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ORIGINAL ARTICLE

Investigating the Effects of Land Cover Changes on Water Erosion Intensity Using the RUSLE Model in the Sahlabad Watershed

Fatemeh Jafarpour[a], Elham Yousefi[a*], Mohammad Hossein Sayadi[b]

[a]Department of Environment, Faculty of natural resources and environment, University of Birjand, Birjand, Iran.
[b]Iranian National Institute for Oceanography and Atmospheric Science, Tehran, 1411813389, Iran.

*Corresponding Author E-mail Address: e_yusefi_31@birjand.ac.ir

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Abstract

Water erosion, especially in dry and semi-arid regions, is one of the most significant environmental challenges, playing a crucial role in the degradation of natural resources. Modeling tools such as RUSLE, in conjunction with GIS for spatial analysis and remote sensing, provide the ability to quantify and map erosion-prone areas. This study was conducted in the Sahlabad watershed to evaluate water erosion intensity and assess the influence of environmental factors, including rainfall erosivity, soil erodibility, topography, vegetation cover, and conservation practices. The RUSLE model was applied using meteorological data and spatial information derived from remote sensing and GIS techniques. Ultimately, water erosion intensity was classified into five categories: very low, low, moderate, high, and very high. The respective percentages for each category, from very low to very high erosion, were 79.49%, 0.95%, 8.83%, 10.21%, and 0.50%, respectively. The results highlight the importance of vegetation conservation and appropriate land management practices for reducing soil loss and protecting the Kaji Wetland. To reduce soil loss, preventing cultivation in vulnerable areas and planting Tamarix trees are recommended.

Keywords: Land Use, RUSLE Model, South Khorasan, Water Erosion

1. Introduction

Water erosion is one of the most serious global environmental challenges, leading to the loss of soil nutrients and land degradation. This phenomenon has widespread impacts on agriculture, water quality, and ecosystems, interacting with climate change and land use changes (Zare et al. 2016). Erosion hazard assessment methods include quantitative models such as USLE and RUSLE, which rely on complex data such as rainfall, vegetation cover, and land slope. GIS technology and remote sensing play a crucial role in generating spatial distribution maps of erosion and use satellite data to evaluate land use changes and monitor erosion intensity (Panagos et al. 2015). On the other hand, over the past five decades, agricultural lands have been severely degraded, with water erosion continuing globally at a rate of 10 million hectares per year.

This trend results in soil quality degradation, reduced agricultural production, and increased dust storms, which have detrimental effects on human health and ecosystems (Kidane and Alemu 2015). In this study, the RUSLE model is used to assess erosion rates in the Sahlabad watershed. The RUSLE model is used to assess erosion rates in the Sahlabad watershed. Water erosion has widespread effects globally and regionally, including soil fertility loss, sediment deposition, and land degradation (Safari et al. 2018). In Iran, this phenomenon has been exacerbated by inappropriate land use changes and poor land management practices. The rate of water erosion is considered a key indicator for assessing the sustainable development of countries, and determining the spatial pattern of erosion can contribute to reducing and combating this issue. Understanding land use changes and their impact on erosion is an important tool for natural resource management (Abiyat et al. 2021).

Traditional methods for calculating water erosion have been developed based on empirical models and mathematical equations. However, the RUSLE model, as an improved version of the USLE, when combined with GIS, offers a greater capacity for accurately estimating water erosion. The RUSLE model simulates erosion using factors such as rainfall erosivity (*R*), soil erodibility (*K*), slope and slope length (*LS*), vegetation cover (*C*), and conservation practices (*P*) (Wischmeier and Smith 1978). The R factor, representing the intensity of rainfall, has a significant impact on erosion. The *K* factor is dependent on soil characteristics and is estimated using empirical models. The length and steepness of slopes also play a determining role in increasing runoff speed and erosion intensity. Vegetation cover reduces the energy of raindrop impact and stabilizes the soil, playing a vital role in controlling erosion (Mohammadi et al. 2016).

Additionally, the P factor reflects the impact of management practices, such as contour plowing and terracing, in reducing erosion (Renard 1997). The combination of the RUSLE model with GIS improves the accuracy of erosion maps and facilitates the assessment of erosion risk at various scales. However, challenges such as the accuracy of input data and methods for estimating model coefficients still exist. The RUSLE model was initially designed for small watersheds but has seen increased effectiveness in larger watersheds with recent advancements in GIS technology. This model uses three primary databases: climate data, crop products, and soil properties, allowing the prediction of land use and vegetation cover changes on erosion (Jahun et al. 2015). Several domestic studies have been conducted on water erosion using the RUSLE model.

Karami et al. (2017) investigated the effect of land management on soil erodibility in part of the Zayandeh-Rud watershed by evaluating soil properties, including particle size distribution, bulk density, soil permeability, organic matter, calcium carbonate, aggregate stability, and shear strength. Teimouri et al. (2019) assessed the effects of climate change and land use changes on water erosion in the Khandran watershed using the RUSLE model and climate scenarios.

Madadi et al. (2024) investigated forest cover changes in the Galleh-Roodkhan watershed and found that the reduction of forest areas and their conversion into agricultural lands, rangelands, and residential areas increased water erosion potential. Hesami et al. (2024) applied the RUSLE-3D model to estimate soil erosion in the Gaushan watershed and showed that topography and land cover were key factors controlling erosion intensity.

More recent studies have further emphasized the role of remote sensing and GIS-based models in erosion assessment. Peyvazi et al. (2025) analyzed the effects of land use changes on water erosion intensity in Meshkinshahr County and reported that changes toward agricultural and barren lands increased erosion. Babaei and Abedini et al. (2025) showed that water erosion in the Virmuni watershed was strongly related to slope, land use, and vegetation cover, and that vegetation management reduced erosion risk. Abedini et al. (2025) investigated the relationship between vegetation indices, morphometric characteristics, and water erosion in the Meshkin-Chay watershed and confirmed the effectiveness of the RUSLE model combined with remote sensing data for identifying erosion-prone areas.

Several international studies have also examined the relationship between land use, vegetation cover, and water erosion. Bogale (2020) evaluated the impact of land use changes on water erosion in the Lake Tana region of Ethiopia and reported that population growth and inappropriate agricultural practices increased soil loss and sedimentation. Das et al. (2021) compared the RUSLE and MMF models in India and showed the suitability of these models for estimating soil loss and supporting conservation planning.

Recent international studies have focused on integrating RUSLE, GIS, and remote sensing techniques. Weslati and Serbaji (2024) assessed water-induced erosion in the Mellegue watershed using RUSLE, GIS, and remote sensing and found that steep slopes and agricultural land uses were associated with higher erosion rates. Birhanu et al. (2024) evaluated the impact of land use and land cover changes on water erosion in the Dondor watershed and reported that agricultural expansion and reduction of natural vegetation increased erosion intensity. Mathewos et al. (2024) investigated water erosion in the Boyo watershed using the RUSLE model and showed that slope and vegetation cover were the main controlling factors.

In 2025, several studies continued to highlight the importance of spatial modeling for erosion assessment. Nesru (2025) evaluated water erosion in the Woybo watershed using RUSLE, GIS, and remote sensing and reported that steep slopes and low vegetation cover contributed to higher erosion rates. Gebremariam et al. (2025) examined the effects of land use changes on water erosion and sediment production in Ethiopia and showed that conversion of natural vegetation to agricultural land increased erosion. Alemayehu et al. (2025) assessed water erosion and sediment production using RUSLE, GIS, and remote sensing and confirmed the importance of slope and vegetation cover in controlling erosion.

Bogale (2020) conducted a study in the Lake Tana region (Ethiopia) to investigate the impact of land use changes on water erosion. The results indicated that the unprecedented population growth and improper agricultural practices have led to increased soil washout and sedimentation in the lake. Das et al. (2021) compared and evaluated the RUSLE and MMF soil erosion models along with best management practices at the watershed scale in India. Estimating water erosion from agricultural lands is crucial for planning conservation measures. The model used in this study was introduced as an appropriate substitute for estimating soil loss in watersheds. Water erosion depends on factors such as soil texture, structure, permeability, topography, land use, and other erosive factors. Analyzing these parameters can help estimate annual soil loss. The RUSLE and MMF models showed similar results in estimating soil loss. Amah et al. (2020) used the Revised Universal Soil Loss Equation (RUSLE) to study water erosion processes in the Cross River watershed in southern Nigeria. They used Digital Elevation Model (DEM) data, satellite images, and base maps. The results showed that 18.8% of the land available for development was at very high risk of erosion. The findings of this research can be applied for conservation and adaptation purposes. This research is particularly crucial because the only national wetland of South Khorasan Province lies within this watershed. Given the way the Kaji Salt Marsh was formed based on its topography, calculating the sediment load in the watershed is essential for understanding the filling rate of the wetland. This study aimed utilizing the RUSLE model and GIS technology, examines land cover changes and their impact on water erosion in the Sahlabad watershed, providing strategies to mitigate environmental damage and promote sustainable land management.

2. Materials and Methods

2.1. Study area

The study area of Sahlabad is one of the research regions in the Lut Desert watershed. Its geographical coordinates range from 59°34' to 60°14' East longitude and from 31°45' to 32°30' North latitude. The total area of the Sahlabad study area is 2,615 square kilometers, with the desert and mountain areas covering 1,021 and 1,594 square kilometers, respectively. The aquifer area of the region is 603.31 square kilometers, and the average annual temperature of the area is 16.6°C. The total annual evaporation is 2,918.5 mm, and the average annual precipitation over a long-term period is approximately 161.9 mm. The region has a dry and desert climate. In terms of soil characteristics, the largest portion of the area consists of rocky outcrops, Antisols, and Aridisols. These soils, which are specific to dry and desert regions, may contain clay and sedimentary materials such as salts and carbonates in some areas. The wetland area itself has medium to heavy-textured soils, primarily of the Antisol/Aridisol type. The location of the study area is shown in Fig. 1.

2.2. Research methodology

The Revised Universal Soil Loss Equation (RUSLE) model has been widely used worldwide for long-term predictions of erosion at scales ranging from farm to watershed, incorporating various management practices. This model does not have the capability to simulate sediment transport in waterways and has limitations when applied to very small or very large areas. Nonetheless, RUSLE remains the most practical and accessible model for predicting erosion, as it can be easily used at local or regional scales. RUSLE can seamlessly integrate various parameters, such as slope, slope direction, land cover and land use maps derived from digital elevation models (DEM) and satellite imagery. The model utilizes five raster-based maps: rainfall erosivity, soil erodibility, slope length and steepness, vegetation cover, and conservation practices.

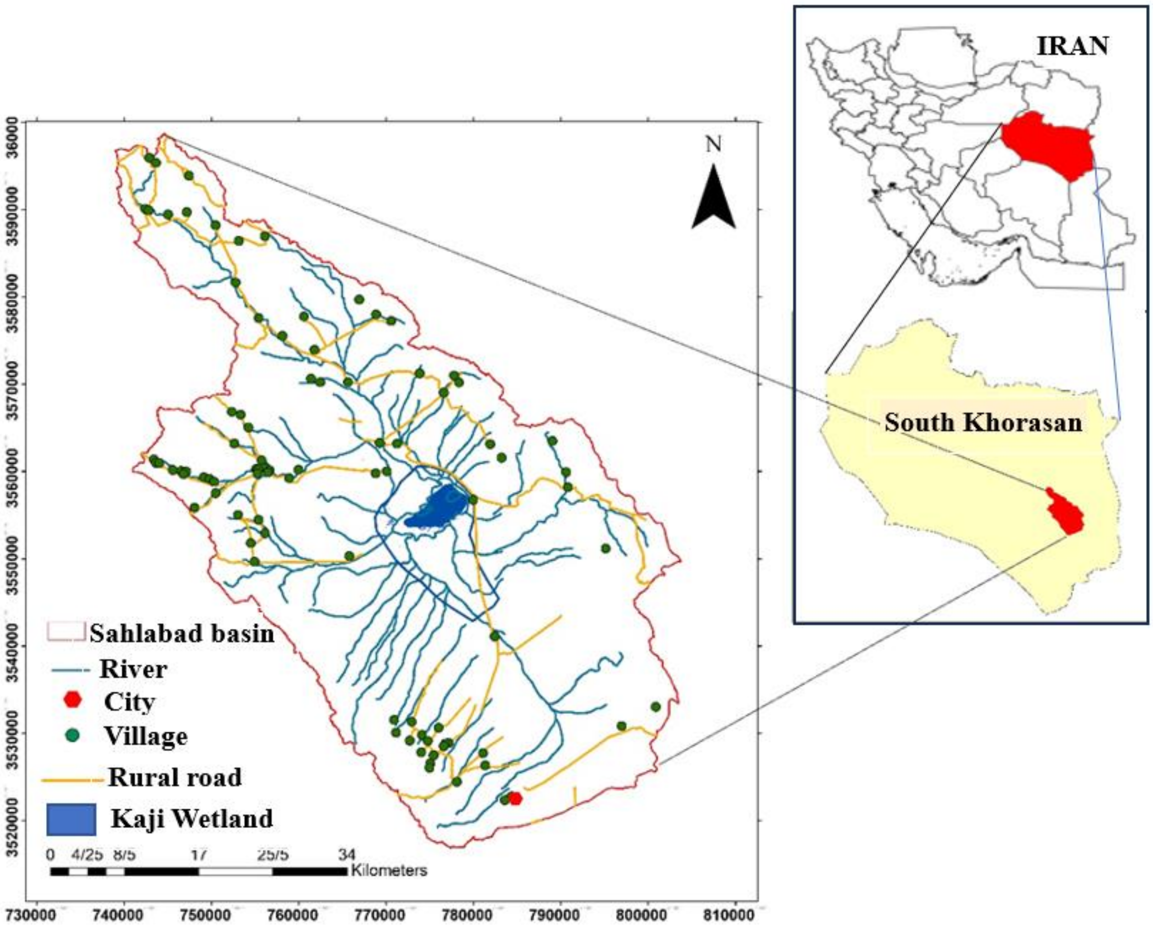

Fig. 1. Geographical location of the study area.

These factors depend on other environmental variables and are variable across both time and space (Mohammadi et al. 2016). To estimate water erosion, the RUSLE model was used, with its input layers derived using GIS and remote sensing techniques. The first attempt to formulate water erosion was made by Cook, who included factors such as rainfall erosivity and soil erodibility. The initial equation proposed for estimating erosion in a region was Zing's equation, which considered only two factors: slope length and steepness. This model was later developed by Wischmeier and Smith, leading to the introduction of the Universal Soil Loss Equation (USLE) (Refahi 2009). Subsequently, the modified USLE, known as RUSLE, was introduced by Renard in 1997. This model is applicable to both agricultural lands and natural resources. It is a single-event model capable of calculating erosion for any given event (Shahab Arkhazloo et al. 2016). This model is designed to estimate soil erosion and is related to six factors, as expressed in Eq. 1 (Wischmeier and Smith 1978).

$$A=R.K.LS.C.\,P \qquad (1)$$

In this equation, A represents the average water erosion per unit area (tons per hectare), R is the rainfall erosivity factor (MegaJoules per millimeter per hectare per hour per year), K is the soil erodibility factor (tons per hour per MegaJoule per millimeter), L is the slope length factor, S is the slope steepness factor, C is the vegetation cover factor, and P is the conservation practice factor. P, LS, and C are dimensionless (Renard 1997). The rainfall erosivity factor (*R*) was estimated using long-term rainfall data obtained from 10 meteorological stations located within and around the Sahlabad watershed over a 10-year period. Monthly and annual precipitation values were calculated for each station, and the Modified Fournier Index (MFI) was calculated using Eq. 2. The MFI values were then converted into the rainfall erosivity factor (*R*) using the empirical relationship proposed by Arnoldus (1980). The calculated R values were assigned to the corresponding meteorological stations and spatially interpolated using the Inverse Distance Weighting (IDW) method in ArcGIS 10.6 to generate the rainfall erosivity map. Subsequently, the R, K, LS, C, and P raster layers were prepared and integrated using the Raster Calculator tool to estimate the annual soil erosion rate based on the RUSLE model. The final soil erosion map was classified into different erosion intensity classes to evaluate the spatial variation of erosion across the watershed.

3. Results and Discussion

3.1. Revised universal soil loss equation

3.1.1. Rainfall erosivity factor (R)

Rainfall erosivity represents the ability of rainfall to detach and transport soil particles and is one of the main factors affecting soil erosion in the RUSLE model. In the original USLE and RUSLE models, the R factor is calculated based on rainfall kinetic energy and the maximum 30-minute rainfall intensity. However, due to the lack of high-resolution rainfall intensity data in the study area, the rainfall erosivity factor was estimated using long-term precipitation data and the Modified Fournier Index (MFI) method (Renard 1997).

In this study, monthly and annual precipitation data from 10 meteorological stations located within and around the Sahlabad watershed were collected for a 10-year period. The average monthly and annual rainfall values were calculated for each station, and the completeness of the dataset was verified before analysis. No rainfall data reconstruction was required.

In the next step, the Fournier index (*F*) was estimated for the stations based on Eq. 2:

$$MFI = \sum_{i=1}^{12} {Pi^2}/{P} \tag{2}$$

Since the MFI value exceeded 55 at all stations, Eq. 3 was used to calculate the *R* value:

$$R = L\frac{0.07397 \times \mathrm{MFI}^{1.848}}{17.2} \tag{3}$$

The resulting numerical *R* values were then entered into a GIS layer representing the stations, and using the Inverse Distance Weighting (IDW) interpolation method, the interpolated *R* index map was generated. According to the results, the highest rainfall erosivity (R = 2093.63) was observed in the northern regions of the watershed, which have higher elevations. In contrast, the lowest value (R = 982.28) was recorded in the southern regions, which are predominantly flat land areas. Therefore, the rainfall erosivity is higher in the northern part of the watershed, making these areas more susceptible to erosion. The results of this analysis are presented in Table 1 and Fig. 2.

Table 1. Fournier Index (F), MFI, and MFI^2 values at the rainfall stations in the study area.

Station Name	MFI	MFI^2	R
Khajeh Dochahi	15.194	22.37649	982.2842
Akbarabad Giv	25.224	6.50288	1320.902
Nehbandan	7.194	9.37908	988.0208
Tighab	190	36.100	939.5395
Chabok	8.209	4.44016	1152.071
Darvishabad	32.356	9.126963	3400.627
Dehsalm	1.105	1.11046	274.7444
Chahdashi	56.123	7.15267	385.2788
Khoshab	94.257	4.66533	1759.506
Barak	6.279	16.78176	2074.741

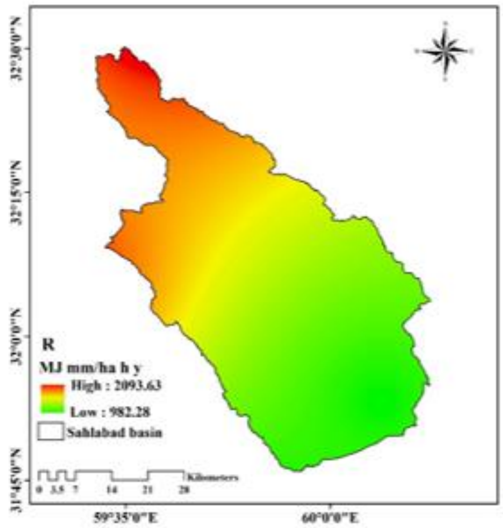

Fig. 2. R Factor map of the Sahlabad watershed

3.1.2. Soil erodibility factor (K)

Soil erodibility factor (*K*) represents the susceptibility of soil to detachment and transport by rainfall and runoff. It is controlled by soil properties such as particle size distribution, organic matter content, soil structure, and permeability. In the RUSLE model, the *K* factor is expressed as the amount of soil loss per unit of rainfall erosivity and slope conditions. Higher *K* values indicate greater soil vulnerability to erosion (Wischmeier and Smith 1978).

In this study, the *K* factor was calculated using soil texture and physicochemical properties obtained from the soil map and available soil database of the study area. The required parameters, including the percentage of silt, very fine sand, clay content, organic matter, soil structure, and permeability class, were extracted for each soil unit. The *K* factor was then calculated using Eq. 4 proposed by Wischmeier and Smith (1978):

$$K = 27.66 \times M^{1.14} \times 10^{-8} (12 - a) + (0.0043(B - 2)) + (0.0033(C - 3)) \quad (4)$$

Where *M* is the particle-size parameter calculated from the percentage of silt and very fine sand multiplied by the percentage of clay content, a represents the percentage of organic matter, *B* is the soil structure code, and *C* represents the soil permeability class. The calculated *K* values were assigned to the corresponding soil units and converted into a raster layer using ArcGIS 10.6.

To calculate the *K* factor, a soil texture map of the Sahlabad watershed was first prepared (Fig. 3). In this area, the soil was classified into very light sandy, medium-heavy, medium gravel, light sandy, and light gravel textures. Based on the collected data, the *K* value ranged from 0.15 to 0.6. The highest sensitivity to erosion was observed in the northern part of the watershed, where the very light sandy texture and high rainfall made it more prone to erosion.

The lowest soil erodibility was recorded in the southern part of the watershed, where the soil is loamy-sandy, with a high clay content and lower rainfall. The results of this analysis, including the soil erodibility sensitivity in different areas, are presented in Table 2, the soil texture map in Fig. 3, and the *K* factor map in Fig. 4 for the Sahlabad watershed.

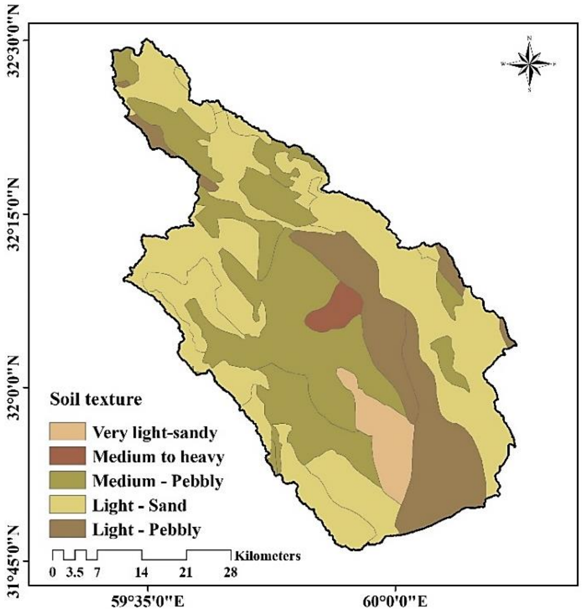

Fig. 3. Soil texture map of the Sahlabad watershed.

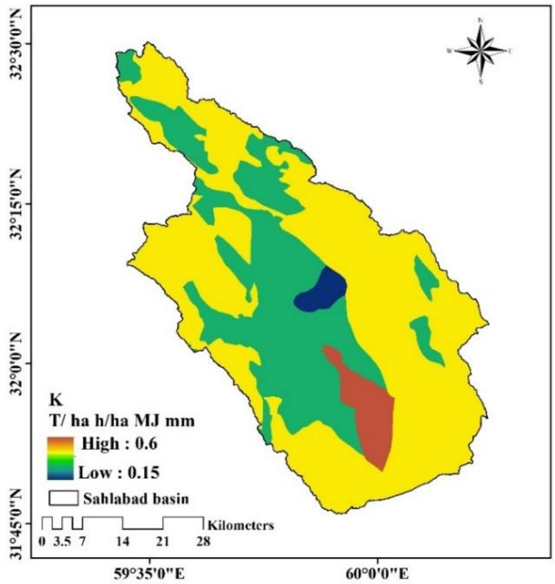

Fig. 4. K factor map of the Sahlabad watershed.

Table 2. Soil erodibility sensitivity in different areas

Erodibility	Soil Texture	K Factor
Very Low	Loamy sandy	0.15 to 0.25
Low	Medium (silt) and clay	0.25 to 0.3
Moderate	Loamy, clay loam, silty clay	0.3 to 0.36
High	Sandy	≥ 0.36

3.1.3. Topographic Factor (LS)

The topographic factor (*LS*) represents the combined effect of slope length and slope steepness on soil erosion in the RUSLE model. Slope length affects the accumulation of surface runoff, while slope steepness influences flow velocity and erosive power. Generally, erosion intensity increases with increasing slope length and slope gradient (Wischmeier and Smith 1978).

In this study, the LS factor was derived from a 30 m Digital Elevation Model (DEM) using GIS-based spatial analysis. The DEM was processed in the ArcGIS 10.6 environment using the ArcHydro extension to generate flow direction and flow accumulation maps. The slope map and flow accumulation map were used as input parameters for calculating the *LS* factor.

The *LS* factor was calculated using Eq. 5 in the Raster Calculator tool. The equation integrates slope steepness and slope length effects based on flow accumulation and slope characteristics:

$$ls = \left[fa \times \frac{cell\ size}{22.3}\right]^{0.4} \times \left[\frac{\sin lsf \ \times 0.01745}{0.0896}\right]^{1.3} \quad (5)$$

where *fa* represents the flow accumulation value, Cell Size is the DEM spatial resolution (30 m), and θ represents the slope angle. The parameters m and n are empirical coefficients related to slope characteristics. The final *LS* raster layer was generated for the Sahlabad watershed.

The *LS* factor map was then integrated with other RUSLE input layers to estimate the spatial distribution of soil erosion.

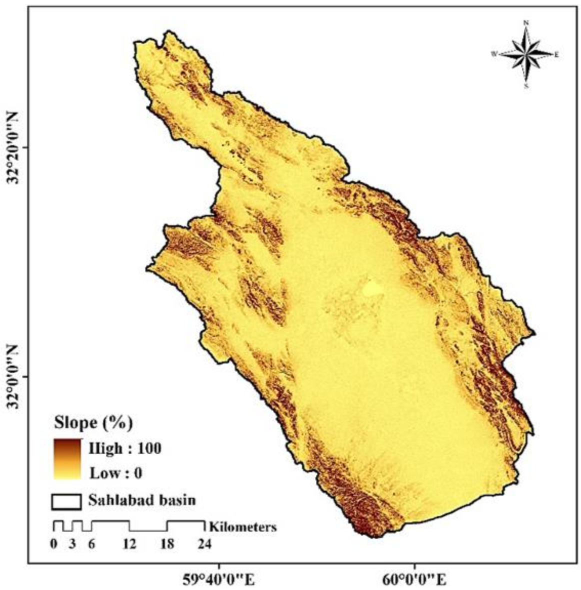

Fig. 5. Slope percentage map of the Sahlabad watershed

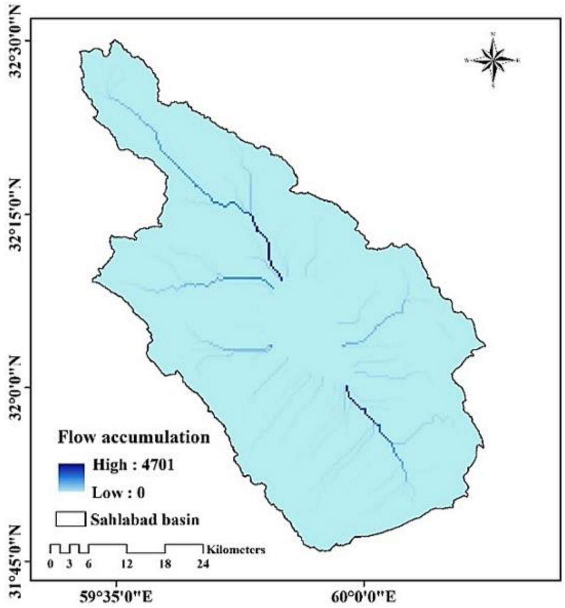

Fig. 6. Flow accumulation map of the Sahlabad watershed used for LS factor calculation

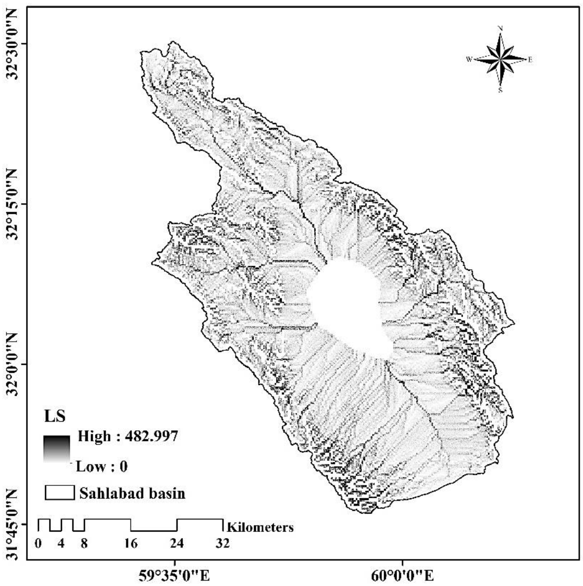

Fig. 7. LS factor map of the Sahlabad watershed

According to the *LS* factor map of the Sahlabad watershed (Fig. 7), the erosion intensity is higher in the elevated areas, which have steeper slopes.

3.1.4. Vegetation cover factor (C)

The vegetation cover factor (C) represents the effect of vegetation and land cover management on reducing soil erosion. This factor indicates the relative soil loss under specific vegetation conditions compared with bare soil. Higher vegetation density results in lower *C* values and reduced erosion potential (Wischmeier and Smith 1978).

In this study, the C factor was estimated using the Normalized Difference Vegetation Index (NDVI) derived from Landsat 8 satellite imagery acquired in summer 2021. The NDVI was calculated using the following Eq. 6:

$$C = \exp\left[-a\,\frac{NDVI}{B - NDVI}\right] \quad (6)$$

The values of the *C* factor range from 0 to 1. Lower C values indicate higher vegetation cover and greater soil protection, whereas values close to 1 represent bare soil or areas with poor vegetation cover and higher erosion potential. After calculating the C factor using the NDVI-based equation, the resulting values were normalized to the range of 0–1. Pixels with values below 0 were assigned a value of 0, while pixels with values above 1 were assigned a value of 1. Wetland areas were excluded from the C factor calculation because their vegetation characteristics and soil conditions differ from terrestrial areas . The final vegetation cover factor (C) map was generated in ArcGIS 10.6 (Fig. 9).

3.1.5. Conservation practice factor (P)

The conservation practice factor (P) represents the effect of soil conservation practices on reducing erosion by modifying surface runoff and flow direction. Conservation practices such as contour farming, strip cropping, and terracing reduce runoff velocity and soil loss. The P factor is expressed as the ratio of soil loss under a specific conservation practice to that under up-and-down slope cultivation (Wischmeier and Smith 1978).

In this study, due to the lack of spatial information on conservation practices within the Sahlabad watershed and the absence of intensive agricultural management practices, the *P* factor was assigned a value of 1 for the study area. This value represents areas without effective conservation measures and was applied as a uniform raster layer in the RUSLE model. The *P* factor layer was prepared in ArcGIS 10.6 and integrated with the other RUSLE factors to estimate the spatial distribution of soil erosion.

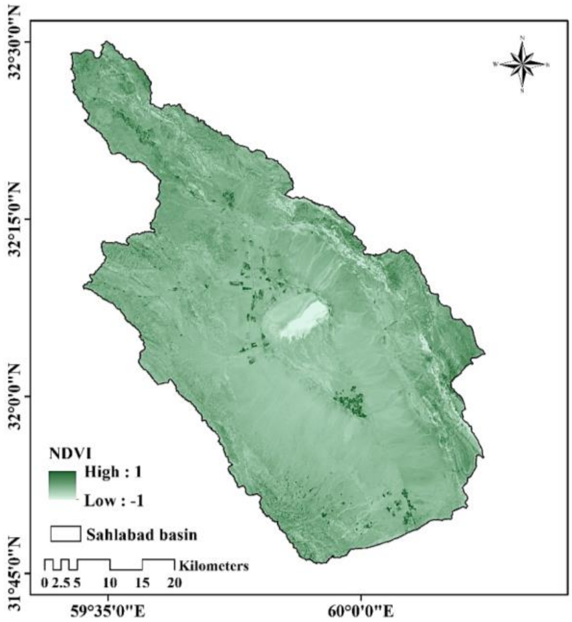

Fig. 8. NDVI map of the Sahlabad.

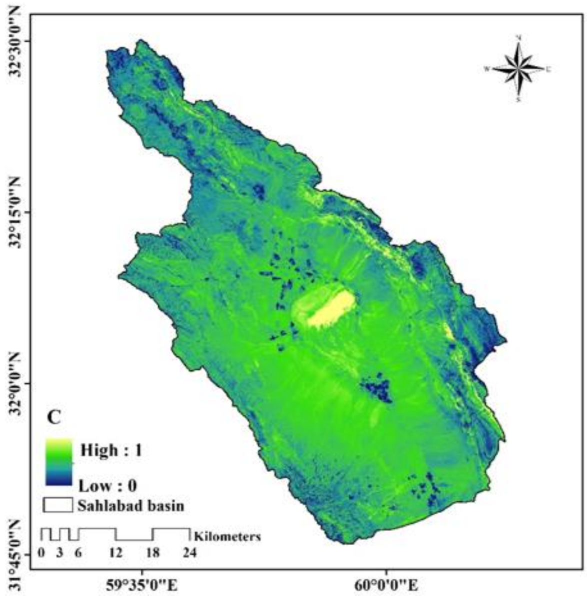

Fig. 9. The *C* factor map of the Sahlabad watershed after excluding wetland areas.

Based on the land use/land cover map and data obtained from the General Directorate of Natural Resources and Watershed Management of South Khorasan Province (Fig. 10), *P* factor values were assigned to each land use/land cover class according to the values presented in Table 3. The assigned P values were converted into a raster layer using ArcGIS 10.6, and the final *P* factor map was generated (Fig. 11). The P factor values were selected based on previous RUSLE studies and conservation practice conditions (Wischmeier and Smith 1978; Renard 1997).

Table 3. Assigned P factor values for different land use/land cover classes in the Sahlabad watershed

P_value	Land Use
0.1	Desert, saline lands, salt marshes, clay flats, rocky outcrops
0.9	Rainfed agriculture, irrigated agriculture, orchards
0.8	Riverbed
0.5	Residential areas
0.4	Semi-dense rangelands
0.3	Sparse rangelands
0.1	Natural *Tamarix* (Tāghzār), afforestation, waterlogged areas, groves and shrublands, sparse forests, and plantations

According to Fig. 11, the highest level of erosion is observed in desert areas, saline and salt marshes, clay flats, and rocky outcrops.

3.2. Layer integration and water erosion map preparation (RUSLE)

After preparing all the required layers, the five layers were multiplied together in the Arc Map software environment using the Raster Calculator tool, and the RUSLE map was generated (Fig. 12).

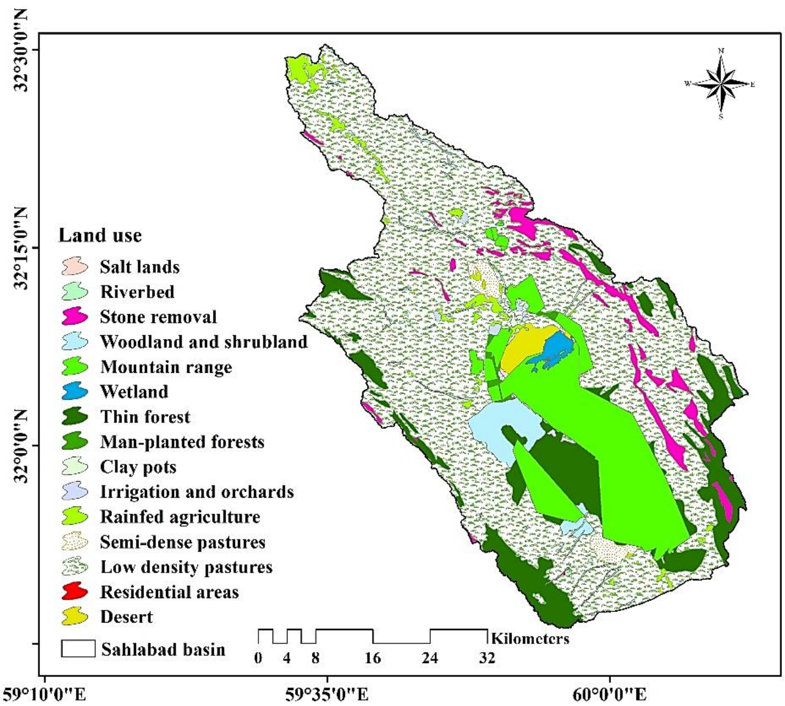

Fig. 10. Land use/land cover map of the Sahlabad watershed.

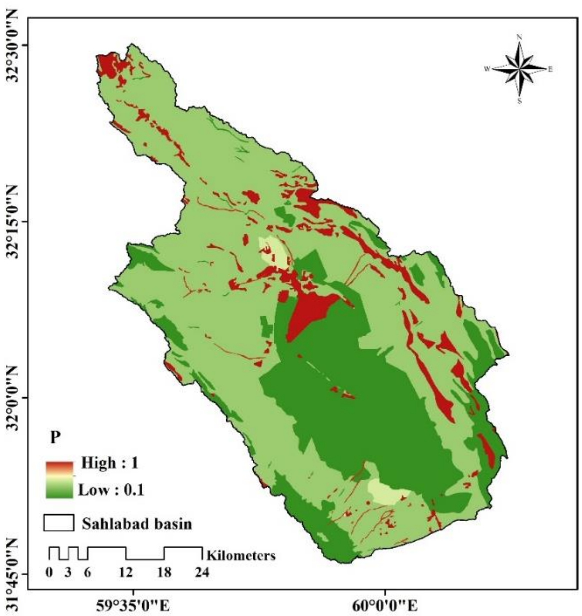

Fig. 11. Final *P* factor map of the Sahlabad watershed.

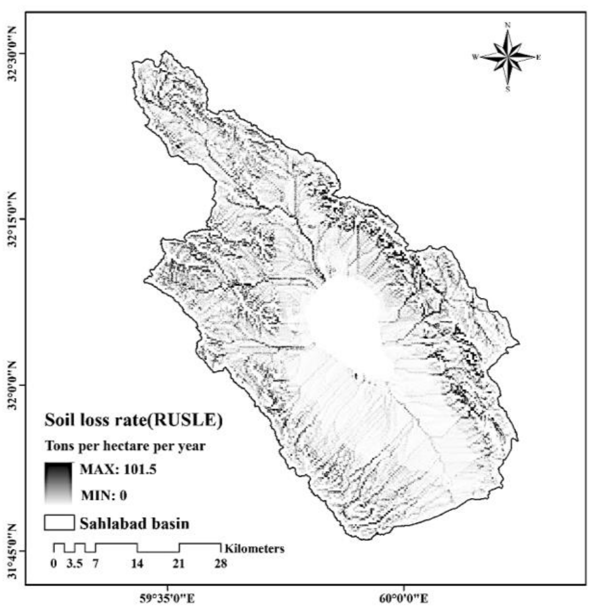

Fig. 12. Soil loss map of the Sahlabad watershed using the RUSLE model (Tons/hec/year).

In the next step, the estimated soil loss map obtained from the RUSLE model was classified using the Reclassify tool in ArcGIS 10.6 into five erosion intensity classes: very low, low, moderate, high, and very high. The classified soil loss map of the Sahlabad watershed is presented in Fig. 13. Wetland areas were evaluated separately due to their different hydrological and soil characteristics, which affect the spatial pattern of soil erosion.

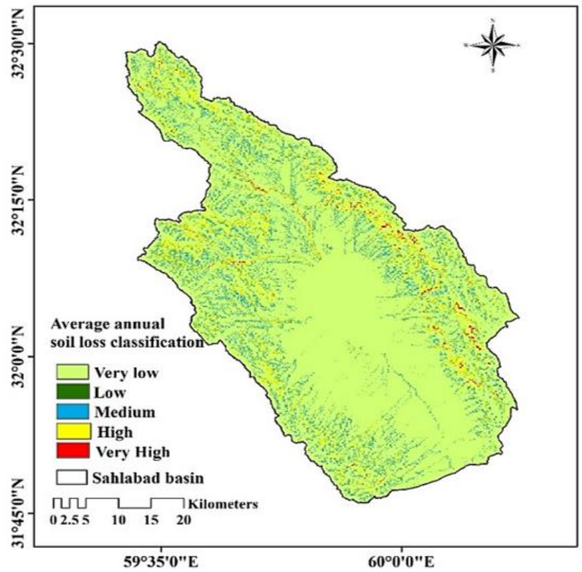

Fig. 13. Classified soil loss map of the Sahlabad watershed based on the RUSLE model (Tons/hec/year).

According to Fig. 13, the red-colored areas represent regions with very high erosion, while the light green areas indicate regions with very low erosion in the study area. Based on Table 4, the distribution of area in these classes is as follows: very high erosion (79.49%), high (10.21%), moderate (8.83%), low (0.95%), and very low (0.5%). These results highlight the importance of conservation measures to reduce erosion in high-risk areas (Fathollahzadeh 2015).

Table 4. Percentage and amount of water erosion in the study area

Erosion Percentage	Area (km²)	Erosion Intensity
79.49%	2072.3	Very Low
0.95%	25	Low
8.83%	230.3	Moderate
10.21%	266.3	High
0.50%	13.06	Very High

Water erosion, especially in developing countries, is increasing and leads to a reduction in the fertility of agricultural soils and the pollution of water resources.

In this study, the amount of water erosion in the Sahlabad watershed was evaluated using the RUSLE model and GIS technology. The results showed that the rainfall erosivity factor (*R*) was higher in the northern and elevated parts of the watershed. This pattern is related to the spatial distribution of precipitation, as higher elevation areas receive greater rainfall amounts, resulting in higher MFI values and consequently higher *R* values. The soil erodibility factor (*K*) in the region ranges from 0.05 to 0.15, with the highest sensitivity to erosion observed in the southern part of the wetland and the lowest in the central part of the watershed.

The topographic factor (*LS*) is higher in areas with steep slopes and elevation differences, while the vegetation cover factor (*C*) was calculated using the NDVI index and varies between 0 and 1. The findings showed that vegetation cover decreases with increasing elevation and slope.

Additionally, the analysis indicated that areas with steep slopes and no vegetation cover, particularly agricultural lands, have the highest levels of erosion. Land use changes, including the expansion of agricultural areas and the reduction of native vegetation cover, have increased erosion and led to the shallowing of the Kaji Salt Marsh in Nehbandan. These results align with similar international studies.

Teku and Workie (2025) in the Lake Zivi watershed in Ethiopia demonstrated that water erosion is most intense in sloping and agricultural lands, affecting agricultural sustainability and food security. Yadav et al. (2025) in a sub-watershed of Hillzi, Karnataka, India, reported higher erosion risks in sloping and agricultural areas using RUSLE and geographic technologies. Sud et al. (2024), by integrating the RUSLE model with Google Earth Engine in the Satluj watershed in India, found that hilly and sloping areas experience the highest erosion rates. Pandey and Kumari (2025) in an agricultural watershed in Jharkhand, India, identified high-risk areas using RUSLE and multi-criteria AHP analysis. Domestic studies also align with these findings.

Gholami et al. (2024) in the Chardavol watershed in Ilam showed that land use changes and the reduction of vegetation cover have increased water erosion. Ghahremani et al. (2025) in the Chikan and Morzian watersheds examined the effect of biological measures and vegetation management on soil erosion reduction using the RUSLE model, confirming the results that increased vegetation cover reduces erosion.

This consistency indicates that the use of the RUSLE model combined with GIS and remote sensing is a reliable and globally standardized approach for identifying high-risk areas and developing management strategies. Based on the results, it is recommended to avoid farming in steep watersheds and to plant native species such as *Tamarix* in areas lacking vegetation cover. Additionally, future research should consider not only natural factors but also human factors and geomorphological indices (such as land undulations, topographic position, and relative active tectonics) to make the analyses more comprehensive and management-oriented.

4. Conclusion

This study highlights the significant role of land use/land cover characteristics and vegetation cover in influencing water erosion in the Sahlabad watershed, using the RUSLE model and GIS technology. The results demonstrate that areas with higher elevation and steeper slopes are more susceptible to erosion, particularly in regions with limited vegetation cover and agricultural land use. Additionally, the study emphasizes the importance of conservation measures, including avoiding cultivation in steep and erosion-prone areas and introducing native species such as Tamarix in areas with low vegetation cover to mitigate soil loss and protect soil resources.

The findings confirm the effectiveness of the RUSLE model, GIS, and remote sensing techniques for identifying erosion-prone areas and supporting sustainable land management strategies. Future studies should incorporate additional environmental factors, human activities, and geomorphological indices, such as landforms and tectonic conditions, to provide a more comprehensive understanding of soil erosion processes.

5. Conflict of Interest

The authors declare no conflict of interest over this paper.

6. References

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