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Effect of Soil Physical and Organic Matter on Soil Erodibility in Duhok Dam Sub Drainage Basin

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ABSTRACT

Soil erosion is a barrier to achieving sustainable land use especially in semi-arid regions with multiple soil types. This work evaluates the soil erodibility factor (K) at twelve sampling locations in Duhok Dam (Kurdistan Region, Iraq), it investigates impact of key physical and chemical soil properties including bulk density, permeability, organic matter, textural and structural properties of these soil samples. Organic matter content and soil texture were found to be the major drivers for controlling K-factor under different land uses, according the sensitivity analysis. The sensitivity to erosion decreased with increasing clay content of the soils, while sandy soils suffered from greater susceptibility to the erosion because of their lower permeability. The k-values had been predicted by a regression model, which accounted for 98.66% of the total variance (R2 = 98.6%). The increasing of bulk density and permeability have variable effects on erodibility. A Study of various soil properties shows significant correlations between bulk density, erodibility (K), permeability and OM content indicating useful information about the behavior and erosiveness property of the soil. The positive relationship between erodibility and bulk density implies that denser soils are more easily eroded, possibly because reduced porosity in such soils results in increased surface runoff. It is also interesting to note that as the erodibility increases, the permeability of soils tends to increase; thus, with greater water movement in susceptible soils, detachment and transport of particles could be quickened. On the other hand, the soil bulk density had a negative relationship with organic matter content, which is evidence of the importance of organic materials for maintaining good soil structure and reducing compaction. This emphasizes the interdependence between soil physical properties and their joint impact on land degradation, and draws attention for integrated soil management strategies aimed at mitigating the risk of erosion in vulnerable catchments.

***Keywords*:** Soil erodibility, Erosion, soil texture, organic matter, permeability, bulk density.

INTRODUCTION

Soil erodibility, referred to as the K-factor in the Universal Soil Loss Equation (USLE) and revised (RUSLE) soil erosion model that is widely utilized, is an important factor to estimate soil erosion. The findings emphasize the relevance of detailed soil property studies in the assessment of the erosion risk and for designing targeted conservation interventions in fragile areas. Soil characteristics such as texture, organic matter content, structure and permeability, are associated with K-factor that represents a soil's susceptibility to erosion. The degree of susceptibility to water erosion is different in various types of soil. The K-factor (soil erodibility) is the measure of how easily runoff and rainfall can erode soil [24]. Erodibility of soil is influenced by various physical and chemical properties of the soil [3]. In this research, the main physical and hydraulic properties influencing soil erodibility include permeability, which is the capability of soils to conduct air and water through their matrix, organic matter, primary size distribution and structure of soil [8].

As stated by [11], porosity, the type of pore and the pore size play a very important role in soil permeability, and depend on things like the soil organic matter, the clay particles´ rate of swelling and shrinkage, and the extent of aggregation. The speed at which water penetrates soil and its strata is called infiltration. It can also be expressed as a soil's saturated hydraulic conductance. Texture, structure (aggregate), and pore size all influence SWI into the soil [18]. an Erodibility is controlled primarily by texture. More sandy soils have lower erodibility, despite low aggregate stability, owing to their high infiltration rates; the erodibility of silty soils and higher clay textured soils is increased due to weak particle cohesion and detachment susceptibility. Permeability, organic matter and structure are also a factor. Soils which have high organic matter content and high rate of infiltration and their structure is better that soils are erosion resistant. Soil erodibility indices are independent of the soil type. An understanding of soil erodibility is important to develop successful soil conservation practices, especially for land and agriculture management.

The most common model for large spatial scales at global, continental, country and regional levels is the empirical Revised Universal Soil Loss Equation (RUSLE) [20]. which estimates average annual soil loss due to raindrop splash and runoff over field slope [17]. Therefore, measurements taken on sampling field plots are the most accurate estimate of soil erodibility [12]. Yet, field measurements are costly and have low spatial transferability, and, therefore, authors investigated the relation between "classical" soil descriptors and soil erodibility. High soil erodibility factor can lead to little erosion even in naturally low soil [5]. The other factors are crop factor (C), slope length factor (LS), rainfall factor (R), soil erodibility factor (K), and control practice factor (P).

A = R.K.LS.C. P

The soil erodibility factor K is an expression of the relative susceptibility of a particular soil to erosion by water at different rates, where the other factors affecting erosion are under control. This is accounted for in the universal soil loss equation as A = R.K.LS.C. P [7]. Several equations have been proposed to estimate the soil erodibility and the most famous equation for it is the one developed by [28], [4] . Other equations, such as [29], require traits (such as bulk density) which are generally unavailable for predicting soil erodibility. The organic and chemical constituents of soil are significant in that they influence aggregate stability. In the 1990s, [21], [26] and [30] derived simpler equations where primarily soil texture was considered.

Erodible soils are those with an organic matter content of less than 2% [2]. Further, the soil organic carbon makes the soil more resistant to erosion through increase in aggregate stability, soil structure and retention of water. Surface roughness such as that caused by plant residues, soil clods, or irregularities reduces runoff and dampens the impact of raindrops, so the permissible erosion risk is reduced. The impact of these physical soil properties on soil erosion can be managed by land managers through activities such as maintaining vegetation cover, increasing the organic matter content of soils, and adopting conservation tillage.

Soil bulk density is also a physical property; it has a strong effect on soil erodibility: when the bulk density is high the soil particles are immobilized and pore space for water flow is reduced. With a smaller pore space, less rain can enter the soil [27]. Due to this, surface runoff increases which may cause higher soil erosion and less water access for plants. Higher bulk density enhances erosion risk, worsens runoff and limits infiltration. Conversely, low bulk density generally implies high porosity and runoff generation is influenced by soil permeability; that is, how readily water passes through the soil profile. Soils with low permeability retain much of the surface water, which increases the likelihood of erosion.

Objectives of the study:

1. Estimate the soil erodibility factor (K) for different soil types around Duhok Dam.
2. Investigate how selected soil physical and chemical properties -such as texture, structure, organic matter content, permeability, and bulk density - influence soil erodibility.
3. Develop a regression model based on easily measureable soil properties to calculate the K-factor, enabling erosion risk assessment without the need for costly and time -consuming field experiment.

Materials And Methods

Study Area and Preparation of Soil Sample in Fieldwork

The soil samples were collected and prepared directly from the fieldwork site, which is located in Duhok Governorate, Kurdistan region, Iraq near Duhok Dam, in one of the streams in which carried water to the lake of Duhok Dam. Twelve predetermined Points 1.7 km apart are GPS tagged (latitude and longitude) from commencement on Peromara road to end in Ghaziava Village. northwest of Duhok Dam (Table 1 and figure 1). Soil samples were collected from each site for soil physical and chemical analyses at a 0-30 cm depth. The samples were then air-dried, ground and sieved through a 2 mm sieve.

Table (1) The coordinates of the soil sampling locations in the study area using GPS.

Location	Latitude	Longitude	Elevation(m)
1	36.876579	43.000471	619
2	36.886657	42.991533	661
3	36.892307	42.993149	621
4	36.900197	42.99461	635

5	36.90887	42.992788	663
6	36.920097	42.988319	659
7	36.926253	42.984125	654
8	36.934373	42.976184	669
9	36.939567	42.973486	682
10	36.935885	42.964342	687
11	36.943283	42.93558	761
12	36.947019	42.933157	761

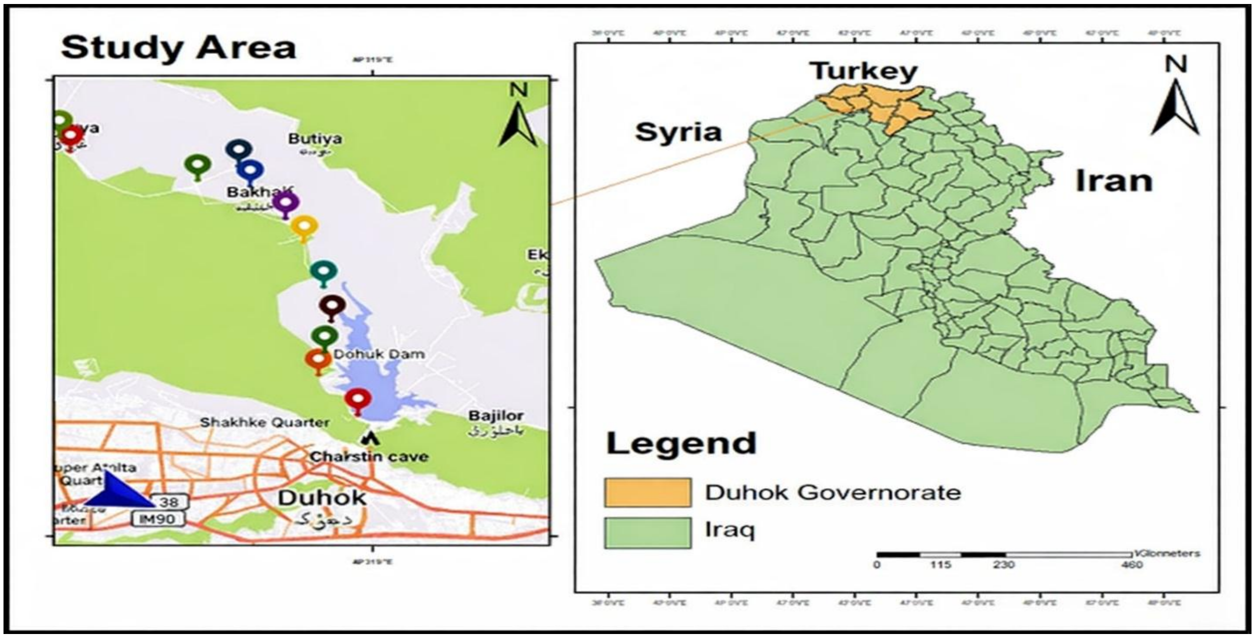


Figure (1) showing the location of the study area

Soil Physical And Chemical Analysis

The particle size analysis was carried out using hydrometer method [22] while bulk density was determined using wax paraffin coated clod method [1]. The soil structure was investigated by soil clods dropped from a height of (1) meter, and by analyzing their dimensions and broken subunits. Field test where a hole is filled with water and the time taken to empty tells us how permeable the soil [6] and Organic matter (OM) was determined according to the dichromate oxidization method [16] and erodibility depending on nomograph according to [9].

Results And Discussion

The data reveals that soil texture is a major factor affecting the erodibility (Table 2). Generally, according to the statistical analysis. Soil erodibility tends to be higher in soils with a high silt contenting a moderate amount of clay. It is also evident from Table 2 that the soil erodibility factor ranged from as low as (0.051) for the sample 5 to as high as 0.052 for sample 4. Overall, the soil erodibility factor averaged 0.040 metric units. It seems from the results of Table 2 that the silt content is the major contributor of soil erodibility fluctuation in the study area. This is in agreement with previous studies on silt particles tending to be more readily mobilized and transported by water runoff, as a result of their moderate size and cohesion [19]. On the other hand, higher sand-sized content samples like Sample 5 (57.25% sand) have slightly lower erodibility (K = 0.051) as sandy soils are generally better drained and less surface sealed even though they are more prone to detachment due to lower cohesiveness. Notably, Sample 2 (19.75% sand, 45.45% silt, 34.8% clay) has a relatively low K value (0.029), indicating that, for certain soil structure, high clay content (>30%) would potentially result in stronger aggregate stability and therefore lower erodibility. [25], enhanced cohesion and resistance to shear are the factors that normally reduce erodibility with increasing clay and plasticity index. Texture and structural stability are closely linked, so even a relatively clayey soil like Sample 12 (39.98% clay) can demonstrate moderately erodible properties if aggregate stability is reduced.

Table (2) Some Soil Physical and Chemical Properties of the Study Area													
No.	Texture					Structure		%O.M	Permeability			Rb g.cm^3	Permeability(K) (Mg.hr/Mj.mm)
	Sand%	Silt%	Clay%	V. FS %	Class	Class	Code		cm/hr.	Class	Code		
1	35.2	40	24.8	9.15	Loam	Med. granular	3	0.55	0.6613	Moderately Slow	3	1.349	0.047
2	19.75	45.45	34.8	4.35	Silty Clay Loam	Fine Granular	2	2.55	0.3887	Slow	2	1.278	0.029
3	12.25	50.45	37.3	2.57	Silty Clay Loam	Fine Granular	2	1.17	0.3809	Slow	2	1.257	0.031
4	37.25	45.45	17.3	10.06	Loam	Platy	4	0.35	1.3568	Moderately Slow	3	1.403	0.052
5	57.25	27.95	14.8	17.75	Sandy Loam	Platy	4	0.5	1.5624	Moderately Slow	3	1.450	0.051
6	50.2	30	19.8	15.06	Loam	Blocky	4	0.29	0.9413	Moderately Slow	3	1.399	0.051
7	29.75	45.56	24.79	7.44	Loam	Med. granular	3	2.07	0.7040	Moderately Slow	3	1.342	0.046
8	23.5	46.7	29.8	5.41	Clay Loam	Fine granular	2	3.45	0.5085	Moderately Slow	3	1.306	0.030
9	36	44.2	19.8	9.36	Loam	Fine granular	2	0.83	1.0513	Moderately Slow	3	1.383	0.044
10	47.25	35.45	17.3	13.70	Loam	Fine Granular	2	2.76	1.2511	Moderately Slow	3	1.416	0.040
11	46.25	26.45	27.3	12.95	Silty Clay	Fine granular	2	0.69	0.4738	Slow	2	1.349	0.030
12	24.30	35.72	39.98	5.83	Clay Loam	Fine granular	2	1.03	0.2754	Slow	2	1.264	0.034

Erodibility is also contingent on structure of the soil, granular and crumb having more stability against shear and platy and blocky ones having less aggregation (weaker soil) and erosion as a consequence. Granule (1-2 mm size) received a “good” rating for strong agglomeration and non-tendency of breakup. Conversely, blocky and platy (<10 mm) structure classes were very poor in ranking indicating low cohesion and high susceptibility to erosion. Soil erodibility is influenced in large part by soil structure, which influences aggregate stability, infiltration capacity, and binding forces restricting the erosion of particles. As can be observed from Table 2, medium structured (code 3) and fine structured (code 1 and 2) datasets, are in general presented with a lower erodibility. These attributes contribute to high aggregate stability and porosity, and thus to improved water infiltration and reduced surface runoff with the subsequent reduction of soil particle detachment and transport. Meanwhile, blocky and platy (code 4) formations generally have higher erodibility. Due to their horizontal organization, platy structures restrict vertical water movement and enhance surface sealing that leads to runoff and particle detachment. In the case of blocky buildings, erosion is exacerbated if the blocks are not well-compacted, as this leads to a lower cohesiveness, less resistance to shear forces [23].

Organic Matter as Attributing Component

The organic matter content differed substantially among the samples, with values that went from 0.29% to 3.45% (Table 2). Organic matter, which is one of the contributing factors to soil erodibility, was highest in granular and crumb structures, causing higher aggregate stability, more infiltration, and less surface runoff. There is an obvious negative correlation between K-value and OM content in the data. Permeability and Erodibility Permeability, which is a measure of the velocity of water entry into soil pores, is important for erodibility. For example, Samples 2 (2.55% organic matter) and 8 (3.45% organic matter) were found to have lower erodibility parameters, K = 0.029 and 0.030, respectively, while Samples 4 (0.35% organic matter) and 6 (0.29% organic matter) exhibited higher K-values, 0.052 and 0.051, respectively, that indicated greater susceptibility to erosion [10].

Permeability readings were ranged from 0.2754 cm/hr to 1.5624 cm/hr (slow). The result of this test demonstrate that the permeability of soil sample classified as "Moderately Slow" (Sample 5 with 1.5624 cm/hr. velocity and K = 0.052) have higher erodibilities than Sample 2 (0.3887 cm/hr. of the soils categorized as "Slow inefficient" (Sample = 2. and K = 0.029) (Table 2). This may indicate that although medium-type soils, for example, facilitate high infiltration, their detachment ability is also that much higher due to an absence of high surface sealing and high water flow that potentially may lead to aggregate disruption.

Statistical Analysis

K=-4.83 + 0.0443 Sand + 0.0437 Silt + 0.0455 Clay - 0.00271 % V. FS + 0.002575 Structure Code - 0.003392 %O.M + 0.01016 Permeability Code + 0.317 Rb g.cm^3

Based on several soil factors, soil erodibility factor (K) can be predicted by this regression equation. All three coefficients are positive: when the content of sand, silt and clay increases, the K value will also increase. The coefficient of V. FS sand (%) is negative, indicating that its higher proportions reduce K.

Table (3) illustrate the Correlation between soil properties and Erodibility (k)

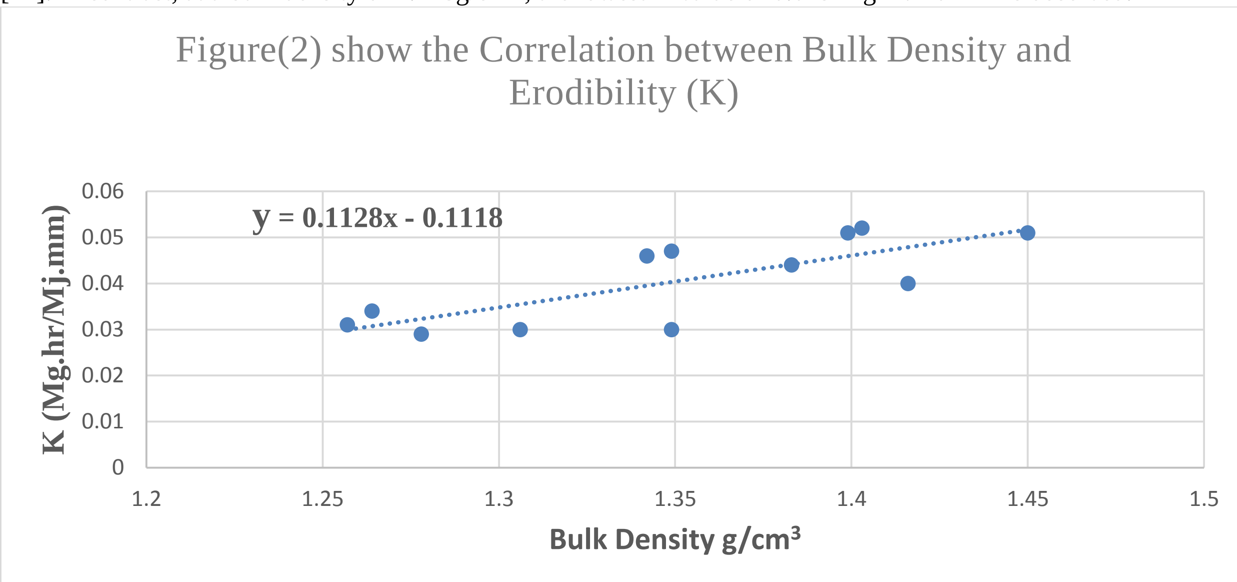
Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	-4.83	2.61	-1.85	0.161	
Sand	0.0443	0.0256	1.73	0.182	308720.47
Silt	0.0437	0.0257	1.70	0.188	111944.63
Clay	0.0455	0.0259	1.76	0.177	119970.24
% V. FS	-0.00271	0.00223	-1.21	0.312	276.02
Structure Code	0.002575	0.000933	2.76	0.070	3.37
%O.M	-0.003392	0.000805	-4.21	0.024	1.91
Permeability Code	0.01016	0.00279	3.65	0.036	4.82
Rb g.cm^3	0.317	0.138	2.29	0.106	195.39

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.0020736	98.60%	94.88%	67.92%

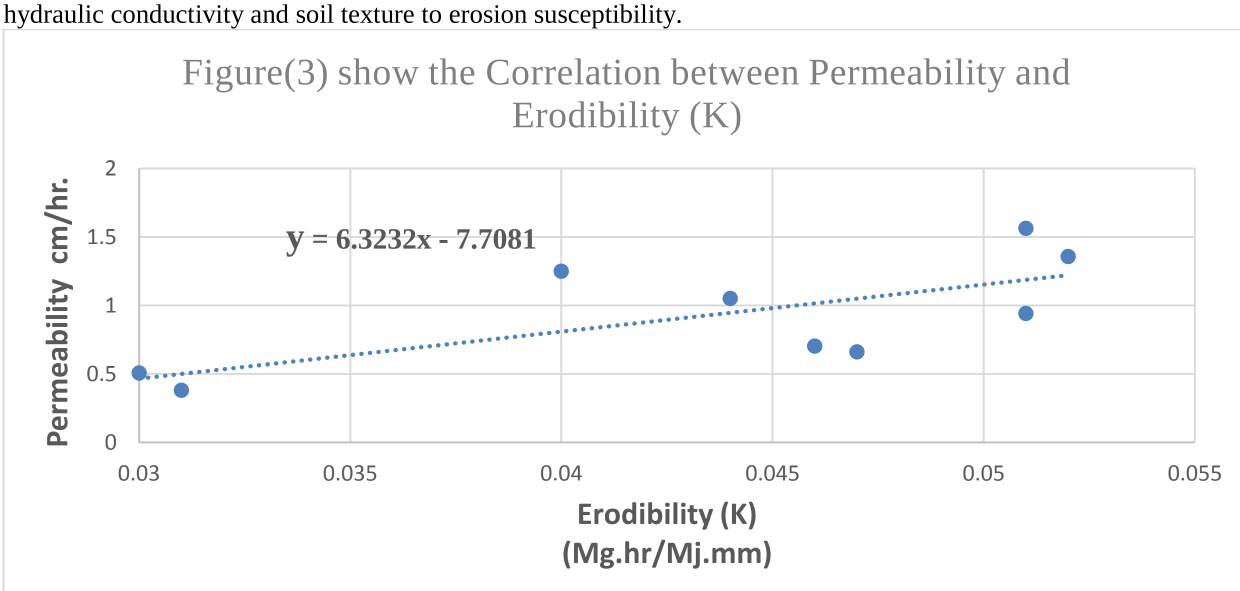
Relationships between bulk density and erodibility (K)

Relationship of bulk density with erosion is shown mainly in an inverse manner Table (2) and (Fig.2). As bulk density increases, k eroded tends to decrease. Minimum and maximum values of the bulk density are 1.257 and 1.45 g/cm³, respectively, which are linked with K values of 0.031 Mg·hr/MJ·mm and 0.051 Mg·hr/MJ·mm. At 1.403 g/cm³ the maximum K value was measured as 0.052 Mg·hr/MJ·mm, which shows that higher-density can give less erosion [14]. In contrast, at a bulk density of 1.278g/cm ^{3}, the lowest K value of 0.029 Mg·hr/MJ·mm is observed.



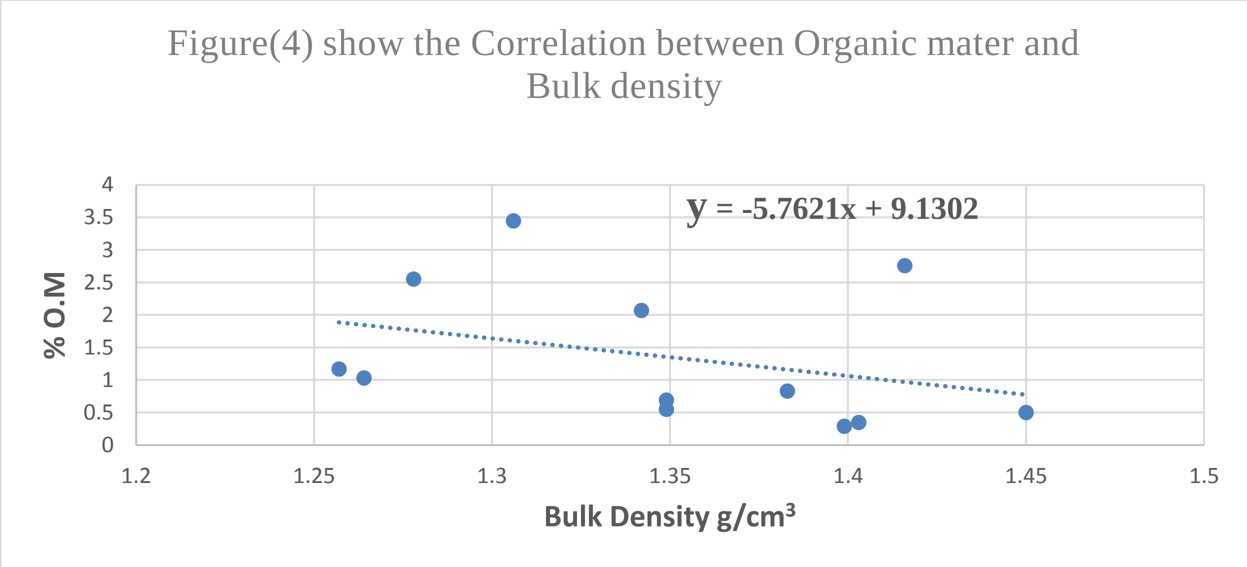
Relation between permeability and erodibility (K)

Figure 3 shows a positive correlation between permeability and soil erodibility. Soils with high permeability, often with sand texture, tend to be high erodible due to their weak structure and low cohesion. In contrast, soils with low permeability, typically clayey, are more resistance to detachment. This relationship is supported by [13], who linked hydraulic conductivity and soil texture to erosion susceptibility.



Relationship between organic matter and bulk density.

The apparent relationship between organic matter and bulk density is also the case. These data indicate that larger permeability may be a signature of increased erodibility in some cases. Bulk densities were generally lower in more organic soils. The organic matter content of 1.17% is related to the 1.257 g/cm³ lowest observed bulk density, while the content of 0.35% is related to the 1.45 g/cm³ highest observed bulk density. The organic matter value was 3.45% at bulk density of 1.306 g cm^{-3} and 0.29% at bulk density of 1.342 g cm^{-3}. These findings further reveal that organic matter mitigates soil compaction leading to a decline in bulk density and an enhancement of soil structure [10].



Recommendations

1) Manage soil permeability and bulk density by preventing compaction, increasing infiltration, and maintaining vegetation cover to reduce surface runoff and erosion susceptibility
2) Use GPS-referenced data and predictive modelling to identify erosion-prone areas and implement site-specific measures, such as contour farming, vegetative buffers, and conservation tillage
3) Monitor Soil Physical Condition.
4) Improve infiltration vegetation cover to reduce surface runoff and erosion susceptibility by avoiding compaction and managing soil permeability and bulk density.

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تأثير الخصائص الفيزيائية للتربة والمادة العضوية على قابلية التربة للتعرية في الحوض الفرعي لسد دهوك

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الخلاصة

تُعدّ تعرية التربة عائقًا رئيسيًا أمام تحقيق الاستخدام المستدام للأراضي، لا سيما في المناطق شبه الجافة التي تتميز بتنوع في أنواع التربة. تهدف هذه الدراسة إلى تقييم معامل قابلية التربة للتعرية (***K***) في اثني عشر موقعًا للعينات ضمن منطقة سد دهوك (إقليم كردستان، العراق). وقد تم التحقيق في تأثير الخصائص الفيزيائية والكيميائية الرئيسية للتربة، بما في ذلك الكثافة الظاهرية، النفاذية، المادة العضوية، والخصائص الهيكلية والنسيجية لهذه العينات. أظهرت نتائج التحاليل الى أن محتوى المادة العضوية ونسجة التربة هما العاملان الرئيسيان في التحكم بمعامل ***K*** تحت أنماط استخدام الأراضي المختلفة. كما تبين أن الحساسية للتعرية تنخفض مع زيادة المحتوى الطيني في التربة، في حين أن الترب الرملية تُظهر قابلية أكبر للتعرية نتيجة لانخفاض نفاذيتها. تم التنبؤ بقيم ***K*** باستخدام نموذج انحدار يفسر 98.66% من التباين الكلي (***R^2 = 98.6%***). وقد تبين أن زيادة الكثافة الظاهرية والنفاذية تؤثر بشكل متباين على قابلية التربة للتعرية. كما أظهرت الدراسة وجود علاقات ارتباط مهمة بين الكثافة الظاهرية، معامل التعرية (***K***)، النفاذية، ومحتوى المادة العضوية، مما يوفر معلومات مفيدة حول سلوك التربة وخصائصها المتعلقة بالتعرية. تشير الى ان العلاقة إيجابية بين معامل التعرية والكثافة الظاهرية و إلى أن الترب الأكثر كثافة تكون أكثر عرضة للتعرية، ربما بسبب انخفاض المسامية فيها مما يؤدي إلى زيادة الجريان السطحي. ومن المثير للاهتمام أيضًا أن زيادة قابلية التعرية ترتبط بزيادة نفاذية التربة، مما يعزز حركة المياه ويُسرّع من عملية انفصال ونقل الجزيئات. من ناحية أخرى، أظهرت الكثافة الظاهرية علاقة سلبية مع محتوى المادة العضوية، مما يدل على أهمية المواد العضوية في الحفاظ على بنية التربة الجيدة وتقليل الانضغاط. وتؤكد هذه النتائج على الترابط بين الخصائص الفيزيائية للتربة وتأثيرها المشترك على تدهور الأراضي، مما يستدعي اعتماد استراتيجيات متكاملة لإدارة التربة تهدف إلى الحد من خطر التعرية في المناطق الهشة.

الكلمات المفتاحية: قابلية التربة للتعرية، التعرية، نسجة التربة، المادة العضوية، النفاذية، والكثافة الظاهرية.