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

The behavioral changes in soil erodibility factor (KUSLE) due to Ca-carbonate content were determined in four calcareous soils located at northern Iraq. The procedure for KUSLE 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 (KUSLE). 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 KUSLE. Regression analysis of data showed that about 87.8% of the variability in KUSLE could be explained by a high Ca-carbonate content, as it was in these soils. This relationship gives us a knowledge to make a correction for the calculated erodibility factor KUSLE 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 (Mg 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

(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 E₁₃₀ from a control plot (Standard plot). A control plot would be 22.1 m long with a 9% uniform slope and cultivated continuous fallow plot (Refahi, 1997). Thus, the KUSLE 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 (I₁₃₀) from a unit plot (Farzin et al. 2010) as in the following:

A = RK → K = A / R = A / E * I₁₃₀

(2)

To allow estimation of soil erodibility KUSLE from measurable soil properties, the soil erodibility nomograph was published in the early 1970s (Wischmeier et al. 1971). Factors which affect soil erodibility KUSLE 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 KUSLE can be approximated from a nomograph if this information is known.
In computing the \( K_{\text{USLE}} \) 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 \( K_{\text{USLE}} \) "especially particle size distribution, soil structure and permeability".

Proper evaluation of soil erodibility factor \( K_{\text{USLE}} \) 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 \( K_{\text{USLE}} \) (obtained form the nomograph and equations given by Wishmeier 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, Qara, Hammam Alil and Telkef), located at northern Iraq were sampled to study the effect of Ca-carbonate on the soil erodibility factor \( K_{\text{USLE}} \) 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>
<thead>
<tr>
<th>Soil* Symbol</th>
<th>Site</th>
<th>Clay</th>
<th>Silt</th>
<th>Sand</th>
<th>Texture</th>
<th>pH</th>
<th>EC</th>
<th>CaCO₃</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ca-20</td>
<td>Mosul</td>
<td>15.0</td>
<td>55.0</td>
<td>30.0</td>
<td>SiL</td>
<td>7.6</td>
<td>0.4</td>
<td>20</td>
</tr>
<tr>
<td>Ca-26</td>
<td>Qara</td>
<td>22.0</td>
<td>34.0</td>
<td>44.0</td>
<td>L</td>
<td>7.8</td>
<td>0.4</td>
<td>26</td>
</tr>
<tr>
<td>Ca-33</td>
<td>Hammam-Alil</td>
<td>25.6</td>
<td>40.0</td>
<td>34.4</td>
<td>CL</td>
<td>7.7</td>
<td>0.6</td>
<td>33</td>
</tr>
<tr>
<td>Ca-38</td>
<td>Telkef</td>
<td>33.6</td>
<td>24.4</td>
<td>42.0</td>
<td>SiCL</td>
<td>7.4</td>
<td>0.3</td>
<td>38</td>
</tr>
</tbody>
</table>

*Symbol represent the percent of Ca-carbonate in soil

Determination of soil erodibility factor \( K_{\text{USLE}} \) 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 \( K_{\text{USLE}} \) 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).

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 \( (t \text{ ha} \text{ hr} / \text{ ha} MJ \text{ mm}) \) as given by Rosewell (1993) and based on the following equation:

\[
K = 27.66 \times m^{1.14} \times 10^{-8} \times (12 - a) + 0.0043 \times (b - 2) + 0.0033 \times (c - 3) \tag{3}
\]

in which

\( K = \) Soil erodibility factor \( (t. \text{ ha} \_MJ^{-1} \_\text{mm}^{-1}) \)

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

\( a = \) 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 \( Mg \text{ h} MJ^{-1} \text{ mm}^{-1} \) (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.

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*m*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

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

Depending on these data of $K_{USLE}$, the four tested soils are fall within the low erodible class of Anonymous classification (1983) because they have a low $K_{USLE}$ value less than 0.039 t*ha/MJ*m/mm (Table 3).
Table (3). Soil erodibility classes of K<sub>USLE</sub> (Anonymous, 1995)

<table>
<thead>
<tr>
<th>Series</th>
<th>Class</th>
<th>K-factor t<em>ha/MJ</em>mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Low</td>
<td>&lt;0.039</td>
</tr>
<tr>
<td>2</td>
<td>Moderate</td>
<td>0.039 - 0.053</td>
</tr>
<tr>
<td>3</td>
<td>High</td>
<td>0.053 - 0.066</td>
</tr>
<tr>
<td>4</td>
<td>Very high</td>
<td>0.066</td>
</tr>
</tbody>
</table>

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<sub>USLE</sub> after Ca-carbonate removal

<table>
<thead>
<tr>
<th>Soils</th>
<th>Organic matter</th>
<th>Silt 0.002-0.05mm</th>
<th>V&lt;sub&gt;f&lt;/sub&gt; sand 0.05-0.1 mm</th>
<th>Sand 0.1-2 mm</th>
<th>Structure Code</th>
<th>Permeability Cm/hr</th>
<th>K&lt;sub&gt;USLE&lt;/sub&gt; t<em>ha/MJ</em>mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ca-20</td>
<td>2.1</td>
<td>55.5</td>
<td>15.0</td>
<td>0.0</td>
<td>3</td>
<td>2.70</td>
<td>0.018</td>
</tr>
<tr>
<td>Ca-26</td>
<td>1.1</td>
<td>34.1</td>
<td>10.0</td>
<td>10.0</td>
<td>2</td>
<td>3.00</td>
<td>0.011</td>
</tr>
<tr>
<td>Ca-33</td>
<td>1.0</td>
<td>40.9</td>
<td>11.0</td>
<td>15.5</td>
<td>4</td>
<td>1.20</td>
<td>0.015</td>
</tr>
<tr>
<td>Ca-38</td>
<td>1.2</td>
<td>50.1</td>
<td>11.0</td>
<td>5.0</td>
<td>4</td>
<td>1.10</td>
<td>0.025</td>
</tr>
</tbody>
</table>

In more detailed the K<sub>USLE</sub> 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<sub>USLE</sub> related physical properties especially texture, structure, and permeability. Factors important in determining the response of the soil erodibility K<sub>USLE</sub> 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.
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:

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

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

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

\[ K_{\text{ACR}} = \text{Soil erodibility factor after carbonate removal} \]
\[ K_{\text{BCR}} = \text{Soil erodibility factor before carbonate removal} \]

\[ K_{\text{BCR}} = 0.735K_{\text{ACR}} + 0.001 \]
\[ R^2 = 0.878 \]

\[ K_{\text{ACR}} = 1.1937K_{\text{BCR}} + 0.0008 \]
\[ R^2 = 0.8781 \]

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

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 \((K_{\text{USLE}})\). 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 erodibility factor of calcareous soils to distinguish it from that of non-calcareous soil.
تأثير كاربونات الكالسيوم على قابلية الترب الكلسية للتعرية المائية
خالد فالح حسن                                     معتصم داود أغا
قسم علوم التربة والموارد المائية / كلية الزراعة والغابات / جامعة الموصل / العراق

الخلاصة
استهدفت الدراسة اختبار التغيرات السلوكية التي تطرأ على عامل قابلية التربة للتعرية KUSLE
المعادلة العامة لفقد التربة بالتعرية المائية بسبب وجود كاربونات الكالسيوم في أربعة ترب كلسية تحت الظروف المناخية شبه الجافة في شمال العراق حيث تم تقدير عامل قابلية التربة للتعرية KUSLE
للتراب المدروسة قبل وبعد إزالة الكاربونات باستخدام طريقة التوموكراف وتعتبر المعايير المحورة المعدة من قبل العالمان Wischmeier و Smith. أشارت النتائج إلى أن التغير في محتوى التربة من الكاربونات أدى إلى تغير معنوي في عامل QUSLE
قيمه عامل قابلية النحافة للتعرية KUSLE والذي يعود سببه إلى التغير الحاصل في نسج التربة (التوظيف الحجمي لدفائق
الترية) أما الخصائص الأخرى التي لم تؤثر بنظر الاعتبار كالفاكلة التربة والبناء يمكن أن تساهم في التأثير المتغير
على عامل قابلية التربة للتعرية KUSLE واعتماداً على تحليل الانحدار فإن 87% من التغير في عامل قابلية التربة للتعرية
الكلسية يعود سبيه إلى المحتوى العالي من كاربونات الكالسيوم كما في التربة المدروسة لذا فإنه يتطلب إجراء
تصحيح لعامل قابلية التربة للتعرية المائية كونه غير KUSLE

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