.02	0.29	6.88
Prof. 36	5.62	80.52	1.18	16.94	1.18	16.91	6.98
Prof. 37	6.74	89.04	1.76	23.29	0.01	0.13	7.57
Prof. 38	5.28	70.12	2.20	29.24	0.47	6.24	7.53
Total	**102.14**	**1085.74**	**61.45**	**643.75**	**19.79**	**170.61**	**173.61**
Average	**5.67**	**60.32**	**3.41**	**35.76**	**1.10**	**9.48**	**9.65**
SE	**1.18**	**9.65**	**0.86**	**7.96**	**0.72**	**4.96**	**1.30**

**These columns present the % of $CaCO_3$ in the size of each soil separate (C=clay, Z=silt, S=sand).*
*** These columns represent the % contribution of the $CaCO_3$ in the size of each soil separates to the total $CaCO_3$.*

REDCOMMENDATION:

It could be recommendedthat:

1) $CaCO_3$ should be removed from calcareous soil prior to determination of soil texture otherwise the soil is likely to have a faulty texture.
2) Addition of HCl to the soil will, most likely, raise the EC value of the soil: water suspension. Therefore, it is highly recommended to check soil salinity and to lower EC of the suspension to values of less than 4dSm-1 before proceedings to disperse the soil for determination of texture.
3) Clay sized $CaCO_3$ must be determined and added to the silt fraction before deciding on the texture of the soil.
4) Further work is needed to cover soils under different climatic zones in the Sudan e.g. desert, arid, semi-arid and dry sub-humid zones.

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