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Spatial Analysis Of Soil Erodibility Factor (K Factor) In Skikda Province Using Geographic Information Systems (GIS)

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Abstract
Water erosion is considered one of the most dangerous environmental phenomena that contributes to the degradation of agricultural lands and the decline of agricultural productivity, in addition to its negative impact on the stability of ecosystems and the balance of natural resources. Algeria is among the countries most affected by this phenomenon due to its diverse climatic and terrain characteristics, as coastal areas with steep slopes and heavy rains are exposed to high rates of soil loss. Understanding the factors affecting erosion, particularly soil susceptibility to erosion (K factor), is an essential step towards developing effective strategies to conserve soil and reduce soil erosion.
This study aims to evaluate and analyze the soil erodibility factor (K Factor) in Skikda Province, based on the physical properties of the soil, such as sand, silt, clay, and organic matter content. Geographic Information Systems (GIS) were used to integrate and analyze spatial data, and apply global empirical equations to estimate K-factor values, enabling the production of a digital map showing the spatial distribution of soil erosion susceptibility at the state level. The results of this study contribute to providing an accurate scientific basis to support environmental planning programs and sustainable management of land resources, especially in areas exposed to severe water erosion.
Keywords: *water erosion, soil erodibility factor (K Factor), Geographic Information Systems (GIS), Skikda, Algeria, soil degradation, physical properties of soil.*

INTRODUCTION

Water erosion is one of the most prominent geomorphological phenomena that threaten ecosystems and the natural balance in agricultural areas, as it causes the loss of the fertile surface layer of soil, deterioration of agricultural productivity, and increased sedimentation in valleys and dams (Lal, 2001). Soil is considered a limited strategic resource, as the formation of a layer one centimeter thick takes hundreds of years, while it can be lost due to erosion in just a few years (Pimentel, 2006).
From this perspective, estimating soil erodibility is a fundamental step in understanding the dynamics of water erosion and assessing the associated environmental risks.
The soil erodibility factor (K Factor) depends on the physical and chemical properties of the soil, such as the proportions of clay (Fclay), sand (Fsand), and silt (Fsilt), as well as organic matter (Forg), which directly affect the soil's resistance to runoff forces and raindrop thrust (Renard et al., 1997). Sandy soils are usually more susceptible to erosion due to their poor structural cohesion, while clay soils show greater resistance thanks to the accumulation of colloidal materials and high organic content (Wischmeier & Smith, 1978)
Recent advances in geographic information systems (GIS) and remote sensing (Remote Sensing) have contributed to improving methods for studying water erosion, by building high-resolution spatial databases that allow linking topographical, climatic, geological, and soil properties (Angima et al., 2003). These tools are an effective way to apply mathematical models such as RUSLE (Revised Universal Soil Loss Equation) to estimate the amount of annual soil loss, and to identify the most environmentally fragile areas (Renard et al., 1997; Panagos et al., 2015.
In the Algerian context, water erosion is one of the most prominent manifestations of environmental degradation, especially in the northern regions with a Mediterranean climate characterized by intermittent heavy rains and strong slopes. Several studies have indicated that states such as Skikda, Bejaia, Guelma, and Tizi Ouzou are experiencing high rates of land loss, which negatively impacts agricultural and water resources (Benkaci et al., 2021)
Therefore, studying soil erosion susceptibility in Skikda Province represents an important scientific step to understand the dynamics of erosion in the region, identify sensitive areas, and propose effective suggestions for sustainable environmental management.
This research aims to analyze the spatial distribution of the soil erosion susceptibility factor (K factor) in Skikda Province using Geographic Information Systems (GIS), by constructing objective maps representing the basic soil

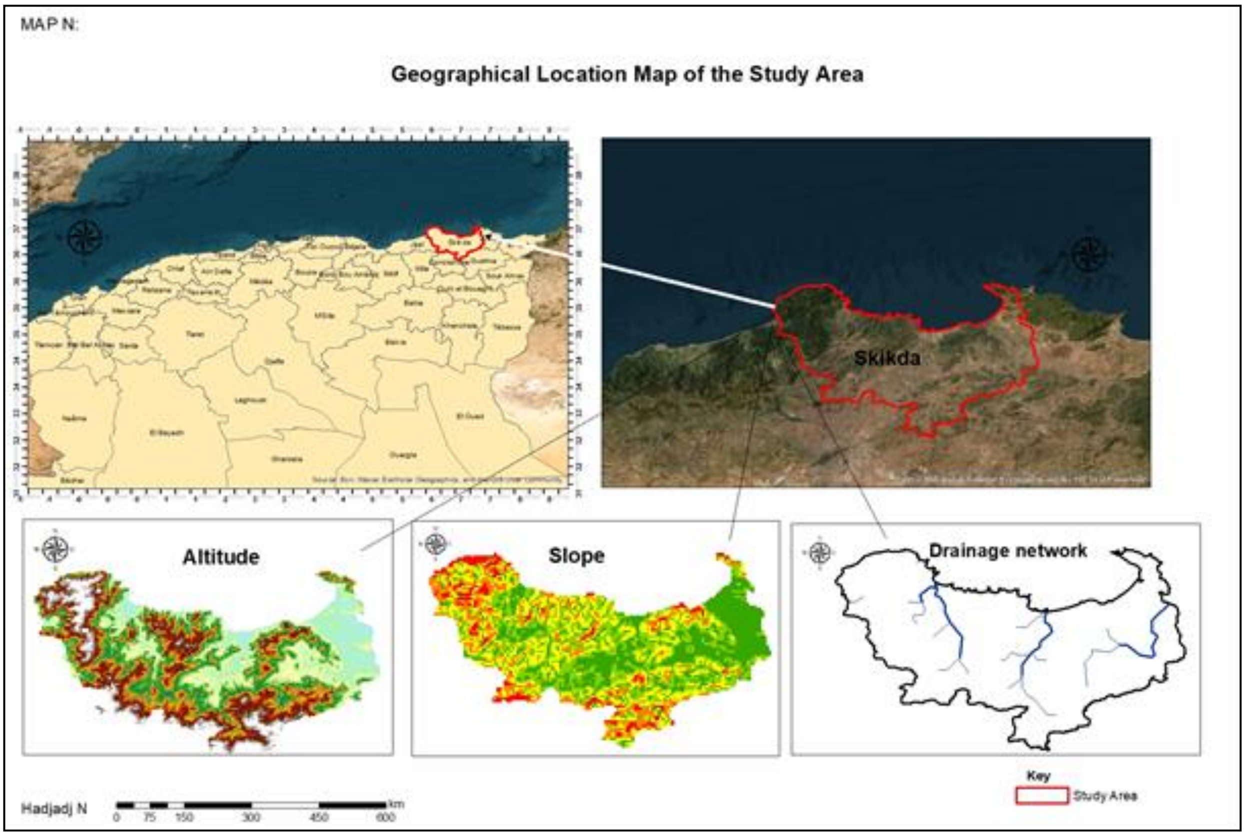
components (Fsand, Fclay, Fsilt, Forg), and then integrating them to calculate the final K map. The research also aims to explain the spatial variation in K values and link it to local soil characteristics, in order to support land management efforts and combat environmental degradation in the region.

2-Stady Area

Skikda Province is located in the northeastern part of Algeria, bordered by the **Mediterranean Sea** to the north, **Annaba Province** to the east, **Jijel Province** to the west, and **Guelma** and **Mila Provinces** to the south. It extends between longitudes **6°36′ and 7°14′ E** and latitudes **36°40′ and 37°10′ N**, covering an area of approximately **4,137 km²**.

The province is characterized by a highly varied topography, with elevations ranging from **−1 m to 1,281 m above sea level (Map 1)**. The highest point is **Mount Sidi Idris**, which dominates the southern mountainous area. The relief gradually decreases toward the northern coastal plains, reflecting noticeable differences in slope steepness, as confirmed by slope analysis (**Map 2**). This geomorphological diversity has contributed to the formation of a dense hydrographic network composed mainly of **Oued El-Kebir**, **Oued Guebli**, and **Oued Safsaf**, which play a significant role in agricultural irrigation and water drainage into the Mediterranean Sea (**Map 3**).

Hydrological studies have emphasized the importance of these river systems in the regional water balance and resource management of northeastern Algeria (Titi Benrabah et al., 2013; Ghachi et al., 2021). Furthermore, recent analyses of inland waterway development (Ghennaï et al., 2023) and wetland water quality assessments (Houhamdi et al., 2025) highlight the ecological and economic significance of the Skikda hydrological system within the national context.



3 Data and Methodology

2.1. Data Used The data used

Soil property data from digital maps sourced from FAO were adopted, including the percentages of sand, silt, clay, and organic matter.

The data was also entered into the ArcGIS 10 environment for spatial analysis using the Raster Calculator tool.

2-2. Account of auxiliary transactions

Auxiliary transactions were calculated as follows:

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The sand ratio factor (f_sand) is one of the basic components in the mathematical formula for calculating the erosion factor (K), as it reflects the effect of the size and proportion of sand particles in the soil on its resistance to water erosion**.**

The mathematical formula for this factor is:
fsand=0.2+0.3×e−0.0256×sand×(1−silt100)f_{sand} = 0.2 + 0.3 \times e^{-0.0256 \times sand \times (1 - \frac{silt}{100})}fsand=0.2+0.3×e−0.0256×sand×(1−100silt) (Shirazi & Boersma, 1984)
Where:
- **sand**: Represents the percentage of sand in the soil (%).
- **silt**: Represents the percentage of silt in the soil (%).

-This equation reflects the inverse relationship between the sand content and the soil's resistance to erosion:

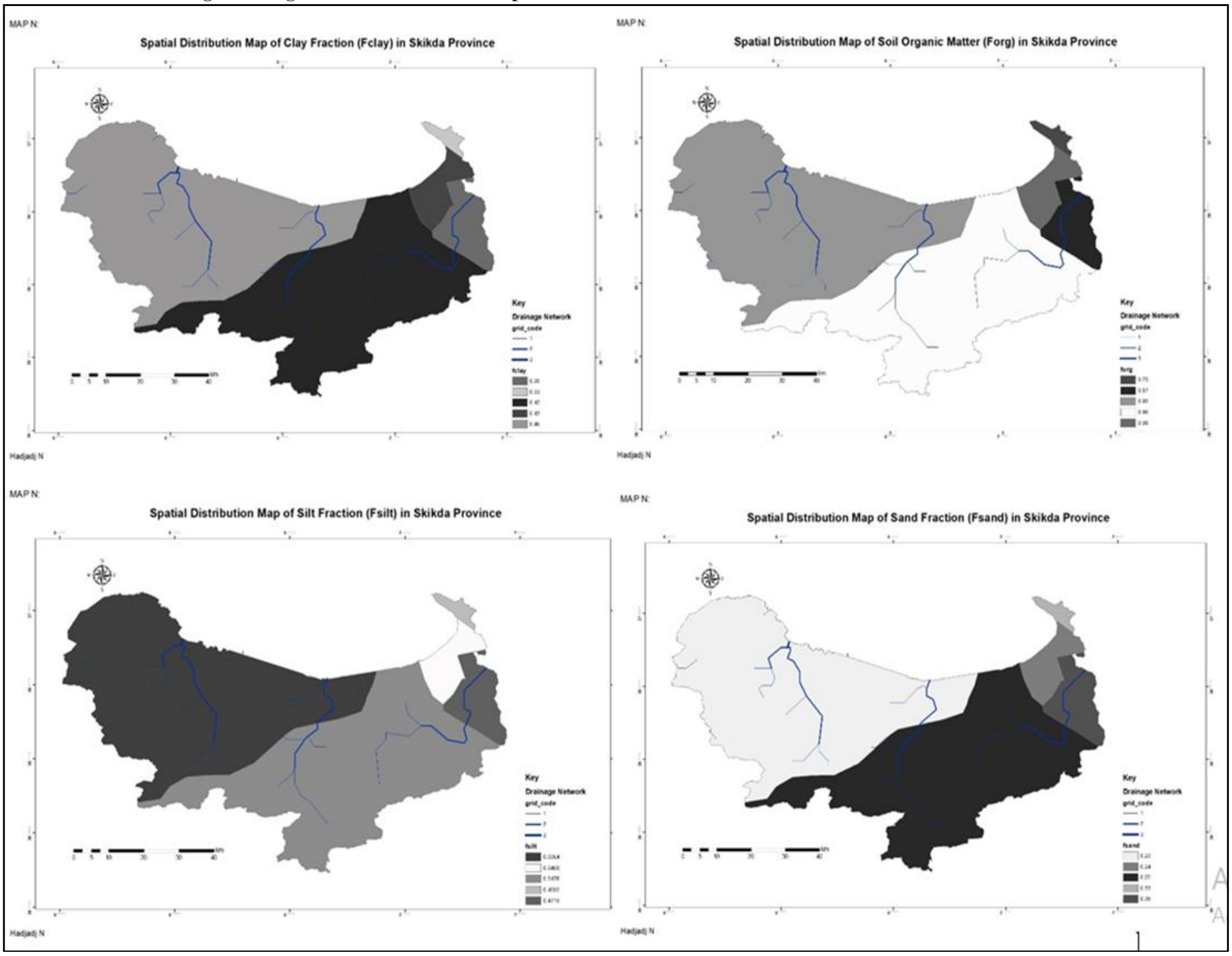
When the sand content in the soil increases, its ability to retain water decreases, and consequently, its susceptibility to erosion increases, because larger sand particles are less cohesive.
The constants (0.2 and 0.3) represent an experimental range determined based on laboratory and field studies conducted on different soil types, such as those included in the Wischmeier and Smith (1978) model that developed the USLE equation.
:f_silt The factor Fsilt expresses the ratio of silt compared to the total sum of both silt and clay in the soil, and it is calculated according to the following equation:
fsilt=siltsilt+clayf_{silt} = \frac{silt}{silt + clay}fsilt=silt+claysilt
Where:
- silt: represents the percentage of silt in the sample (%).
- clay: Represents the percentage of clay in the sample (%).

This equation aims to determine the dominance of silt compared to clay within the fine soil components. The higher the value of fsilt, the more it indicates that the soil contains a high percentage of silt compared to clay, meaning its texture tends to be silty or silty-sandy. Consequently, it is more prone to water erosion because silt is characterized by loose particles that easily detach due to rainwater and surface runoff.
- Conversely, if the value of fsilt is low, clay constitutes the largest proportion in the mixture, making the soil more cohesive and stable, and thus less prone to erosion.
- Therefore, this factor plays an important role in distinguishing the fine structural properties of the soil and their impact on erosion susceptibility within the USLE model (Wischmeier & Smith, 1978).
- The clay factor (Fclay) is calculated according to the following equation:

fclay=claysilt+clayf_{clay} = \frac{clay}{silt + clay}fclay=silt+clayclay
Where:
- clay: Represents the percentage of clay in the soil (%).
- silt: Represents the percentage of silt in the soil (%).

This factor expresses the extent of the clay component's contribution to the soil's microstructure compared to the total of silt and clay together.
The higher the value of fclay, the more it indicates that the soil contains a high percentage of clay, which gives it greater cohesion and higher resistance to water erosion, due to the small size of clay particles and their strong adhesion that limits their erosion by rainwater or surface runoff.
In the case of a decrease in the value of fclay, this indicates the dominance of silt, making the soil more fragile and weaker in its resistance to erosion, as silt is less cohesive and is easily removed by water flows.
fclay is one of the essential elements in determining soil erosion susceptibility because clay plays an opposite role to the effect of sand and silt:
While sand and silt increase the likelihood of erosion.
Clay reduces it thanks to its physical and chemical properties that improve soil cohesion and structure. Therefore, incorporating this factor into the equations designed to calculate the K factor helps to realistically represent the extent of soil fragility or hardness against water processes.
Organic matter (f_org): The value of the organic matter factor is calculated according to the following equation:
forg=1−orgC100f_{org} = 1 - \frac{orgC}{100}forg=1−100orgC
where:

• orgC: Represents the percentage of organic carbon in the soil (%).
f_{org}: It is the factor that reflects the impact of organic matter in reducing soil erosion susceptibility.
This factor expresses the extent to which organic matter contributes to enhancing soil structure stability and its resistance to water erosion.
The higher the organic carbon (orgC) content in the soil, the lower the Forg value, indicating that the soil is more resistant to erosion, because organic matter - It increases the cohesion of soil particles,
• And improve aeration and fertility,
• And it works to increase the soil's ability to absorb water instead of surface runoff.
Conversely, when the organic matter content is low (i.e., when orgC approaches zero), the value of Forg becomes approximately 1, which means that the soil is fragile, poorly structured, and more susceptible to erosion by water.
Forg is included in the equation for calculating the soil erodibility factor (K) within the USLE model, as it is used to adjust the effect of the soil's mineral components (sand, silt, clay) according to the amount of organic matter present in it.
The increase in organic matter means a decrease in the erosion rate due to its role in improving the granular structure and strengthening the bonds between particles.



3. Calculation of the Soil Erosion Factor (K Factor)
The modified equation by Wischmeier & Smith (1978) was adopted as follows:
K=FSILT×FSAND×FCLAY×FORG×0.1317

4. RESULTS AND DISCUSSION RESULTS AND DISCUSSION

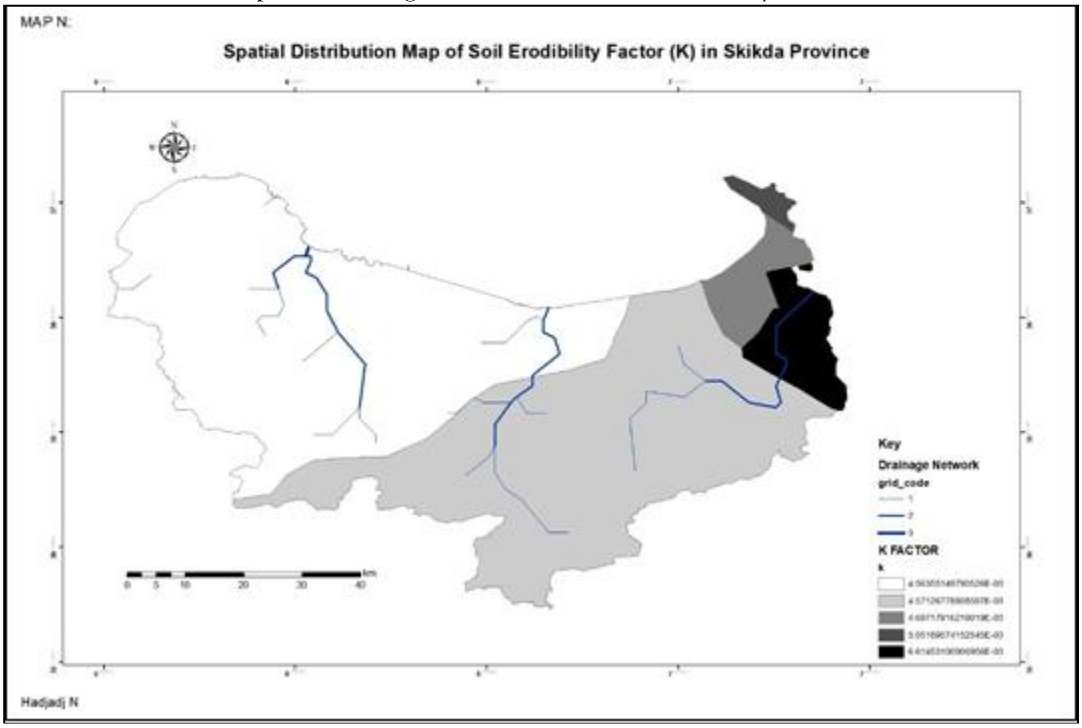
Soil erodibility is considered one of the most important physical properties affecting the dynamics of soil loss and erosion. The soil erodibility factor K was calculated based on the physical properties of the soil and organic content, according to the modified equation of Wischmeier & Smith (1978).

The calculated values show that the soil in Skikda Province has an erosion susceptibility ranging between 0.0046 and 0.0066, which are low to moderate values, indicating that the soil has a moderate resistance to erosion processes caused by rainwater and surface runoff.

These values are explained by the differences in the proportions of the soil's granular components (sand, silt, and clay); as increases in the sand ratio improve permeability and reduce particle cohesion, making the soil more prone to loss. On the other hand, an increase in the clay content enhances structural cohesion and increases the soil's resistance to erosion.

As for silt, it is the component most sensitive to erosion, as its increase is associated with a higher K factor due to its weak cohesion and high susceptibility to water transport.

On the other hand, organic content (OrgC) plays a crucial role in reducing erosion susceptibility, as organic materials contribute to improving soil structure and increasing its cohesion by forming stable granular aggregates, thereby limiting its loss. The results showed that areas with low organic matter values exhibit higher K factor values, which aligns with the findings of Wischmeier and Smith (1978) and Renard et al. (1997) who confirmed the inverse relationship between organic matter and soil erodibility.



Based on these results, it can be said that the soil composition in Skikda reflects a balance between structural texture and organic content, making most soil types in the province moderately susceptible to erosion. However, areas with weakly structured clayey soils and sloped lands remain more susceptible to degradation, necessitating the implementation of agricultural and conservation practices to reduce soil loss.

5. CONCLUSION

The study demonstrated the effectiveness of Geographic Information Systems (GIS) in calculating and interpreting the K Factor at a regional scale, providing valuable support for planning soil conservation and erosion control projects. Integrating this factor with other components of the RUSLE model is recommended to achieve a comprehensive analysis of soil loss and to enhance the accuracy of erosion risk assessments. This integrated approach enables the identification of high-risk areas and supports targeted interventions for sustainable land management.

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