Available online at:
http://journal.unila.ac.id/index.php/tropicalsoil
DOI: 10.5400/jts.2025.v30i1.25-35

Spatial Simulation of The Organic Carbon Content and its Effects on the Erodibility and Soil Erosion with Universal Soil Loss Equation and Geographic Information Systems

Yagus Wijayanto*, Julvia Nurlaeli Firmawati, Ika Purnamasari and Suci Ristiyana

Faculty of Agriculture University Jember, Jl. Kalimantan, Jember-68121, Indonesia
**e-mail: yaguswijayanto001.faperta@unej.ac.id*

Received 26 April 2024, Revised 01 July 2024; Accepted 03 September 2024

ABSTRACT

Universal Soil Loss Equation (USLE) and Geographical Information Systems are two spatial soil erosion analysis models because both have a spatial context. As an important factor, soil erodibility is crucial in determining soil erosion, with C-organic significantly influencing the K value. The main aim of this study is to characterize soil erodibility and soil loss based on spatial simulation of the effects of soil C-organic in a GIS environment. Research findings indicated that by simulating within a GIS environment, C-organic can affect soil erodibility and erosion. Low C-organic levels can increase soil erodibility, while high C-organic levels can decrease it. A reduction in C-organic by 10%, 20%, and 30% will increase K by 1.10%, 1.17%, and 1.21%, respectively. Conversely, adding 10%, 20%, and 30% C-organic will decrease K by 1.12%, 1.27%, and 1.46%, respectively. A 10%, 20%, and 30% increase in C-organic can reduce soil loss by 1.2%, 1.3%, and 1.5%, while a reduction in C-organic will increase soil loss by 1.1%, 1.2%, and 1.3%, respectively. A low K value indicates slight erosion, while a high K value suggests high erosion. Continuous C-organic and properly managing vegetation are necessary to maintain and improve soil quality.

Keywords: C-organic, Soil Erodibility, Soil Erosion, Spatial, USLE

INTRODUCTION

Soil erosion (SE) profoundly impacts agriculture and industry, resulting in decreased soil fertility, ecological degradation, and damage to soil and water. As a global issue, erosion has contributed to land degradation and a decline in ecosystem services and poses a serious threat to public health safety (Fiantis et al., 2022; Mishra et al., 2022). The total amount of SE resulting from changes in land usage has risen by 2.5% from 2001 to 2012. Indonesia, in particular, faces the most severe SE globally, causing extensive ecological limitations and severely hampering regional socio-economic development (Fiantis et al., 2022). The key to making macroscopic decisions for soil erosion control and conservation lies in predominantly quantitative examinations of soil erosion, factors, and the analysis of its spatial distribution (Panagos *et al.*, 2022). Various approaches have been developed for assessing soil erosion. Quantitative models enable numerical estimation of erosion and may encompass direct or indirect assessment methods. Direct assessment involves field measurements on erosion-prone plots or the measurement of variables such as sediment in runoff water, often extrapolated to homogeneous areas using rainfall simulators (Borrelli *et al.*, 2017). Indirect assessment methods involve simplified models representing reality, with statistical, physical, and parametric models falling within this category.

The universal soil loss equation (USLE) and its application within Geographical Information Systems (GIS) is the main focus of the study conducted by Helmi (2023), with the main aim of providing sediment estimation. The USLE model for predicting soil loss has been evident in the study conducted by Pham, Degener, and Kappas (2018) by considering all factors in The Universal Soil Loss Equation (R, K, LS, C, and P). The results showed different soil loss for each land use, with the lowest in the forest area and the highest in agricultural land. These factors contribute to notable variations between observed erosion rates and estimates derived from the USLE model. The choice of the USLE model in this research is primarily driven by its widespread use and relative simplicity in assessing soil loss due to sheet and furrow erosion, incorporating the influences of precipitation, soil texture, topography, soil cover or land use, and conservation practices on soil loss estimates.

One of the most important factors of soil loss in the USLE equation is soil erodibility (K), and one of the most influential factors of K is Soil Organic Carbon (C-organic). According to Georgiou et al. (2022) and (Kriuchkov & Makarov, 2023), soil organic carbon (C-organic) plays a crucial role in influencing soil erosion, and its effects can be both protective and influential in the erosion process: (a) C-organic contributes to the formation and stability of soil aggregates; (b) C-organic enhances the water-holding capacity of soils and improves water infiltration. Soils with higher organic carbon content are generally more resistant to surface runoff, reducing the potential for water erosion; (c) Organic carbon supports the growth of vegetation, and plant roots play a significant role in stabilizing soil against erosion; (d) Organic carbon can help prevent the formation of surface crusts on the soil. Soil crusts can impede water infiltration, increasing surface runoff and erosion; (e) Incorporating organic matter can protect the soil from raindrops' impact and reduce water's erosive forces. Relating soil loss and C-organics can become a fascinating study due to the direct and indirect effects of C-organics on soil erosion. Therefore, the main aim of this study is to characterize spatial soil loss and study the effects of C-organic on soil loss through spatial simulation using GIS.

MATERIALS AND METHODS

This research was conducted by analysing maps and field data and performing laboratory analysis to obtain supporting data to determine the erosion potential in the Bedadung Watershed, Panti Sub-district. This study was broadly conducted in 5 stages: (1) Preparation Stage, (2) Field Survey Stage, (3) Soil Sampling Stage, (4) Soil Sample Analysis Stage, and (5) Data Analysis Stage.

Preparation Stages

Provision of Map Materials

Indonesian Topographic Map: The 2019 Topographic Map of Jember Regency was obtained from indogeospasial.com at a scale of 1:25,000. This digital base map is the foundation for determining administrative boundaries that can be overlaid with other maps. Land Cover Map: The land cover map was obtained by overlaying data from various land cover sources on the topographic map for the year 2019. Soil Type Map:The soil type map was obtained through georeferencing soil type data. The soil type data for the Jember Regency used in this study was obtained from BBSDLP 2017. Land Slope Map: The land slope map was obtained from DEMNAS (National Digital Elevation Model) data, which has precision files with an accuracy of about 10 meters.

Land Unit Map

The work map is a land unit (SPL) created to determine sample points and collect soil samples. The land unit map is obtained through an overlay of land cover, soil type, and land slope maps. Sample points on the land will be determined after the SPL has been successfully created. Secondary data is also collected simultaneously with the creation of the SPL. The secondary data collected includes rainfall data obtained from the Regional Agency for Water Resources and Spatial Planning (DPU BMSDA) of the Jember Regency.

Field Survey Stage

Field surveys are conducted to understand the area's conditions before data collection and to verify the Land Unit Map (LUM). They are carried out by visually observing and documenting observations in the field, collecting supporting information, and determining the locations for soil sample collection.

Soil Sampling Stage

Soil sampling is based on the sample points that have been created. Sample points are determined using the stratified random sampling method based on LUM. The GPS Garmin and UTM Geo Maps assist in reaching observation points. Soil samples are taken at a depth of 20–30 cm.

Soil Sample Analysis Stage

Soil sample analysis determines the physical and chemical properties used to determine the soil erodibility value. The soil physical and chemical properties analysis for determining soil erodibility includes soil texture analysis, soil permeability analysis, organic carbon content analysis, and soil structure analysis.

Data Analysis Stage

Rainfall Erosivity Factor (R)

Putri et al. (2023) stated that rainfall erosivity is rain's ability to erode the soil surface's upper layer, causing erosion. The rainfall erosivity factor uses monthly rainfall data for the last 10 years from several stations around the research area. The erosivity value is calculated using the Bols equation (1978) (Nasjono, Hangge, and Kelen, 2022):

$$Rm = 6{,}119\ (R)^{1,21} \times (D)^{-0,47} \times (M)^{0,53}$$

In this case:
Rm = Monthly Rainfall Erosivity Index
R = Average Monthly Rainfall (cm)
D = Number of Rainy Days per Month (days)
M = Maximum Monthly Rainfall (cm)

Soil Erodibility Factor (K)

Soil erodibility analysis is obtained from calculating soil samples that have been analyzed using the required method. Then, the resulting values are calculated using the Wishmeier and Smith equation (1978) in (Belasri & Lakhouili (2016) and Table 1 as follows (Injiliana,Widiastuti and Riyono, 2021):

$$100K = 2.1 \times M^{1.14} (10\text{-}4) (12\text{-}a) + 3.25 (b\text{-}2) + 2.5 (c\text{-}3)$$

In this case:
K = Soil erodibility
M = Particle Size (% fine sand + % silt) × (100 - % clay)
a = Organic matter content
b = Soil structure class
c = Soil permeability class

Length and Slope Factor (LS)

The slope map is obtained by analysing DEMNAS data using spatial analyst features (slope) and then classified into slope classes based on the Department of Forestry to obtain the slope map. The following equation, created by Christian and Stewart (1968) in (Belasri & Lakhouili, 2016), calculates the LS value, and the Table shows the results.

$$L = (L/22.13)^{m}$$

where:
L = slope length in meters
m = slope coefficient, which depends on the slope gradient

The slope steepness factor S represents the effect of slope steepness on soil erosion. The equation for calculating the S factor is:

$$S = 0.065 + 0.045 \tan(\theta) + 0.006\tan(\theta)^{2}$$

Where:
θ = Slope gradient in degrees (the angle of the slope).

In order to calculate the LS factor, the formula used is :

$$LS = L \times S$$

Where L and S was calculated from the above formula

Crop Management Factor (C) and Conservation Practice Factor (P)

The crop management factor (C) depends on the type, combination, density, harvest, and crop rotation within one year. Based on observations, the values of C and P will be assigned to LUM to obtain the crop management factor (C) and Conservation practice (P) values by using Table 2 (for C values) and Table 3 (for P values) below.

Analysis of Erosion Hazard Level

The erosion hazard level is calculated using the USLE equation to obtain the erosion rate measured in Mg ha^{-1} year^{-1}. The steps involved include inputting the rainfall erosivity map, soil erodibility map, slope length and slope factor map, and the crop management and conservation map into QGIS. The next step is to analyse these maps using the USLE method through the Raster Calculator to obtain the erosion rate values. The final step is to determine the erosion hazard level according to the erosion hazard classification table and calculate the area for each erosion hazard class obtained. Table 4 was used to calculate erosion hazard.

Table 1. Soil K Value Classification.

Soil Erodibility Class	Range of K Values	Criteria
1	0.00 – 0.10	Very low
2	0.11 – 0.21	low
3	0.22 – 0.32	Intermediate
4	0.33 – 0.44	Slightly high
5	0.45 – 0.55	High
6	0.56 – 0.64	Very high

Table 2. The Value of Vegetation Factors in Crop Management.

No.	Types of use	Vegetation factor (C)
1	Open ground	1.0
2	Ricefield	0.01
3	Moor	0.7
4	Cassava	0.8
5	Corn	0.7
6	Soya bean	0.399
7	Potato	0.4
8	Peanuts	0.2
9	Paddy	0.561
10	Sugarcane	0.2
11	Banana	0.6
12	Vetiver	0.4
13	Bede grass (first year)	0.287
14	Bede grass (second year)	0.02
15	Coffee	0.6
16	Rubber	0.6
17	Taro	0.85
18	Mixed gardens: - high density	0.1
	- medium density	0.2
	- low density	0.5
19	Farming	0.4
20	Natural forest: - lots of litter	0.01
	- less litter	0.05
21	Production forest: - clear cutting	0.5
	- selective cutting	0.2
22	Shrubs	0.3
23	Rotating tumpeng plant pattern + straw mulch	0.08
24	Sequential plant pattern + mulch of plant residues	0.357
25	Pure reeds are fertile	0.001

Table 3. P Factor Value in Soil Conservation Activities.

No	Soil Conservation Techniques	P
1	Bech Terrace:	
	a. Good Construction	0.04
	b. Moderate Construction	0.15
	c. Less-than-Good Construction	0.35
	d. Traditional Terrace	0.40
2	Bahia Grass Strip Planting	0.40
3	Contour plowing:	
	a. Slope 0 – 8%	0.50
	b. Slope 9 – 20%	0.75
	c. Slope > 20%	0.90
4	Estate Crops:	
	a. With densed crop cover	0.10
	b. With quite a densed cover	0.50
5	Without any conservation measures	1.00

Table 4. Erosion Hazard Classification.

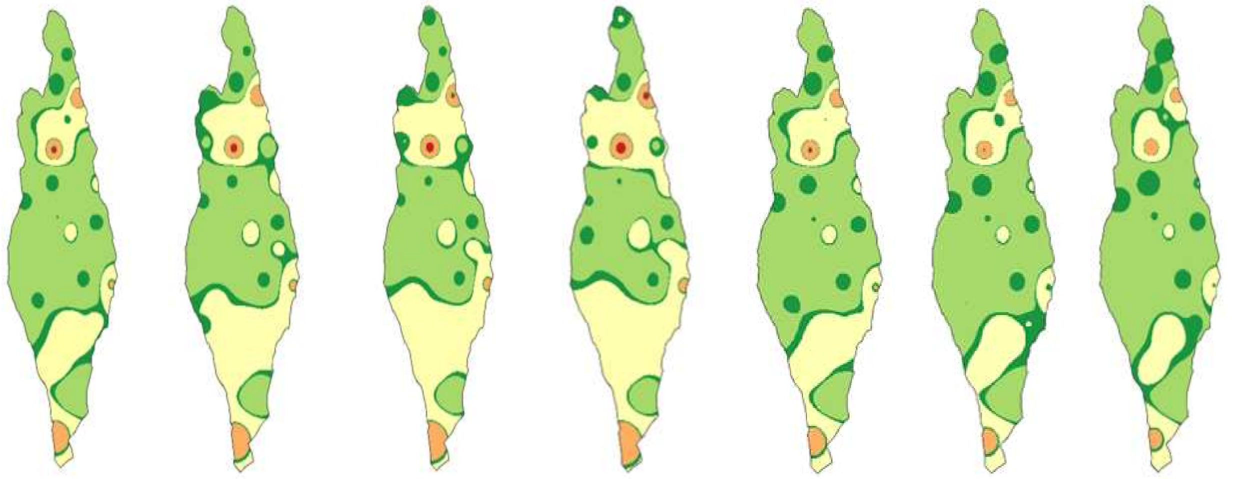
No	Erosion hazard class	Erosion rate	Explanation
1	I	<15	Very Low
2	II	15 – 60	Low
3	III	60 – 180	Medium
4	IV	180 – 480	Heavy
5	V	>480	Very Heavy

RESULTS AND DISCUSSION

The Relationship between C-organic Values on Soil Erodibility (K)

The calculation of soil erodibility value (K) involves the physical and chemical properties of the soil, one of which is organic matter calculated from the C-organic content of the soil. The reason for analysing the relationship between C-organic Values and the K values is that there is a relationship between these two soil properties. The difference in C-organic content in the soil will affect the resulting K value. As shown in Figure 1, the reduction in the C-organic content of the soil can increase the soil erodibility value. In contrast, increasing the C-organic content can decrease the soil erodibility value (Figure 1). Increasing the C-organic content of the soil can decrease the soil erodibility value in terraced and non-terraced paddy fields (Arunrat *et al.*, 2022). The reduction in C-organic can increase the area of high K values from an initial area of 5.54 hectares to 9.87 hectares (-10%), 15.25 hectares (-20%), and 24.42 hectares (-30%). The area of the highest K value also decreases with the addition of C-organic, becoming 1.73 hectares (+10%) and ultimately diminishing with 20% and 30% C-organic additions (Table 5).

Salih et al. (2023) explain that various factors, such as soil texture and the percentage of C-organic content in the soil, influence the soil erodibility value. C-organic presence in the soil is crucial for sustainable soil health processes because organic carbon is an essential component of agroecosystems (Ramesh *et al.*, 2019). C-organics stored in the soil profile vary due to factors such as plant roots and soil biota (Chertov *et al.*, 2017). Other factors influencing the amount of C-organic in the soil include soil type, topographical conditions (Cardinael *et al.*, 2017), land use and management, and soil sampling depth (Li *et al.*, 2017). Differences in C-organic soil values are related to changes in soil biogeochemical properties, such as soil aggregate damage and formation, erosion of C-organic, and soil layer shifting (Xiao *et al.*, 2018). Effective land use and management are evaluated to increase soil



K-Normal -10% C-org -20% C-org -30% C-org +10% C-org +20% C-org +30% C-org

Figure 1. Spatial distribution of erodibility in study area. K Factor 🟩 : 0 - 0.10 (very low), 🟩 : 0.11 - 0.21 (low), 🟨 : 0.22 - 0.44 (medium), 🟧 : 0.33 - 0.44 (a bit high), 🟥 : 0.45 - 0.55 (high).

Table 5. Area of erodibility factor in the study area.

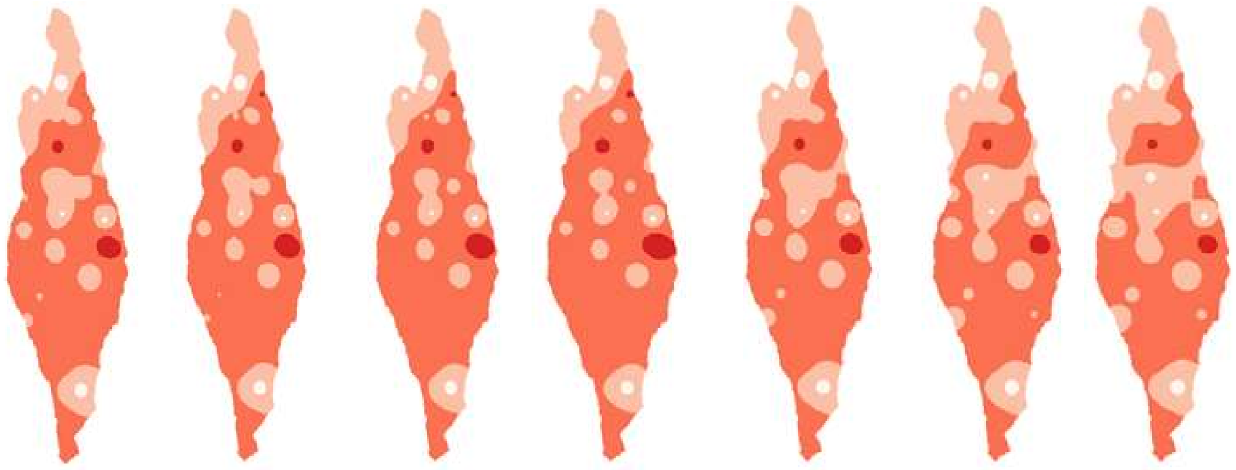
Class	Area of erodibility factor (Ha)						
	Normal	-10%	-20%	-30%	+10%	+20%	+30%
Very low	866.69	1004.24	906.91	850.09	895.46	1051.16	1162.89
Low	4632.14	3493.52	3155.77	2818.55	4409.92	4684.25	4931.04
Medium	1740.77	2699.75	3077.33	3443.32	1974.41	1576.59	1248.20
A bit high	221.34	259.10	290.79	330.10	184.97	154.49	124.36
High	5.54	9.87	15.25	24.42	1.73	-	-
Total	7466.49	7466.49	7466.49	7466.49	7466.49	7466.49	7466.49

C-organic content. Soils with high C-organic also have stable soil aggregates, enhancing soil resistance to erosion.

Quijano et al. (2017) state that soil C-organics are one of the soil's chemical properties that play a crucial role in soil fertility. C-organic presence in the soil impacts physical parameters, such as water retention and soil aggregate stability (Ramesh *et al.*, 2019). The high or low content of C-organic in the soil can affect the soil erodibility value. The organic carbon content in the soil and the mechanical composition of the soil are key parameters used to characterize soil erodibility values (Huang *et al.*, 2022). High C-organic content can increase microorganism populations and improve nutrient availability, reducing land degradation and suppressing erosion potential. C-organics in the soil are also determinants of soil mineral quality, where higher C-organic levels indicate better soil quality, resulting in lower soil erodibility values. Low C-organic content can lead to instability in soil aggregates, increasing soil erodibility values. High soil erodibility indicates that the soil is more vulnerable to erosion, while low erodibility values indicate that the soil is more resistant to erosion (Salih, Keya, and Mohammed, 2023).

The Effect of Soil Erodibility Factor (K) on Soil Erosion (A)

Predicting soil loss using the Universal Soil Loss Equation (USLE) involves calculating rainfall erosivity, soil erodibility, slope steepness, and conservation and crop management practices. Soil erodibility is a crucial factor in soil loss calculations because the erodibility factor (K) is related to the physical and chemical properties of the soil. Accurate quantification of the soil erodibility factor plays a significant role in soil erosion modeling (Efthimiou, 2020). The soil's C-organic content influences the soil erodibility value and is also related to the predicted soil loss. As shown in Figure 2, reducing C-organic content increases the soil erodibility value, thus elevating the soil loss. Conversely, increased C-organic content reduces



K-Normal -10% C-org -20% C-org -30% C-org +10% C-org +20% C-org +30% C-org

Figure 2. Spatial distribution of soil loss in study area. A class □ : < 15 (very low), ■ : 15 - 60 (low), ■ : 60 -180 (medium), ■ : 180 - 480 (heavy).

Table 6. Area of soil loss in the study area.

Klasifikasi	Area of Soil Loss (Ha)						
	Normal	-10%	-20%	-30%	+10%	+20%	+30%
Very Low	99.59	93.01	87.64	82.10	106.70	121.94	137.70
Low	2299.69	2096.69	1940.11	1795.83	2497.01	2744.12	3051.04
Medium	4930.02	5115.35	5254.73	5378.95	4745.51	4502.28	4196.64
High	137.19	161.44	184.00	209.61	117.28	98.15	81.12
Total	7466.49	7466.49	7466.49	7466.49	7466.49	7466.49	7466.49

the soil erodibility value, decreasing soil loss. Soil loss values (A) in the research area are dominated by the moderate class, followed by light, heavy, and very light classes. A reduction in C-organic content can be observed with an increase in the area of heavy points, starting from an initial area of 137.19 hectares and expanding to 161.44 hectares (-10%), 184 hectares (-20%), and 209.61 hectares (-30%). The area of heavy points also decreases with the addition of C-organic, reducing to 117.28 hectares (+10%), 98.15 hectares (+20%), and 81.12 hectares (+30%) (Table 6).

Kirkels et al. (2014) state that soil erosion can affect the C-organic content of the soil. The dynamics of soil C-organic are influenced by soil erosion, indicating that heavy soil erosion corresponds to low C-organic content and high soil erodibility values. Factors influencing erodibility include soil nutrients, texture, soil type, topography, and human activities. Variable erodibility values are observed based on natural parameters such as rainfall, topography, and anthropogenic influences (Xiao *et al.*, 2014). Another significant factor influencing soil erodibility is vegetation and the duration of growth. The type of vegetation and biomass patterns in the soil affect organic carbon accumulation, generating variables that indicate soil resistance to erosion (Huang *et al.*, 2022).

Reducing soil organic carbon (C-organic) content can increase the soil erodibility value. Figure 3 illustrates that higher soil erodibility values correspond to greater soil loss and increased vulnerability to erosion. Soils with high erosion risk have high soil erodibility values. High soil erodibility makes the soil susceptible to erosion, leading to nutrient loss and soil fertility decline (Tunç, 2020). Soils with medium fine and medium texture are highly vulnerable to erosion, resulting in high erodibility values. Medium fine and medium-textured soils consist of easily detachable soil particles, accelerating surface runoff (Efthimiou, 2020). Low soil aggregates can elevate soil erodibility values,

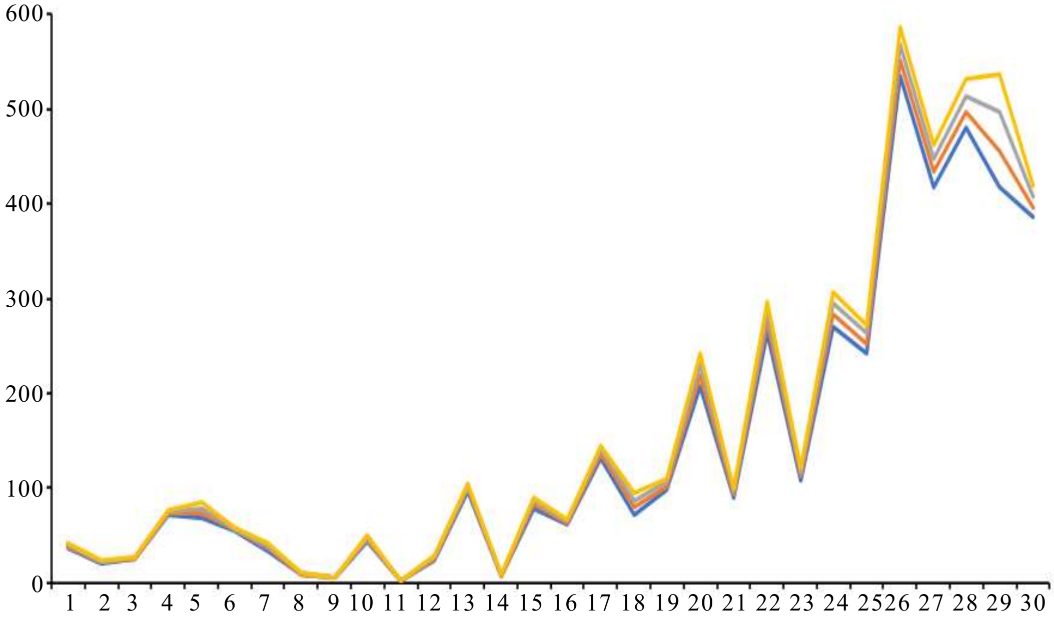


Figure 3. Correlation between K factors (-SOC) and A factors. ▬ : A (Normal), ▬ A (-10%), ▬ A (-20%), ▬ A (-30%).

making the soil more susceptible to erosion. Soils predominantly composed of clay have low infiltration capacity and tend to close surface pores, resulting in high erodibility values and easy soil erosion (Benslama et al., 2020).

The high soil erodibility factor that causes elevated soil loss values must be addressed and mitigated. High soil erodibility indicates the high amount of soil lost due to erosion (Ostovari *et al.*, 2019). Several actions can be taken to minimize soil loss, such as improving soil structure and texture, increasing soil organic carbon content, and employing appropriate soil management practices. Cebel et al. (2013) emphasize that actions to reduce soil loss include increasing soil organic carbon content and improving soil structure. Other measures for erosion-prone soils include enhancing soil structure, increasing hydraulic permeability, raising organic matter content, and preventing damage to vegetation. Long-term erosion control can be done by conserving vegetation cover and replanting vegetation (Tsegaye, Addis, and Hassen, 2019).

Efthimiou (2020) states that the soil erodibility factor (Factor K) is a parameter indicating the vulnerability of soil to erosion caused by climate factors such as surface runoff and rainfall. The data graph illustrates that low soil erodibility values can decrease soil loss, making the soil more resistant to erosion (Figure 4). An increase influences the decrease in soil erodibility in soil organic carbon. Changes in soil erodibility values are influenced by soil climate, structure, and land use (Alaboz et al., 2021). Particle size in the soil is an important soil property related to various soil factors. Soil particle size can affect soil properties such as stability and structure, nutrient and water retention, soil porosity, and soil organic carbon (Deiss et al., 2017; Yang, Yang, and Lu, 2019). Soil organic carbon can improve soil structure, enhance soil cation exchange capacity, and support water retention. Therefore, increasing C-organic can reduce soil erodibility values, thus decreasing soil loss. C-organic is mainly found near the soil surface (Pereira *et al.*, 2018).

Amundson et al. (2015) state that soil erosion is the primary global water and food security threat. Soil erodibility is a crucial parameter for predicting erosion and soil conservation management. Soil factors influencing soil erodibility values include soil texture and structure, soil organic matter, and soil permeability (Liu et al., 2020). Soil aggregates are always associated with soil organic carbon, where soil aggregates are bound by soil organic matter in forming soil structure. Water-resistant soil structure prevents soil erosion (Alaboz et al., 2021). Soils with high clay content can reduce soil erodibility values. Soils with a high clay particle content are erosion-resistant due to their rich organic matter content (Okorafor, Akinbile, and Adeyemo, 2018). Strong clay particle adhesion forms complex humus clay, facilitating soil aggregate formation and reducing soil erodibility values (Othmani et al., 2023). Low erodibility implies low soil vulnerability to hydrological processes, making the soil more resistant to detachment and transport (Eleyowo & Amusa, 2021).

From the above discussion, it is clear that soil organic carbon is crucial for soil fertility and

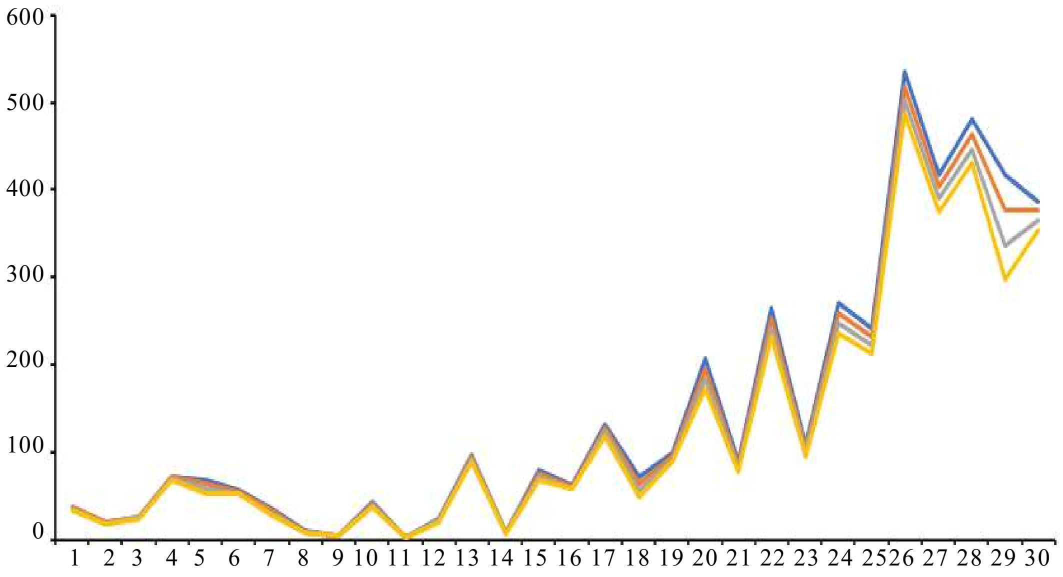


Figure 4. Correlation between K factors (+SOC) and A factors. — : A (Normal), — A (-10%), — A (-20%), — A (-30%).

resilience (Padarian et al., 2022). As a dynamic property, changes in soil organic carbon significantly affect soil erodibility values. Low levels of soil organic carbon increase soil erodibility, making the soil more prone to erosion, while high levels decrease it (Radziuk & Switoniak, 2021). In regions like the Oasis basin as Selmy et al. (2021) show, increasing organic carbon content can reduce soil vulnerability by enhancing water infiltration.

Jhon et al. (2020) highlight that soil organic carbon is a key indicator of soil quality and fertility. High organic carbon levels benefit soil health, fertility, and biota and help reduce soil erosion (Balaji, 2023). Conversely, low organic carbon levels can increase erosion rates, making it essential to add organic matter to minimize soil loss (Purba, Puja, and Sumarniasih, 2021).

Rehman et al. (2022) explain that soil erodibility, a soil's resistance to erosion, is influenced by soil type, structure, texture, permeability, and organic carbon content. Understanding these factors is crucial for measuring soil erosion rates and planning conservation activities (Liu, Zhang, and Li, 2020). Low soil erodibility values indicate good resistance to erosion, while high values mean the soil is easily eroded, increasing vulnerability (de Lima et al., 2022). Maintaining or increasing soil organic carbon content improves soil structure, enhances water infiltration, and reduces soil erodibility and erosion.

CONCLUSIONS

Soil erosion is a significant issue for maintaining soil quality. As demonstrated in the results and discussion, C-organic is one of the soil chemical properties that plays a crucial role in soil fertility and resilience. C-organics in the soil influence soil erodibility, which then affects the prediction of soil loss using the Universal Soil Loss Equation (USLE). A decrease in the C-organic content in the soil can increase the soil erodibility value, indicating that the soil is becoming more susceptible to erosion. An increase in C-organic content in the soil signifies that the soil quality is in good condition, thereby reducing the soil erodibility value and enhancing soil resistance to erosion. However, the type of organic matter, the rate of application, the state of the soil, the activity of microorganisms, and the methods used in soil management all affect the rate of increase. As decomposition and stabilization processes continue, initial increases in C-organic can usually be seen within months to a year, with more notable improvements occurring over a period of one to three years. Since the full benefits take years or even decades to manifest, regular application of organic materials and efficient soil management techniques are essential. Consequently, it is essential to gradually raise soil C-organic levels to reduce soil erosion and enhance soil quality. In addition, it is critical to put in place efficient conservation measures.

ACKNOWLEDGMENT

The authors would like to thank the Department of Highways, Environment, and Water Resources of Jember Regency for assisting in completing the required data. The author would also like to thank the Laboratory of Soil Physics and Chemistry, Faculty of Agriculture, University of Jember, for helping to analyse the data. The researcher also expressed his gratitude to all parties who have supported and contributed to this research.

REFERENCES

Alaboz, P., Dengiz, O., Demir, S., & ªenol, H. (2021). Digital mapping of soil erodibility factors based on decision tree using geostatistical approaches in terrestrial ecosystem. *CATENA*, *207*, 105634. https://doi.org/10.1016/j.catena.2021.105634

Belasri, A., & Lakhouili, A. (2016). Estimation of Soil Erosion Risk Using the Universal Soil Loss Equation (USLE) and Geo-Information Technology in Oued El Makhazine Watershed, Morocco. *Journal of Geographic Information System*, *08*(01), 98–107. https://doi.org/10.4236/jgis.2016.81010

Br Purba, Y. S., Puja, I. N., & Sumarniasih, M. S. (2020). Erosion prediction and conservation planning in the bubuh sub-watershed, Bangli Regency. *Water Conservation and Management*, *4*(2), 103–105. https://doi.org/10.26480/wcm.02.2020.103.105

Cardinael, R., Chevallier, T., Cambou, A., Béral, C., Barthès, B. G., Dupraz, C., Durand, C., Kouakoua, E., & Chenu, C. (2017). Increased soil organic carbon stocks under agroforestry: A survey of six different sites in France. *Agriculture, Ecosystems & Environment*, *236*, 243–255. https://doi.org/10.1016/j.agee.2016.12.011

Chertov, O., Shaw, C., Shashkov, M., Komarov, A., Bykhovets, S., Shanin, V., Grabarnik, P., Frolov, P., Kalinina, O., Priputina, I., & Zubkova, E. (2017). Romul_Hum model of soil organic matter formation coupled with soil biota activity. III. Parameterisation of earthworm activity. *Ecological Modelling*, *345*, 140–149. https://doi.org/10.1016/j.ecolmodel.2016.06.013

De Lima, A. F. L., Campos, M. C. C., Martins, T. S., Silva, G. A., Brito, W. B. M., Dos Santos, L. A. C., De Oliveira, I. A., & Da Cunha, J. M. (2022). Soil chemical attributes in areas under conversion from forest to pasture in southern Brazilian Amazon. *Scientific Reports*, *12*(1), 22555. https://doi.org/10.1038/s41598-022-25406-9

Deiss, L., Franzluebbers, A. J., Amoozegar, A., Hesterberg, D., Polizzotto, M., & Cubbage, F. W. (2017). Soil Carbon Fractions from an Alluvial Soil Texture Gradient in North Carolina. *Soil Science Society of America Journal*, *81*(5), 1096–1106. https://doi.org/10.2136/sssaj2016.09.0304

Efthimiou, N. (2020). The new assessment of soil erodibility in Greece. *Soil and Tillage Research*, *204*, 104720. https://doi.org/10.1016/j.still.2020.104720

Fiantis, D., Rudiyanto, Ginting, F. I., Utami, S. R., Sukarman, Anda, M., Jeon, S. H., & Minasny, B. (2022). Sustaining the productivity and ecosystem services of soils in Indonesia. *Geoderma Regional*, *28*, e00488. https://doi.org/10.1016/j.geodrs.2022.e00488

Georgiou, K., Jackson, R. B., Vindušková, O., Abramoff, R. Z., Ahlström, A., Feng, W., Harden, J. W., Pellegrini, A. F. A., Polley, H. W., Soong, J. L., Riley, W. J., & Torn, M. S. (2022). Global stocks and capacity of mineral-associated soil organic carbon. *Nature Communications*, *13*(1), 3797. https://doi.org/10.1038/s41467-022-31540-9

Huang, X., Lin, L., Ding, S., Tian, Z., Zhu, X., Wu, K., & Zhao, Y. (2022). Characteristics of Soil Erodibility K Value and Its Influencing Factors in the Changyan Watershed, Southwest Hubei, China. *Land*, *11*(1), 134. https://doi.org/10.3390/land11010134

Injiliana, L., Widiastuti, T., & Riyono, J. N. (2021). Erodibilitas Tanah (K) pada berbagai Tutupan Lahan di Desa Baru Kecamatan Silat Hilir Kabupaten Kapuas Hulu. *Jurnal Hutan Lestari*, *8*(4), 773. https://doi.org/10.26418/jhl.v8i4.44323

Kirkels, F. M. S. A., Cammeraat, L. H., & Kuhn, N. J. (2014). The fate of soil organic carbon upon erosion, transport and deposition in agricultural landscapes—A review of different concepts. *Geomorphology*, *226*, 94–105. https://doi.org/10.1016/j.geomorph.2014.07.023

Kriuchkov, N. R., & Makarov, O. A. (2023). Modeling Dynamics of Soil Erosion by Water Due to Soil Organic Matter Change (1980–2020) in the Steppe Zone of Russia. *Agronomy*, *13*(10), 2527. https://doi.org/10.3390/agronomy13102527

Li, Z., Liu, C., Dong, Y., Chang, X., Nie, X., Liu, L., Xiao, H., Lu, Y., & Zeng, G. (2017). Response of soil organic carbon and nitrogen stocks to soil erosion and land use types in the Loess hilly–gully region of China. *Soil and Tillage Research*, *166*, 1–9. https://doi.org/10.1016/j.still.2016.10.004

Liu, M., Han, G., Li, X., Zhang, S., Zhou, W., & Zhang, Q. (2020). Effects of Soil Properties on K Factor in the Granite and Limestone Regions of China. *International Journal of Environmental Research and Public Health*, *17*(3), 801. https://doi.org/10.3390/ijerph17030801

Mishra, P. K., Rai, A., Abdelrahman, K., Rai, S. C., & Tiwari, A. (2022). Land Degradation, Overland Flow, Soil Erosion, and Nutrient Loss in the Eastern Himalayas, India. *Land*, *11*(2), 179. https://doi.org/10.3390/land11020179

Nasjono, J., Hangge, E., & Kelen, M. (2022). Metode Erosivitas Hujan dan Model Sediment Delivery Ratio untuk Prakiraan Erosi dan Sedimentasi pada Bendungan Tilong. *Jurnal Teknik Sumber Daya Air*, *1*(1), 53–64. https://doi.org/10.56860/jtsda.v1i1.15

Othmani, O., Khanchoul, K., Boubehziz, S., Bouguerra, H., Benslama, A., & Navarro-Pedreño, J. (2023). Spatial Variability of Soil Erodibility at the Rhirane Catchment Using Geostatistical Analysis. *Soil Systems*, *7*(2), 32. https://doi.org/10.3390/soilsystems7020032

Padarian, J., Stockmann, U., Minasny, B., & McBratney, A. B. (2022). Monitoring changes in global soil organic carbon stocks from space. *Remote Sensing of Environment*, *281*, 113260. https://doi.org/10.1016/j.rse.2022.113260

Panagos, P., Borrelli, P., Matthews, F., Liakos, L., Bezak, N., Diodato, N., & Ballabio, C. (2022). Global rainfall erosivity projections for 2050 and 2070. *Journal of Hydrology*, *610*, 127865. https://doi.org/10.1016/j.jhydrol.2022.127865

Pereira, P., Bogunovic, I., Muñoz-Rojas, M., & Brevik, E. C. (2018). Soil ecosystem services, sustainability, valuation and management. *Current Opinion in Environmental Science & Health*, *5*, 7–13. https://doi.org/10.1016/j.coesh.2017.12.003

Pham, T. G., Degener, J., & Kappas, M. (2018). Integrated universal soil loss equation (USLE) and Geographical Information System (GIS) for soil erosion estimation in A Sap basin: Central Vietnam. *International Soil and Water Conservation Research*, *6*(2), 99–110. https://doi.org/10.1016/j.iswcr.2018.01.001

Quijano, L., Van Oost, K., Nadeu, E., Gaspar, L., & Navas, A. (2017). Modelling the Effect of Land Management Changes on Soil Organic Carbon Stocks in a Mediterranean Cultivated Field. *Land Degradation & Development*, *28*(2), 515–523. https://doi.org/10.1002/ldr.2637

Radziuk, H., & Œwitoniak, M. (2021). Soil erodibility factor (K) in soils under varying stages of truncation. *Soil Science Annual*. https://doi.org/10.37501/soilsa/134621

Ramesh, T., Bolan, N. S., Kirkham, M. B., Wijesekara, H., Kanchikerimath, M., Srinivasa Rao, C., Sandeep, S., Rinklebe, J., Ok, Y. S., Choudhury, B. U., Wang, H., Tang, C., Wang, X., Song, Z., & Freeman Ii, O. W. (2019). Soil organic carbon dynamics: Impact of land use changes and management practices: A review. In *Advances in Agronomy* (Vol. 156, pp. 1–107). Elsevier. https://doi.org/10.1016/bs.agron.2019.02.001

Rehman, M. A., Mat Desa, S., Abd Rahman, N., Mohd, M. S. F., Aminuddin, N. A. S., Mohd Taib, A., A. Karim, O., Awang, S., & Wan Mohtar, W. H. M. (2022). Correlation between soil erodibility and light penetrometer blows: A case study in Sungai Langat, Malaysia. *Physics and Chemistry of the Earth, Parts A/B/C*, *128*, 103262. https://doi.org/10.1016/j.pce.2022.103262

Salih, H. O., Keya, D. R., & Mohammed, K. M. (2023). Integrated use of USLE, GIS, and remote sensing for soil erosion mapping in Erbil Basin. *Polytechnic Journal*, *13*(2). https://doi.org/10.59341/2707-7799.1716

Selmy, S. A. H., Abd Al-Aziz, S. H., Jiménez-Ballesta, R., García-Navarro, F. J., & Fadl, M. E. (2021). Modeling and Assessing Potential Soil Erosion Hazards Using USLE and Wind Erosion Models in Integration with GIS Techniques: Dakhla Oasis, Egypt. *Agriculture*, *11*(11), 1124. https://doi.org/10.3390/agriculture11111124

Tsegaye, K., Addis, H. K., & Hassen, E. E. (2019). Soil Erosion Impact Assessment using USLE/GIS Approaches to Identify High Erosion Risk Areas in the Lowland Agricultural Watershed of Blue Nile Basin, Ethiopia. *International Annals of Science*, *8*(1), 120–129. https://doi.org/10.21467/ias.8.1.120-129

Universitas Sumatera Utara, Jhon, A. H., Rauf, A., Sabrina, T., & Nyak Akoeb, E. (2020). Soil Macrofauna as Bioindicator on Aek Loba Palm Oil Plantation Land. *Sriwijaya Journal of Environment*, *5*(2), 111–119. https://doi.org/10.22135/sje.2020.5.2.111-119

Xiao, H., Li, Z., Chang, X., Huang, B., Nie, X., Liu, C., Liu, L., Wang, D., & Jiang, J. (2018). The mineralization and sequestration of organic carbon in relation to agricultural soil erosion. *Geoderma*, *329*, 73–81. https://doi.org/10.1016/j.geoderma.2018.05.018

Xiao, L., Xue, S., Liu, G., & Zhang, C. (2014). Fractal features of soil profiles under different land use patterns on the Loess Plateau, China. *Journal of Arid Land*, *6*(5), 550–560. https://doi.org/10.1007/s40333-014-0023-7

Yang, X., Yang, Q., & Lu, Y. (2019). Predicting Annual Mean Profile Soil Moisture from Soil Particle Size Distributions on a Small Scale Hillslope on the Chinese Loess Plateau. *Soil Science Society of America Journal*, *83*(6), 1648–1654. https://doi.org/10.2136/sssaj2019.05.0145