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EFFECTS OF CALCIUM CARBONATE ON THE ERODIBILITY OF SOME CALCAREOUSE SOILS BY WATER EROSION

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ABSTRACT

The behavioral changes in soil erodibility factor (K_{USLE}) due to Ca-carbonate content were determined in four calcareous soils located at northern Iraq. The procedure for K_{USLE} determination in these soils was carried out before and after carbonate removal by using a special nomograph and modified equation given by Wischmeier and Smith(1978). The results indicate that the changes in soil Ca-carbonate content caused a changes in soil erodibility factor (K_{USLE}).Soil texture modification due to Ca-carbonate content was the main factor affecting soil erodibility. Other unconsidered factors, such as soil permeability and structure ,could also have contributed to the remaining variability in K_{USLE}. Regression analysis of data showed that about 87.8 % of the variability in K_{USLE} could be explained by a high Ca-carbonate content, as it was in these soils. This relationship give us a knowledge to make a correction for the calculated erodibility factor K_{USLE} of calcareous soils to distinguish it from that of non-calcareous soils.

.INTRODUCTION

The standard model for most erosion assessment and conservation planning is the empirically based USLE (Universal Soil Loss Equation). The USLE is composed of six factors to predict the long-term average annual soil loss (A) due to water erosion (*M*g ha^{-1} per year),. The equation includes the rainfall erosivity factor (R), the soil erodibility factor (K), the topographic factors (L and S) and the cropping management factors (C)and the support practice factor (P). This is represented in the universal soil loss equation as (Renard *et al*. 1997) :

$$A = RKLSCP \qquad \text{--(1)}$$

In this equation, the concept of soil erodibility is introduced as the K factor, which was defined as the average rate of soil loss per unit of rainfall erosion index EI_{30} from a control plot (Standard plot). A control plot would be 22.1m long with a 9% uniform slope and cultivated continuous fallow plot.(Refahi,1997).Thus, the K_{USLE} factor for a specific soil could only be determined from long-term observations of soil loss (A)and rainfall erosivity factor (R), being a product of total kinetic rainfall energy (E)and its maximal intensity during 30 minutes(I_{30}) from a unit plot (Farzin.*et al* 2010) as in the following;

$$A=RK \rightarrow K = A / R = A / E * I_{30} \qquad \text{--------------------------------(2)}$$

To allow estimation of soil erodibility K_{USLE} from measurable soil properties, the soil erodibility nomograph was published in the early 1970s (Wischmeier *et al.* 1971). Factors which affect soil erodibility K_{USLE} are generally categorized into two groups. One relates to the physical characteristics of soil which are easier dealt with compared to the second one which is related to farming management or conservative actions.(Rousseva 2001; 2002a Farzin.*et al* 2010). The soil erodibility factor K_{USLE} can be approximated from a nomograph if this information is known.

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In computing the K_{USLE} factor in the Universal Soil Loss Equation (USLE), Wishmeier and Smith (1978) do not take into consideration the Ca-carbonate content, which is considered as the most important constituent of calcareous soils. The proportion distribution of this component may affected many soil physical properties that related to nomographic expression for estimating K_{USLE} "especially particle size distribution ,soil structure and permeability" .

Proper evaluation of soil erodibility factor (K_{USLE}) is of great importance in assessment of soil water erosion and has important implication for soil conservation and planning for agricultural land uses**.** For this reason, the present study was planned to quantify the behavioral changes in soil erodibility factor K_{USLE} (obtained form the nomograph and equations given by Wischmeier and Smith) due to presence of Ca-carbonate in calcareous soils. Furthermore, this paper provides us how the changes in soil physical properties due to Ca-carbonate presence and how it relates to soil erodibility .

MATERIALS AND METHODS

Four calcareous soils from four sites (Mosul , Qiara , Hammam Alil and Telkef,), located at northern Iraq were sampled to study the effect of Ca-carbonate on the soil erodibility factor (K_{USLE}) of the Universal Soil Loss Equation (USLE). Composite surface soil samples (0-20Cm) with three replicate were collected from each sit. The four soils were chosen in such away that differing in soil Ca-carbonate content, formed with the same conditions of the same great group of Calciorthids (according to US taxonomy of 1975) or HaploCalcids great group (according to US taxonomy of 2006). The moisture regimes are markedly aridic and soils are mostly alkaline, with low organic matter contents and a dominant clay to loam texture. Data of these properties are given in Table 1, which determined by using standard methods described by Klut (1986).

Table (1) . Basic physical and chemical properties of the four tested soils.

Soil* Symbol	Site	Clay	Silt	Sand	Texture	pH	EC	$CaCO_3$
		%					dS/m	%
Ca-20	Mosul	15.0	55.0	30.0	SiL	7.6	0.4	20
Ca-26	Qiara	22.0	34.0	44.0	L	7.8	0.4	26
Ca-33	Hammam-Alil	25.6	40.0	34.4	CL	7.7	0.6	33
Ca-38	Telkef	33.6	24.4	42.0	SiCL	7.4	0.3	38

*Symbol represent the percent of Ca-carbonate in soil

Determination of soil erodibility factor K_{USLE} was carried out before and after Ca-carbonate removal. Removal of Ca-carbonate from the tested soils was carried out by treating the samples with 0.1N HCl for two weeks up to complete removal of Ca–carbonate. Determination of soil erodibility factor K_{USLE} of the two treatments (with and without Ca-carbonate) was calculated after determination of four soil–related parameters ;

1- Modified sand fraction (0.1–2mm),and very fine sand fraction(0.1- 0.05mm) , were determined by wet sieving. Clay fraction (less than 0.002 mm) and silt fraction (0.002 – 0.05 mm), present in the soil were determined in each sample by the pipette method.. The weight of each fraction was measured and converted into a percentage of the soil sample.

2- Organic matter was determined using Walky and Black method..

3- Unsaturated soil hydraulic conductivity was determined in the laboratory by using the constant head technique.

4- Soil structure codes was obtained from National Soils Handbook No. 430 (Anonymous 1983)as shown in Fig (1).

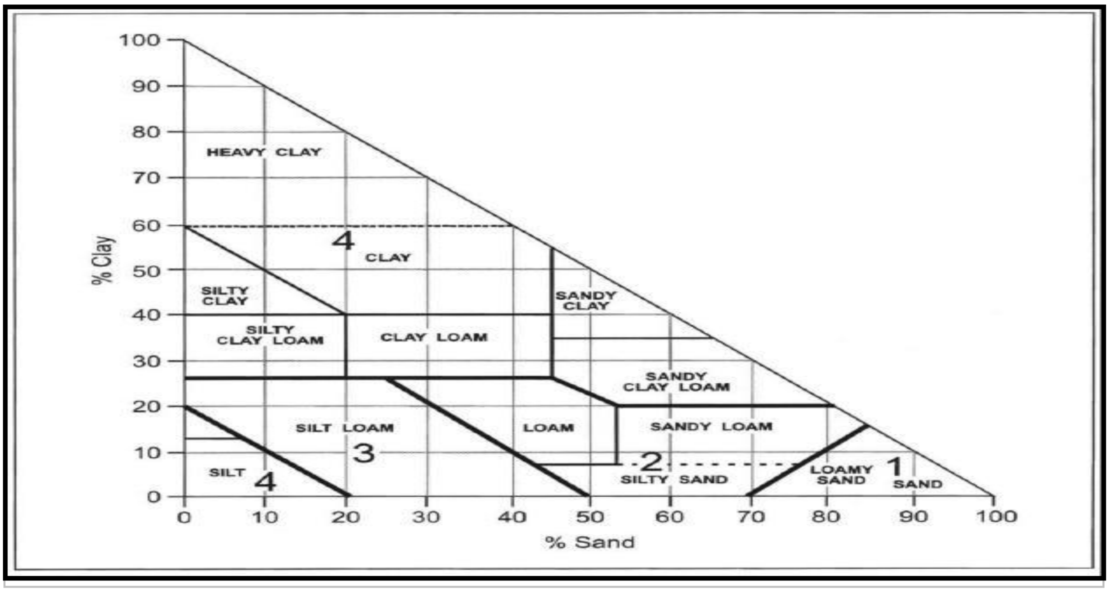


Fig. (1).Soil structure codes from National Soils Handbook No. 430 (Anonymous 1983)

The soil erodibility factor K_{USLE} was determined by plotting these parameters on the special nomograph (Fig.2) or by the modified version of nomographic expression for estimating K_{USLE} in SI units (t ha hr / ha *MJ* mm) as given by Rosewell (1993) and based on the following equation:

$$K = 27.66 * m^{1.14} * 10^{-8} * (12 - a) + 0.0043 (b-2) + 0.0033 (c-3) \quad \text{-----------(3)}$$

in which

K = Soil erodibility factor (t. ha._MJ^{-1}_mm^{-1})

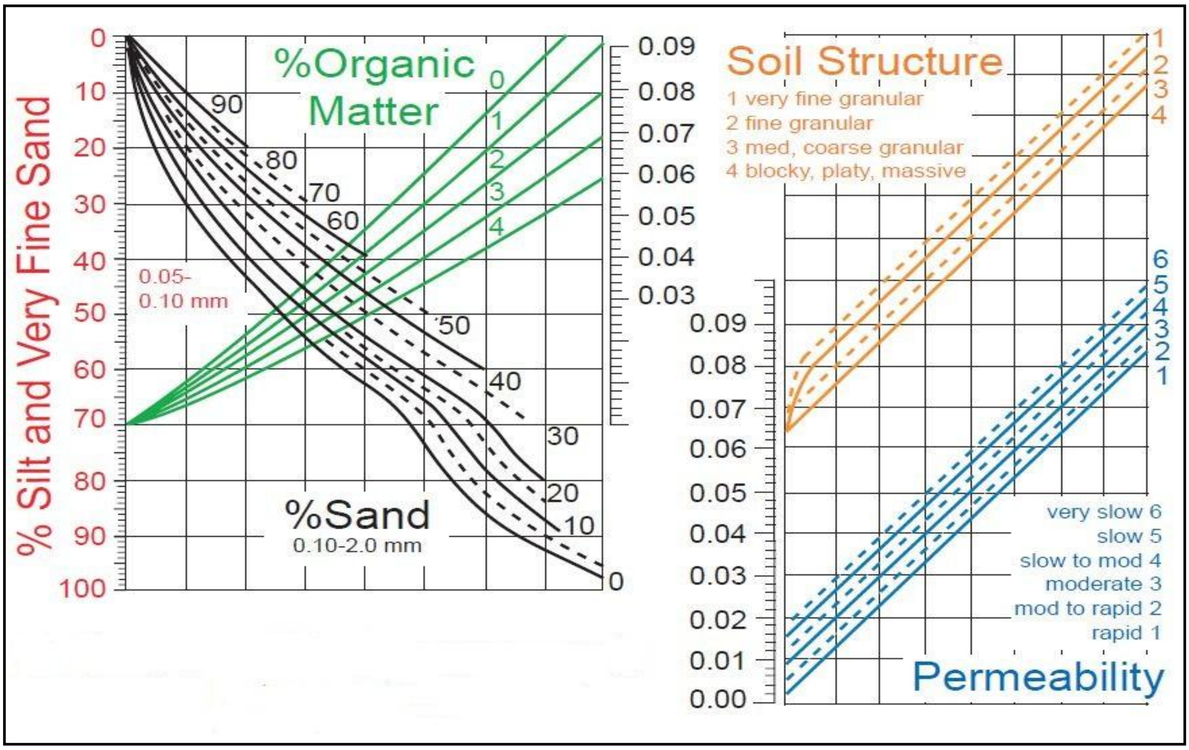
m = [silt (%) + very fine sand (%))(100-clay (%)] [the product of the percent of silt (0.002–0.01 mm) and sand (0.1–2mm) present in the sample]

a = Organic matter (%)

b = Structure code:(1) very fine granular, (2) fine granular, (3)medium or coarse granular and (4) blocky ,platy or massive (Drolet *et al*. 1989)

c = Profile permeability code: (1) rapid, (2) moderate to rapid, (3) moderate, (4) moderate to slow, (5) slow and (6) very slow

This equation results in a K-factor with units of ton acre h [hundreds of acre ft tonf in.]$^{-1}$, thus the result was divided by 7.59 to obtain the equivalent value in SI units of *M*g h MJ^{-1} mm^{-1} (Anonymous ,1995). The results were analyzed statistically to determine the best regression equation that could be adequately described the behavioral changes of K_{USLE} before and after carbonate removal using Microsoft Excel and Minitab package programming systems.



Fig(2). Soil erodibility nomograph in SI units (Foster *et.al.*1981)

RESULTS AND DISCUSSION

The results of the determined erodibility factor K_{USLE} in the tested calcareous soils and the soil-related properties data, are given in Table 2. From the nomograph-based values of the K_{USLE} before Ca-removal , the calculated soil erodibility varies from 0.013 to 0.027 t*ha/*MJ**mm and equal to [0.10 - 0.20 t acre^{-1} h^{-1} (hundreds of acre ft-tonf in.)$^{-1}$] in customary unit.

Table (2). Soil variables related to K_{USLE} before Ca- carbonate removal

Soils	Organic matter	Silt 0.002-0.05mm	Vf sand 0.05-0.1 mm	Sand 0.1- 2 mm	Structure Code	Permeability Cm/hr	K_{USLE} t*ha/*MJ**mm
	%						
Ca-20	2.1	55.0	25.0	5.0	3	2.50	0.023
Ca-26	1.1	34.0	22.0	12.0	2	2.70	0.013
Ca-33	1.0	40.0	15.0	19.6	4	1.10	0.019
Ca-38	1.2	24.4	25.0	17.0	4	1.10	0.027

Depending on these data of K_{USLE} , the four tested .soils are fall within the low erodibile class of Anonymous classification (1983) because they have a low K_{USLE} value less than 0.039 t*ha/*MJ**mm(Table 3).

Table (3) . Soil erodibility classes of K_{USLE} (Anonymous ,1995)

Series	Class	K-factor t*ha/MJ*mm
1	Low	< 0.039
2	Moderate	0.039 - 0.053
3	High	0.053 - 0.066
4	Very high	0.066

In the presence of Ca-carbonate, it can be observed that the Ca-38 soil had a highest erodibility value (0.027 t*ha/MJ*mm) followed by Ca-20 (0.023 t*ha/MJ*mm) , Ca-33 (0.019 t*ha/MJ*mm) and Ca-26 soil (0.013 t*ha/MJ*mm). Removal of Ca-carbonate from the tested soils indicate that there were considerable reduction in soil erodibility (Table 4) .

Table (4) . Soil variables related to K_{USLE} after Ca- carbonate removal

Soils	Organic matter	Silt 0.002-0.05mm	Vf sand 0.05-0.1 mm	Sand 0.1- 2 mm	Structure Code	Permeability Cm/hr	K_{USLE} t*ha/MJ*mm
	%						
Ca-20	2.1	55.5	15.0	0.0	3	2.70	0.018
Ca-26	1.1	34.1	10.0	10.0	2	3.00	0.011
Ca-33	1.0	40.9	11.0	15.5	4	1.20	0.015
Ca-38	1.2	50.1	11.0	5.0	4	1.10	0.025

In more detailed the K_{USLE} values showed a reduction trend from soils before carbonate removal to soil after carbonate removal with minus percentile values equal to,0.05 (21.7 %),0.02 (15.3 %) , 0.04 (22.2 %)and 0.02(7.4 %) t*ha/MJ*mm in the soil of Ca-20, Ca-26, Ca-33 and Ca-38 respectively (Table 5). This marked variation between before and after carbonate removal could be resulted from dynamic change in K_{USLE} related physical properties especially texture, structure,

Table (5) . Absolute and percentile variation between K_{BCR} and K_{ACR} for the four tested soils

Soils	K_{BCR}	K_{ACR}	*Δ K_{USLE}	Δ K_{USLE} %
	t*ha/*MJ**mm			
Ca-20	0.023	0.018	0.005	21.7
Ca-26	0.013	0.011	0.002	15.3
Ca-33	0.019	0.015	0.004	22.2
Ca-38	0.027	0.025	0.002	07.4

Δ Reduction in $K_{USLE} = (K_{BCR} - K_{ACR}) / K_{BCR}$

and permeability. Factors important in determining the response of the soil erodibility K_{USLE} to physical and chemical forces(removal of Ca-carbonate) include fixed one such as organic matter content, and those that were dynamic such as texture, structure and permeability. The effect of Ca-carbonate removal may be reflected by its indirect effect on the particle size distribution (clay ,silt ,very fine and coarse sand) that related to soil erodibility factor. The variation in K_{USLE} between before and after Ca-carbonate removal for the four tested soil is explained in Fig (3).

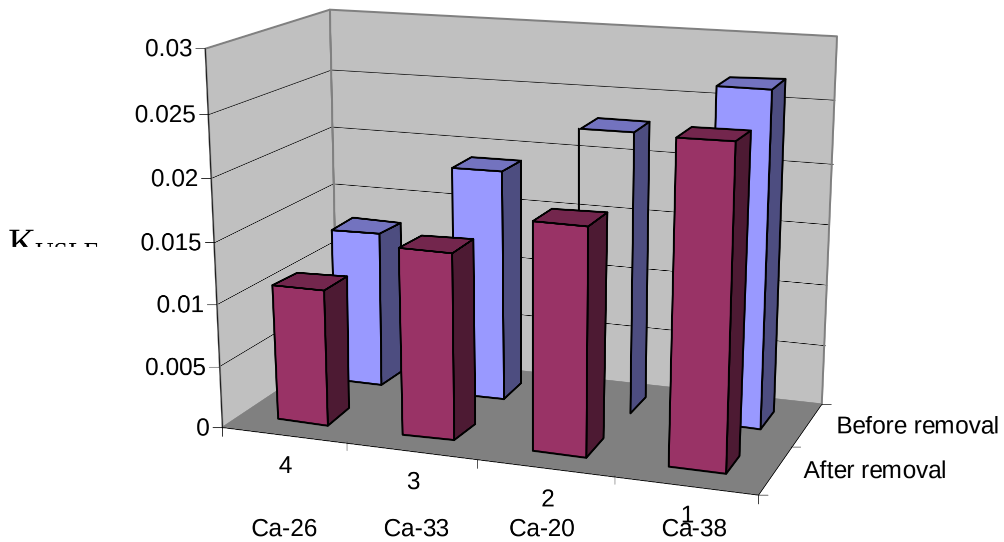


Fig. (3). Soil erodibility K_{USLE} before and after carbonate removal for the four tested soils

As shown in Fig (4), the four tested soils indicate that the removal of Ca-carbonate cause a considerable decrease in percent sand fraction and highly increase in silt and clay fractions . 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(Al-Saedy *et al* 2003). Correlation between the soil erodibility and percent clay indicates that with decreasing clay percent, the erodibility factor will be increased significantly (r = - 0.84). This results can be made more accurate by taking soil structure and permeability into account. Change in the value of the coefficients of structure and permeability were caused by changes in soil particle size distribution**.**

Thus soil with Ca-carbonate, reduced permeability and increased erodibility. Soil structures affects both susceptibility to detachment and infiltration. Permeability of the soil profile affects K_{USLE} because it affects runoff.

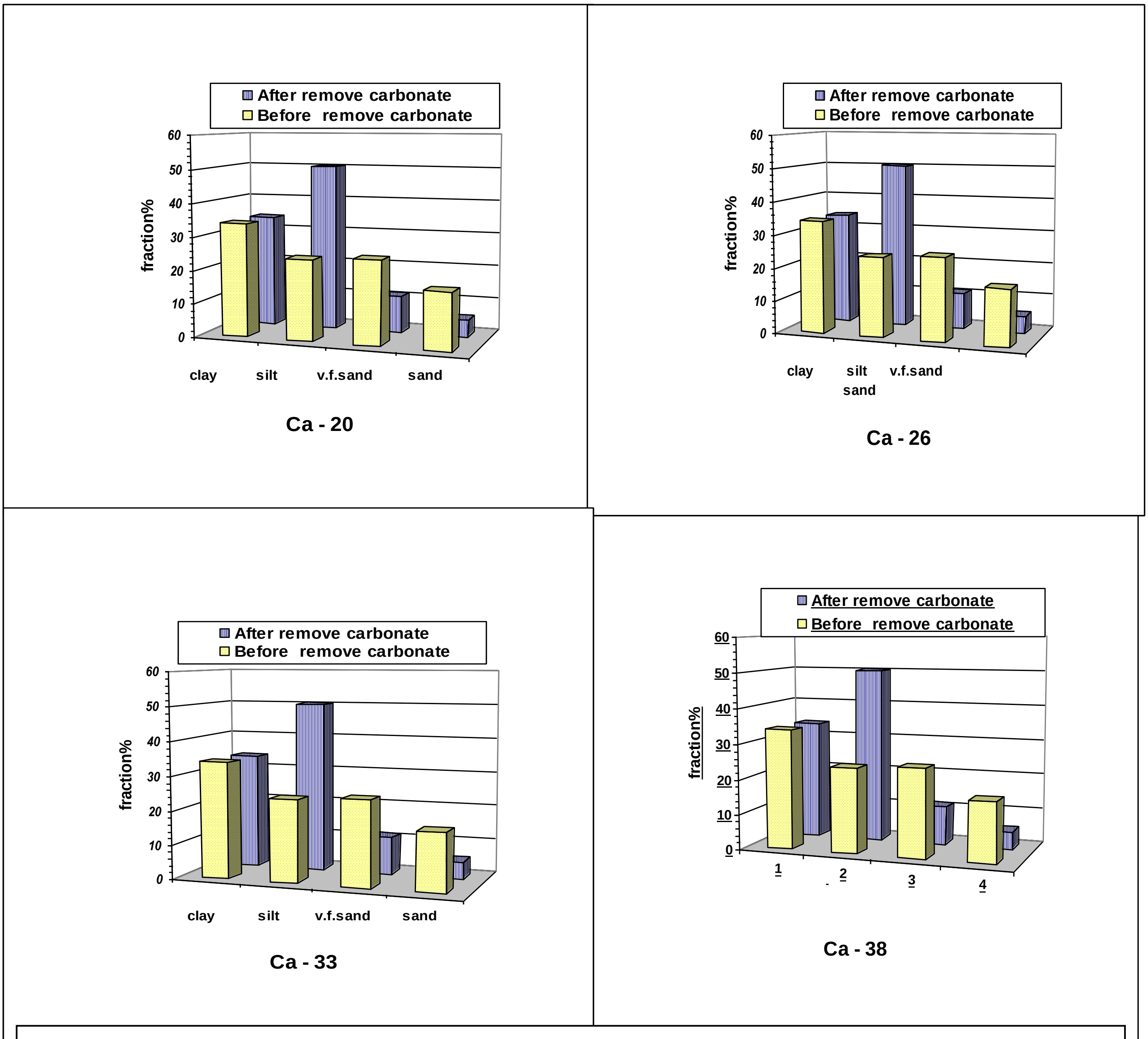


Fig.(4).Particles size distribution(clay, silt, very fine sand and modified sand) before and after carbonate removal for the four tested soils.

In order to normalize the change in K_{USLE} statistically , the relationship between soil erodibility factor before carbonate removal (K_{BCR}) and after carbonate removal (K_{ACR})were combined for all soils in the linear regression analysis (Fig 5)to find the best fitting regression relationship between them.. In the graphs 5-A , the independent K_{ACR} was plotted against K_{BCR} whereas in graphs 5-B the independent K_{ACR} was plotted against K_{BCR} to get a visual idea of how well the model works. This relationship are summarized by the following regression models:

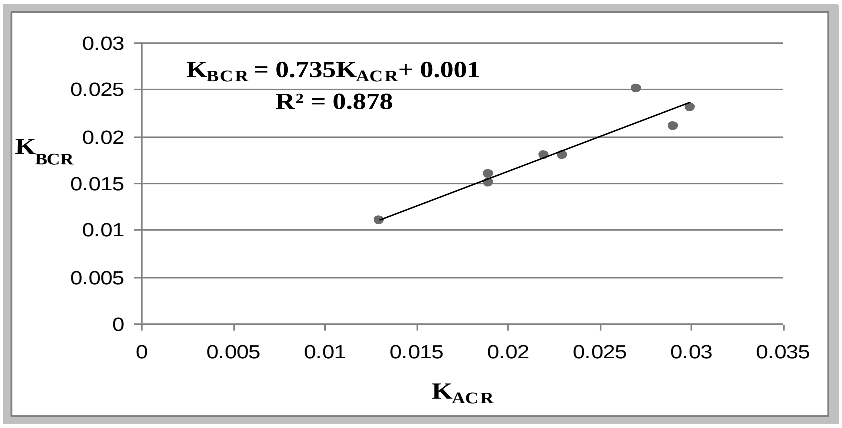
$K_{BCR} = 0.735K_{BCR} + 0.001$ $R^2 = 0.877$ ---------(4)

$K_{ACR} = 1.1937_{ACR} + 0.0008$ $R^2 = 0.878$ --------(5)

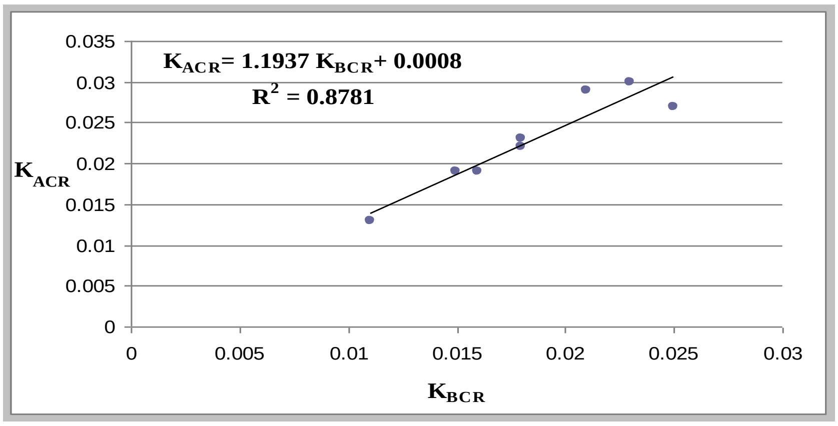
Where;

K_{ACR} = Soil erodibility factor after carbonate removal

K_{BCR} = Soil erodibility factor before carbonate removal



-A-



-B-

Fig.(5). Linear regression relationship between soil erodibility factor before(K_{BCR}) and after carbonate removal(K_{ACR})

The two models showed that R^2 is equal to 0.878 with uniform slope close to 0.001. This mean that 87.8 % of the variability in soil erodibility factor could be resulted by a high Ca-carbonate content, as it was in these soils. This statistical relationship should be took into consideration to correct the estimation of soil erodibility factor of calcareous soils. Finally , it can be concluded that the changes in soil Ca-carbonate content caused some changes in soil erodibility factor (K_{USLE}). Soil texture modification due to Ca-carbonate was the main factor affecting soil erodibility. Other unconsidered factors , such as soil permeability and structure , could also have contributed to the remaining variability in soil erodibility. The high erodibility could be explained by a high sand content and a high Ca-carbonate content, as it was in these soils. This relationship gives us a knowledge to make a correction for the calculated soil erodbility factor of calcareouse soils to distinguish it from that of non-calcareous soil.

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تاثيركاربونات الكالسيوم على قابلية الترب الكلسية للتعرية المائية

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الخلاصة

استهدفت الدراسة اختبار ا لتغيرات السلوكية التي تطرأ على عامل قابلية التربة للتعرية K_{USLE} في المعادلة العامة لفقد التربة بالتعرية المائية بسبب تواجد كاربونات الكالسيوم في أربعة ترب كلسيه تقع تحت الظروف المناخية شبه الجافة في شمال العراق حيث تم تقدير عامل قابلية التربة للتعرية K_{USLE} للترب المدروسة قبل وبعد إزالة الكاربونات باستخدام طريقة النوموكراف والمعادلة المحورة المعدة من قبل العالمان ويشمايروسميث Wischmeier and Smithأشارت النتائج إلى أن التغير في محتوى التربة من الكاربونات أدى إلى تغير معنوي في قيم عامل قابلية التربة للتعرية K_{USLE} والذي يعود سببه إلى التغير الحاصل في نسجه التربة (التوزيع ألحجمي لدقائق التربة)أما الخصائص الأخرى التي لم تؤخذ بنظر الاعتباركنفاذية التربة والبناء يمكن ان تساهم في التأثير المتبقي على عامل قابلية التربة للتعرية K_{USLE} واعتمادا على تحليل الانحدار فان ٨٧ر٧ % من التغير في عامل قابلية التربة للتعرية يعود سببه إلى المحتوى العالي من كاربونات الكالسيوم كما في الترب المدروسة لذا فانه يتطلب إجراء تصحيح لعامل قابلية التربة للتعرية المائية K_{USLE} عند تقديره في الترب الكلسية ل تميزه عن ذلك الذي للترب غير الكلسية.

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