Influence of Soil Organic Matter and Total Calcium Carbonate on Soil Erodibility at Different Locations in Sulaimani Governorate

Marwa Abubakr Ahmed[1*], Bakhan Hamarasul Qadir[2], Sanaa Hamagharib Faraj[3] and Razaw Saeed Saleem[4]

[1]Department of Natural Resources, College of Agricultural Engineering Sciences, University of Sulaimani, Iraq.
[2]Department of Natural Resources, College of Agricultural Engineering Sciences, University of Sulaimani, Iraq.
[3]Department of of Natural Resources, College of Agricultural Engineering Sciences, University of Sulaimani, Iraq.
[4]Department of of Natural Resources, College of Agricultural Engineering Sciences, University of Sulaimani, Iraq.

*Corresponding author's email: marwa.ahmed@univsul.edu.iq
Email addresses of coauthors: bakhan.qader@univsul.edu.iq, sanaa.faraj@univsul.edu.iq, razaw.saleem@univsul.edu.iq

Abstract

Soil erosion is one of the most critical environmental issues facing the world today, which causes the loss of productive topsoil and the degradation of ecosystem stability. Overgrazing and deforestation, which endanger agricultural productivity, significantly accelerate this process. In the calcareous, semi-arid soils of the Sulaimaniyah region in the Kurdistan Region of Iraq, this study aimed to determine soil erodibility (K-factor), soil organic matter (SOM), and calcium carbonate ($CaCO_3$) levels and relationship between them. The experimental research focused on three different locations: Chwarta, Qaradagh and Kharajian. The results indicate that soil texture range from loam to Silty Clay Loam, characterized by slightly alkaline pH and nonsaline conditions. A fundamental finding of this study in the significant inverse between soil constituents and Erodibility. As SOM and $CaCO_3$ concentration increase, the K-factor diminishes, thereby bolstering the soils resistance to detachment. Specifically, the Kharajian site displayed the highest SOM (6.7%) and $CaCO_3$ (13.5%), the result illustrated that there was a negative relationship between soil erodibility and organic matter, also soil erodibility and $CaCO_3$. Resulting in the lowest Erodibility (K=0.245), whereas Chwarta demonstrated the highest vulnerability to erosion. These discoveries underscore the indispensable role of organic matter and calcium ions in augmenting aggregate stability and water infiltration. In the end, this study establishes that enhancing SOM and $CaCO_3$ levels is a cornerstone strategy for future land management to mitigate erosion end ensure sustainable agricultural productivity in the region.

Keywords: Soil Erosion, Soil Erodibility, SOM, Total Calcium Carbonate ($CaCO_3$), Calcareous Soil and Soil properties.

Introduction

Soil erosion is the removing and carrying of soil particles from their original location. Various factors including water and wind can transport particles over long distances. Soil particles are often removed from their original location and deposited in different locations, which also contributes to sedimentation and landscape alteration. This process influences ecosystem health, water quality, and

ISSN 2072-3857

agricultural productivity along with changing the soil physical properties and possibly causing soil deterioration. The removal of natural environmental barriers, for instance intensive grazing and unchecked deforestation, significantly increases soil erosion [1].

Soil erosion is commonly acknowledged that one of the major factors of soil degradation, which results in the loss of fertile topsoil and decreased agricultural production [2]. The tendency of soil to erosion is commonly expressed by the soil erodibility factor (K), which indicates the inherent resistance of soil to displacement and relocation by rainfall and runoff [3].

Soil Erodibility is affected by numerous soil properties, including SOM content, soil texture, soil structure and calcium carbonate ($CaCO_3$) content [4-7]. These characteristics an important role in determining how soil particles remain when face of surface flow and rainfall [8]. The value of K- factor is based on organic matter content and soil textural class [5-7]. Also, Clay soils have low K values [6].

Because of its important influence on agriculture, soil erosion has long been a subject of study and management of land [9]. Soil erosion can reveal issues of a social, economic and chiefly environmental challenges. Soil erosion is also seen as an indicator that causes concern across the world because of the past prevalence in production of crop including ploughing, harrowing, cultivating, and other types of soil disturbance from repeated tillage [10].

Soil organic matter (SOM) is a critical component in quality of soil, significantly affecting soil fertility, soil structure, water retention, and biological activity. It also plays an important role in the biogeochemical carbon cycle makes it a vital factor in atmospheric CO_2 sequestration, providing promising strategies for climate change abatement [11].

Soil organic matter (SOM) is known as an essential element and acts a noticeable role in the protection and enhancement of several characteristics and processes of soil. These roles, greatly affects soil functions, are a pool of particular role of different components of SOM. The soil functions, normally determine the degree of soil degradation, which is defined as measurable changes in a soil's quality over time [12]. A drop in soil structure (crusting, compaction and rooting depth loss and accessible water for plant) in addition to a reduce in (soil organic carbon) and (fertility) are the first signs of erosion-induced soil degradation [13]. Because SOM helps to aggregate formation, it plays a vital role in controlling soil erosion. This is because SOM alters soil physical qualities, particularly soil structure [12].

Another factor that affects soil Erodibility, in many arid and semi-arid regions, soils are calcareous and contain significant levels of $CaCO_3$. Calcium carbonate can affect the soil physical characteristics by providing Ca^{2+} ions that promote flocculation of clay particles and improve soil aggregation. Stronger aggregation generally leads to greater structural stability and reduces the likelihood that soil particles will detach during rainfall events [14].

Currently, soil erosion is one of the world's longest-lasting processes of soil degradation [15]. Soil erosion (SE) damages water and transportation engineering facilities, reduces soil fertility, causes ecological degradation, and negatively impacts the regular development of agriculture and industry. It is a worldwide problem that has seriously threat human public health and safety while causing land degradation and damage of ecosystem functions [16].

Therefore, the main objective of this research is to determine the effects of soil organic matter (SOM) and calcium carbonate equivalent ($CaCO_3$) on soil erodibility (K-factor) in different soils of semi-arid regions located in Sulaimani/Kurdistan of Iraq.

Material and Methods

The Research Area Description

This research was performed on three different soil locations around the Sulaimani city; the sampling sites were presented in Chwarta N (35° 42' 56") E (45° 32' 59"), Qaradagh N (35° 21' 22") E (45° 23' 55") and Kharajian N (35° 27' 48") E (45° 33' 56") (Fig 1).

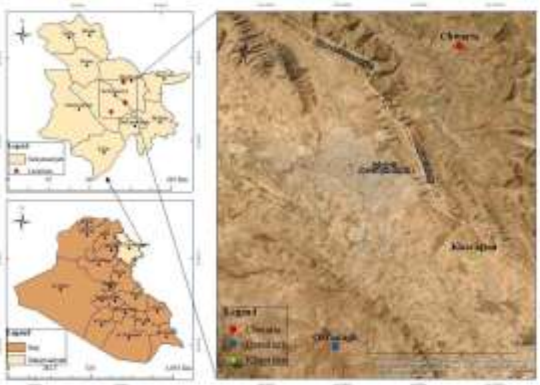

Figure 1: Locations and elevations of the research area.

Soil Analysis

Soil sampling and sample preparation

Soil samples were gathered from the upper (0.30 m) At each point. They were brought to the laboratory, air-dried, grounded by plastic hummer, sieved through a 2-mm sieve and saved in a plastic container until used for various physical and chemical laboratory analyses. The pipette method was utilized to determined soil particle size distribution according to [17]. For the soil dilution extract electrical conductivity (Ec) was measured with using the Ec-meter according to [18], and pH was measured by pH meter, as mentioned by [19]. Soil organic matter (SOM) was measured by utilizing the [20] method, as described by [19]. The percentage of total calcium carbonate ($CaCO_3$ %) equivalent was determined with 1M HCl, and the excess of HCl was titrated with 1M NaOH by using phenolphthalein indicator as mentioned by [21]. Soil erodibility at each location was estimated using the following equation [22].

$$K = 0.277\ 10^{-5}\ M^{1.14}\ (12 - \mathrm{OM}) + 0.043\ (\mathrm{SC} - 2) + 0.033\ (\mathrm{PC} - 3)$$

Where:

K = soil erodibility in metric unit (hr m^{-1} cm^{-1})

M = (100- clay %) (silt % + very fine sand %).

OM = organic matter %.

SC = structure class code.

PC = permeability class code.

Soil permeability codes (PC) were determined by the auger hole method according to [23]. Soil structure codes (SC) were observed from National Soils Handbook No. 430 [24] as shown in Fig (2).

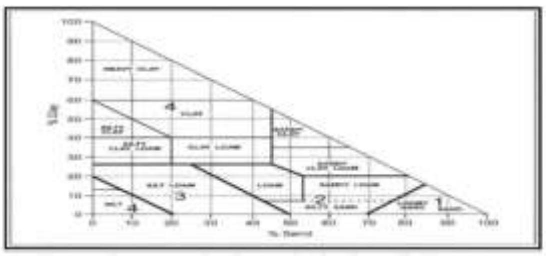

Figure 2: Soil structure codes from National Soils Handbook No. 430 [24].

Results and Discussion

ISSN 2072-3857

Studied soils properties

Table (1) shows the physico-chemical properties results of studied soil sites. The range of sand, silt, and clay were (42.03, 31.27 and 9.1) %, (41.01, 31,38 and 53.62) %, and (16.96, 37.35 and 37.28) % for Chwarta, Qaradagh and Kharajian, respectively. The studied soils were different in texture class, which is Loam for Chwarta, Clay Loam for Qaradagh and Silty Clay Loam for Kharajian, very fine sand content varied among the samples, ranging (7.98, 5.08 and 1.42) % for Chwarta, Qaradagh and Kharajian, respectively. The outcomes obviously illustrate medium-textured soil system with moderate to high nutrient and water holding capacity. Clay soils are more cohesive than sandy soils and thus aggregates with high clay are more difficult detached. While sandy soils are less resistant to erosion than coarse textured soils, individual clay particles are easily transported, but aggregated clay soils are more resistant to separation. While silty soils are one of the soil types are more erodible. On the other hand, coarse particle has a positive correlation with infiltration but fine particles have a negative correlation with infiltration [25].

Structure Code for Chwarta was (2) while its equal for two other Locations were (3), and there was no difference between the samples in Permeability code.

On the other hand, the pH of Chwarta, Qaradagh and Kharajian were 7.60, 7.64 and 7.72, respectively. The pH of studied soils was slightly alkaline, which was reported by the presence of certain cations. Electrical conductivity (EC) values for soil samples were (1.25, 0.41 and 0.30 dS m^{-1}) for Chwarta, Qaradagh and Kharajian, respectively. Also, the found of EC demonstrated that studied soils were non-saline soil due to EC values below 2 dS m^{-1} the limits recommended by [26].

Table 1: Chosen physio-chemical characteristics of the studied soils

Locations	Sand%	Silt%	Clay%	V.F.S%	T.C	S.C	P.C	PH	EC
Chwarta	42.03	41.01	16.96	7.98	L	2	3	7.60	1.25
Qaradagh	31.27	31.38	37.35	5.08	CL	4	3	7.64	0.41
Kharajian	9.1	53.62	37.28	1.42	SCL	4	3	7.72	0.30

V.F.S (Very fine sand), T.C (Texture class), S.C (Structure code), P.C (Permeability code), L (Loamy), CL (Clay Loam), SCL (Silty Clay Loam), PH (Soil reaction), EC (Electrical conductivity).

Relationship between soil organic matter with soil Erodibility

Results of organic matter were displayed in a Table (2). Organic matter contents vary between the studied soil sites ranging from (1.9, 2.8 and 6.7) %, for Chwarta, Qaradagh and Kharajian, respectively. Furthermore, Table 2 illustrates the relation between soil organic matter (OM%) with soil Erodibility (K Factor). The highest K value (0.364) was observed at the site with the lowest OM (1.9%), while the lowest K value (0.245) occurred at the site with the highest OM (6.7%).

The outcomes illustrated that the maximum value of organic matter was observed in Kharajian. The relatively high value of organic matter in this location may result from continuous addition of plant residual to the soil [27]. The result displayed the decreasing K factor with increasing organic matter. Soil Erodibility

ISSN 2072-3857

(K factor) showed a clear inverse relationship with organic matter content across the studied sites. This suggests that increasing organic matter reduces soil susceptibility to erosion. It has negatively and linearly relationship between organic matter and clay content with K (factor), that is K-value decreases with increasing clay content and organic matter. Similar results were conducted in Chamchamal, Erbil and Sulaimani by [28-31]. As organic matter increases soil Erodibility typically shows to decrease appreciably [8]. The recorded reduction in soil Erodibility with increasing organic matter can be attributed to improved soil aggregation and structural stability, which increases resistance to detachment by rainfall and runoff. The SOM modifies the physical properties of soil, especially soil structure [32]; thus, it acts a key role in the control of soil erosion [33]. Well- structured soil is more resistant to erosion because soil structure controls numerous biophysical processes such as soil aeration, water retention as well as activities of soil organisms [12].

Table 2: Relation between soil organic matter with soil Erodibility

Locations	OM%	Soil Erodibility (K) factor
Chwarta	1.9	0.364
Qaradagh	2.8	0.258
Kharajian	6.7	0.245

Figure (3) illustrates the relationship between organic matter (OM) and soil erodibility which shows a noticeable inverse relationship. As organic matter content increases, soil erodibility tends to decrease. The previous analysis also supports this trend, result of R^2 value (0.5391), the results displayed positive significant correlation between soil erodibility and organic matter.

From Fig 3 appeared that high value of organic matter content may act a vital role in effecting the susceptibility of soil to erosion. It is widely known that organic matter improves aggregate steadiness and soil structure. It plays a crucial role as a natural binding agent that helps mineral particles form stable aggregates [34], and these aggregates make the soil more resistant to the effect rainfall and surface runoff to detachment and movement [35]. Soils that contain higher levels of organic matter generally demonstrate better aggregate stability and less susceptible to erosion [36].

Furthermore, organic matter enhances soil porosity and raises water infiltration. Less water flows over the soil surface, which decreases runoff and the erosive force of moving water when infiltration increases. The decreasing trend of soil Erodibility with increasing organic matter obtained in this study is therefore consistent with previous findings that identify organic matter as a key factor controlling soil structural stability and resistance to erosion [34]. Thus; organic matter content in soil is an important component of sustainable agriculture, contributing to soil health, crop productivity [37].

ISSN 2072-3857

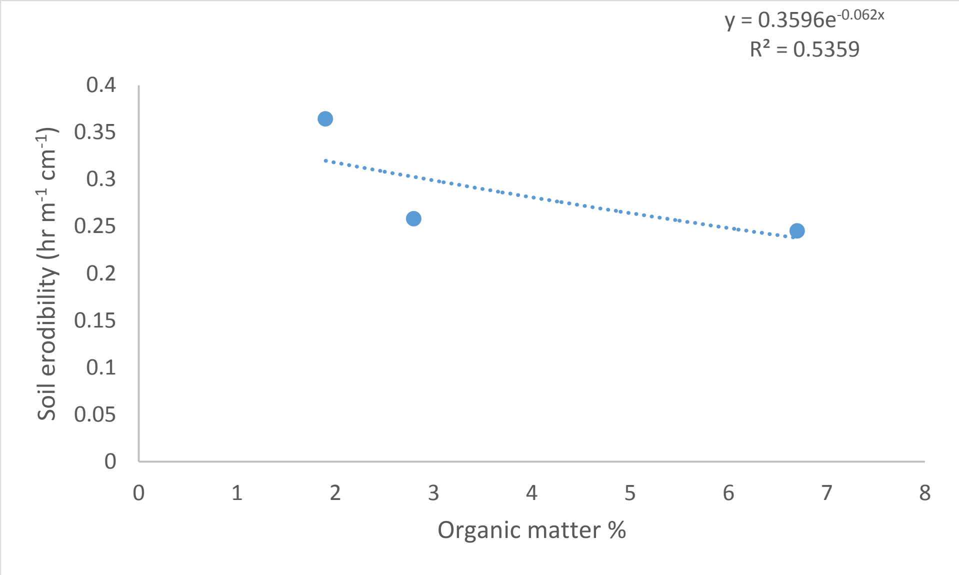

Figure 3: Organic Matter and Soil Erodibility relationship.

Effect of Total Calcium Carbonate ($CaCO_3$ %) on Soil Erodibility of Studied Soil Sample.

The effect of total $CaCO_3$ % on soil Erodibility (K-factor) for the studied sites was shown in Table 3. The results demonstrated that the total $CaCO_3$ % spanned from 13.5% to 6%, while the K-factor varied between 0.245 and 0.364. The highest $CaCO_3$ content was observed at location Kharajian (13.5%), which was exhibited the lowest soil erodibility value (K = 0.245). While, lower $CaCO_3$ contents were recorded at Chwarta (6%) and Qaradagh (7%), with correspondingly higher K-factor values of 0.364 and 0.258, respectively.

Similar to the result of organic matter higher value of total $CaCO_3$ obtained in Kharajian, which leads to the lower value of soil erodibility. This outcome demonstrates a negative relationship between total $CaCO_3$ content and soil Erodibility in the studied soils. Therefore, the results indicate that variations in $CaCO_3$ content may act a crucial role in controlling soil erodibility across the studied locations. This result agreed with the result found by [38], who reported that as carbonate content changes in soil caused a change in soil erodibility (k-factor). The results showed the highest value for both OM content and total $CaCO_3$ % observed at Kharajian location which also exhibits the lowest value of K factor (Table 3 and Table 4). This may be due to in calcareous soils organic matter may interact with calcium ions and clay minerals to form stable organo-mineral complexes, further strengthening soil aggregates. Because both $CaCO_3$ and organic matter affect soil aggregation and structural stability, their combined influence may play a vital role in controlling soil Erodibility [39]. Furthermore, soil structure is a main cause that affecting crop yield and soil fertility. As basic units of soil structure, aggregates play a crucial role in maintaining soil fertility, balancing water retention and soil aeration, and retarding soil erosion [40, 41].

ISSN 2072-3857

Table 3: Relationship between Total Calcium Carbonate ($CaCO_3$ %) with Soil Erodibility.

Locations	Total $CaCO_3$ %	Soil Erodibility (k) factor
Chwarta	6	0.364
Qaradagh	7	0.258
Kharajian	13.5	0.245

The relationship between total calcium carbonate ($CaCO_3$ %) content with soil Erodibility (K-factor) displayed in Fig (3). The result of R^2 = 0.4817 reveals that as $CaCO_3$ % content increases the soil Erodibility decrease and also reveals that has the moderate to strong positive correlation. This mean that there was an opposite relationship between total calcium carbonate and soil Erodibility, demonstrating that an increasing in $CaCO_3$ is related to a decrease in soil Erodibility.

The result of R^2 reveals that as $CaCO_3$ % content increases the soil erodibility decrease appeared in Fig 4. Whereas the relationship is moderate, the observed pattern shows that soils with higher carbonate content may be somewhat more resistant to erosion.

The most of soil physical, chemical and biological properties are inherited are greatly impacted by the $CaCO_3$ % forms [42]. Calcium (Ca^{2+}) released from $CaCO_3$ % improves soil structure and encourages clay particle flocculation, which aids in soil particle binding and the formation of more strength aggregates. Soil particles are less likely to detach and move by rainfall and surface runoff when aggregates are stable [34, 43]. $CaCO_3$ % may also aid in cementation between soil particles in calcareous soils, strengthening soil structure and enhancing aggregate stability [44]. Soil properties that improve structural stability can decrease the susceptibility of soils to water erosion as reported by [45].

However, the moderate R^2 value (0.48) indicates that $CaCO_3$ is not the only factor influencing soil Erodibility in this case. Soil erosion is affected by several interacting factors, including soil structure, soil texture, organic matter content and soil management practices [35]. Soils with higher levels of organic matter content usually show improved aggregate stability, which can further reduce erodibility.

Overall, the observed patterns in the figure indicates that increasing $CaCO_3$ content may decrease soil Erodibility, perhaps, due to its role in enhancing soil aggregation and structural stability. At the same time, the moderate correlation suggests that other properties of soil also act vital roles in determining how susceptible a soil is to erosion.

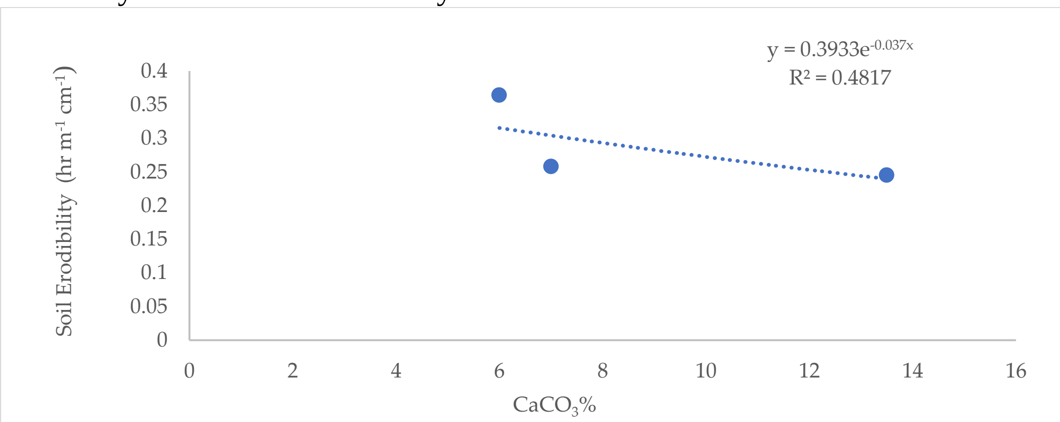

Figure 4: The relationship between Total $CaCO_3$ % with Soil Erodibility.

ISSN 2072-3857

Conclusion

Soil erodibility has a contrast relationship with organic matter and calcium carbonate, which means increased organic matter and calcium carbonate cause decreased soil erodibility, $CaCO_3$ creates stronger soil particles that resist erosion. While, increase organic matter cause to reduce soil erodibility, and because of this decrease soil detachment, increase infiltration, which reduce runoff and erosion when high amount of organic matter. Also, soil has high value of clay content cause to low soil Erodibility (K-factor) because clay soil more resistant to detachment. Finally, the results within the studied soil locations indicate that the changes organic matter, clay and Ca-carbonate content in soil caused to some changes in soil Erodibility factor.

Acknowledgment: We gratefully acknowledge the valuable support provided by Prof. Dr. Zaid Khalaf Khidhir, and the Head of Natural Resources Department, College of Agricultural Engineering Sciences at the University of Sulaimani.

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