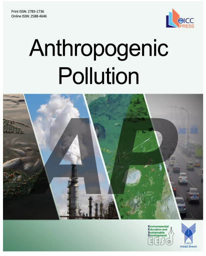

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Scenario-based land use management to restore natural areas and reducing soil erosion rate in a competing land uses condition

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Abstract:

Identifying the contribution of different land uses plays a crucial role in preventing erosion and prioritizing land management activities. This research aimed to assess the impacts of various land use scenarios on mitigating soil erosion in the North West Urmia region of Iran. In addition to the current scenario, 12 land use management scenarios were identified based on the observed trend in changes in land use patterns throughout the study area utilizing GIS. The RUSLE was used, and the necessary input parameters of the RUSLE model, were prepared. The erosion mapping has been done using overlaying the input layers. The baseline scenario (current condition) resulted in an erosion amount of 17.22 (t/ha/yr). Introducing soil conservation techniques in dry farming on steep terrain, as depicted in scenario 6 (conservation and restoration of plowed rangelands), resulted in a reduction of the erosion rate from 17.22 to 9.75 (t/ha/yr). On the other hand, scenario 20, characterized by severe rangeland degradation and overgrazing, exhibited the highest estimated erosion rate at 30.42 (t/ha/yr). In contrast, the most substantial erosion reduction of 43.37% was evident in scenario 6 (conservation and restoration of plowed rangelands). It was observed that the P-factor (support practice factor) had a more pronounced impact than the C-factor (crop/vegetation and management factor) in mitigating erosion. These findings suggest the potential for utilizing a scenario-based framework to evaluate the impact of management scenarios on erosion and prioritize soil and water management measures and strategies.

Keywords: Watershed management; Land use change; Management scenarios; Conservation practices; Scenario Analysis

1. Introduction

Soil erosion presents a notable environmental challenge that exposes natural resources, agriculture, and the environment (Pimentel, 2006). As a result, it is crucial to assess the extent of soil erosion over time and space in order to efficiently address soil erosion and manage sediment through watershed management (Shi et al., 2013; Admas et al., 2023). This not only reduces erosion but also provides decent income for the area's inhabitants (Kumar et al., 2014). Land use is a crucial factor in human-environmental relations, striking a balance between economics, hydrology, and land use ecology (Khiavi et al., 2022). The runoff and sediment yield of a watershed depend on its physiographic characteristics, land use pattern, soil type, rainfall severity and duration, and human interference, with land use playing a more critical role (Khiavi and Mostafazadeh, 2021). Additionally, land use is directly related to human activities through the need for sediment security in deposits and transport. Hence, it is essential to identify the factors that influence erosion and forecast the quantity of soil erosion and sediment in watersheds. This is necessary for implementing soil conservation programs and establishing strategies to reduce erosion and sediment yield, marking the initial phase of soil conservation effort. There is a wide range of models in the field of erosion and sediment studies that differ in their degree of complexity, simulation processes, and nature. The USLE, also known as the Universal Soil Loss Equation, is a widely used model that was created in the 1960s by Wischmeier and Smith as a field-scale model. It was later updated in 1997 to improve the accuracy of the parameter values used in the USLE. The USLE computes soil loss for a specific location by considering six primary factors, each representing a distinct condition that influences the extent of soil erosion at that site (Esmali-Ouri and Abdollahi, 2011; Majhi et al., 2021). The USLE determines the amount of soil loss at a specific site by considering six key factors. Each factor signifies a distinct condition that impacts the degree of soil erosion at that specific site (Majhi et al., 2021) in 2021. Changing weather patterns can lead to considerable variations in estimated erosion values. The RUSLE method provides more accurate long-term averages, considering multiple factors (Fu et al., 2005). Extensive research has explored soil erosion factors and prediction across various watersheds globally. RUSLE's widespread adoption is due to its ability to accommodate diverse contributing factors (Renard et al., 1997; Borrelli et al., 2017). The RUSLE method is highly trusted for soil erosion estimation and forecasting. Its ability to predict soil loss under projected land use and climate scenarios adds to its reliability (Semmahasak, 2014). Scenario-based land use management can mitigate soil erosion and sediment yield, benefiting the environment and society. Success depends on implementing and enforcing conservation practices and integrating social and economic dimensions into land management planning. Talebikhiavi et al. (2017) discovered contour farming and conservation practices reduced sediment yield in Ardabil province's Yamchii dam upstream. They also noted the effectiveness of plant residuals and biological soil conservation in both dry and irrigated farming. Semmahasak (2014) found conversion from deciduous forest to field crops increased soil erosion, even with reduced rainfall, and predicted a synergistic effect on erosion if bare land, field cropland, and rainfall erosivity rise concurrently. Villarreal et al. (2017) assessed future growth patterns' impact on conservation-targeted land, comparing short-term land-development pressure with longer-term growth projections. Aslam et al. (2020) observed increased soil loss severity in Pakistan's Chitral district due to land use changes, with high erosion risk areas doubling from 4% in 2000 to 8% in 2020, mainly due to a 4% increase in agricultural land. Chuenchum et al. (2020) projected soil erosion trends in the Lancang-Mekong River Basin using the modified RUSLE model, revealing forest conversion to agriculture and urban areas, alongside increased rainfall. Behera et al. (2020) employed a geo-spatial approach to assess soil loss in India's Brahmani River basin, identifying severe erosion in 54.2% and high soil loss potential zones in 35.81%. Gong et al. (2022) observed increased forested land in Miyun County, North China, using GIS-based RUSLE, indicating improved ground cover. They noted land use changes impacting soil erosion intensity, with ecological protection shifting from high to low erosion intensity. Sourn et al. (2022) in Battambang Province, Cambodia, linked soil erosion to land use changes, underscoring the need for improved land and crop management.

Singh et al. (2023) used a GIS-integrated RUSLE model to estimate soil loss in the Banas Basin, India, identifying watershed WS18 as the top priority for conservation due to its highest erosion rate. Mekonnen et al. (2023) applied the RUSLE model in Ethiopia's Upper Awash Basin, finding that cultivated land, though low in erosion severity, contributed 59% of total soil loss, with increasing risks as cultivation encroached on forests and grasslands. Guo et al. (2024) examined the impact of land use conversion on soil erosion in the urban agglomeration on the northern slopes of the Tianshan Mountains using the InVEST-SDR model. The study found that converting grassland and barren land to forests significantly reduced soil erosion by 27.3% and 46.3%, respectively. The soil erosion dynamics in the Romanian Subcarpathians were analyzed by Virghileanu et al. (2024). Using the RUSLE and Earth Observation techniques, the study assessed the impact of various land management practices over 35 years. They found that vegetative measures and soil practices can reduce soil loss rates by 50%-70%.

The literature provides insights, yet GIS-based erosion prediction and scenario evaluation offer a deeper understanding of land management impacts. Interdisciplinary research is vital for actionable land management solutions. Scenario-based approaches can drive effective implementation, enforce conservation, and integrate social and economic aspects. Literature highlights land use changes intensifying soil vulnerability, but proactive management can mitigate these impacts.

The reviewed literature proves that vegetation-based management scenarios are effective in reducing soil erosion and sediment yield. These practices have shown promise in several regions, emphasizing their potential to mitigate erosion under different land use conditions. However, there is a distinguished gap in understanding how these biological management practices perform over the long term, especially across diverse geographic regions and under varying climatic conditions. Future research should focus on evaluating the long-term effectiveness of vegetation-based management scenarios, considering different environmental and land use condition settings. It is crucial to explore how these practices can be adapted to ensure their continued effectiveness in reducing soil erosion across a broader range of ecosystems.

West Azarbaijan Province in Iran is particularly vulnerable to agricultural activities, such as dry and irrigated farming, which have frequently disregarded the land's inherent potential, leading to erosion, degradation, and diminished land productivity (Haji et al., 2022). Moreover, the excessive expansion of gardens and the destruction of natural landscapes have caused a decline in vegetation cover and heightened soil erosion, ultimately contributing to reduced groundwater levels and the depletion of water flowing into Urmia Lake. This study aims to assess the levels of soil erosion and sediment yield in the Rozechai watershed of Urmia by employing the RUSLE and GIS models. The study seeks to simulate erosion levels under various land use management scenarios involving erosion reduction measures and subsequently compare the outcomes.

2. Materials and methods

2.1 Study area description

The Rozechai watershed is located in the western part of the West-Azarbaijan Province, Iran, approximately 20 km away. The study area covers about 186.41 km^2 and is situated between 44° 40′ and 45° 55′ East longitudes and 37° 27′ and 37° 36′ North latitudes. The altitude of the study watershed ranges from 1471 to 3545m above mean sea level, with an average watershed slope of approximately 31.8%. The mainstream has a length of about 31.5 km (Mostafazadeh et al., 2017). The location map of the study area is illustrated in Figure 1.

The region experiences cold and wet winters and mild summers, with the Siberian cold, moist anticyclone from the north exerting a significant influence. When there are notable pressure differentials between the high-pressure Siberian anticyclone and the low-pressure southern air over the Persian Gulf, arctic air moves into Azarbaijan, leading to cold temperatures and winter snowfall. Meteorological data, encompassing rainfall, temperature, relative humidity, and evapotranspiration, were gathered from the Urmia synoptic station near the study area to ascertain the climatic needs of various land use categories.

2.2 Methodology

2.2.1 Revised universal soil loss equation (rusle) model

The RUSLE model, as an empirical soil detachment model, aims to forecast the erosion arising from sheet and rill erosion due to surface runoff in agricultural areas (Wischmeier and Smith, 1978). The RUSLE model is obtained from Eq. 1.

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

In the RUSLE model, the average annual soil loss (t/ha/yr) is represented by A, while R, K, LS, C, and P are factors that contribute to soil erosion. R represents the rainfall and runoff erosivity index (MJmm/ha/hr/yr), K denotes the soil erodibility factor (ton hr/MJ/mm), LS signifies the slope and length of the slope factor, C represents the cropping management factor, and P stands for the supporting conservation practice factor.

- Rainfall erosivity factor (*R*)

The rainfall erosivity factor (R) plays a pivotal role in sheet and rill erosion, acting as the primary force behind soil particle removal in the absence of protection. Elevated rainfall rates featuring larger droplets accelerate soil erosion compared to typical rainfall. Moreover, intense storm events can generate substantial runoff, resulting in considerable sheet or rill erosion (Biswas and Pani, 2015). Owing to the absence of rain gauge stations, the R-factor was approximated using Renard and Freimund (1994)'s equation, utilizing data gathered from nearby rain gauge stations. Initially, eight appropriate stations situated within and in proximity to the study area were chosen for the statistical period. The factor (R) was then calculated for the selected stations, based on the Modified Fournier Index (MFI) obtained from Eq. 2.

$$MFI = \sum_{i=1}^{12} \frac{P_{i2}}{P} \quad (2)$$

The modified Fournier Index (MFI) is used to calculate the *R-factor* in the RUSLE model, where P_i, and P, are average monthly and annual precipitation. The improved relation between the two indices was attributed to their unique characteristics (Arnoldus, 1977).

$$R - Factor = 0.264 MFI^{1.5} \quad (3)$$

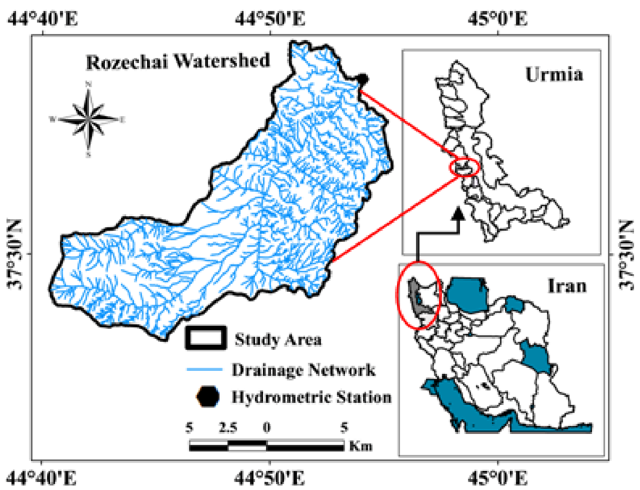

Figure 1. Location map of the study area in the West-Azarbaijan Province, Iran.

The precipitation used to calculate the modified Fournier Index (*MFI*) in Eq. 3 is in mm, while the *R-factor* is presumed to be in units of mega joul millimeter/ha/hr/yr (Renard and Freimund, 1994; Szilassi et al., 2006).

- Soil erodibility factor (*K*)

The *K* factor in the RUSLE model signifies soil vulnerability to erosion and its potential for runoff in terms of quantity and speed. Several soil attributes like texture, organic content, structure, and permeability determine a soil's erodibility. For example, soil organic matter diminishes erodibility (Shi et al., 2013), whereas soil structure affects both detachment susceptibility and infiltration capacity. Soil permeability impacts the *K* factor and the generation of runoff, and the *K* values obtained from graphical nomograph (Wischmeier and Smith, 1978) in 1978. Specific Erodibility Index (EI) zones have been established for certain geographical regions, facilitating time-varying *K* factor calculations. The seasonal variations in *K* are directly influenced by the annual distribution of rainfall erosivity. FAO guidelines (Roose, 1996) suggest soil erosion factors influenced by organic matter, soil composition, and permeability ranging from 0.70 for vulnerable soils to 0.01 for highly stable soils (Rokhbin et al., 2014). Morgan proposed distinct *K* values for various soil types, as summarized in Table. 1.

Table 1. The values of soil erodibility factor considering 1% soil organic matter (Parveen and Kumar, 2012).

Soil type	Soil erodibility factor (*K*)
Surface soil with gravel cover	0.5
Sandy	0.05
Loamy sand	0.12
Clay loam	0.28
Loamy fine sand	0.24

- Slope length and steepness factor (*LS*)

In the RUSLE model, the *LS* factor combines slope and length. In this study, a 10-meter digital elevation model (DEM) was used in ArcGIS 10.1, and the Arc Hydro tool extension was used for physical analysis, including slope length. The field gradient was also extracted from the region DEM. As a result, the study found that slope length and degree have a direct relationship with the amount of erosion (Mhangara et al., 2012). The *LS* value was calculated using Eqs (. 4) and (. 5) from Zhao et al. (2012) and Oliveira et al. (2013).

$$L = (\frac{\lambda}{22.1})^m$$
$$m = \frac{F}{1+F} \qquad F = \frac{\sin B/0.0896}{3(\sin B)^{0.8}+0.56} \tag{4}$$
$$S = 10.8\sin B + 0.03\tan B < 0.09 \tag{5}$$
$$S = 16.8\sin B - 0.5\tan B > 0.09 \tag{6}$$

In the RUSLE model, the *LS* factor is computed using the actual slope length (λ) and the slope length exponent (m). The slope length exponent signifies the proportion of rill to internal erosion. Conversely, the *S* factor (slope steepness factor) represents soil loss compared to a 9% slope, a standard slope utilized in experimental plots. The slope steepness factor is determined based on the slope, according to equation 5; where *S* represent the slope factor, and *B* indicates the slope angle.

- Crop/vegetation and management factor (*C*)

The *C* factor within the RUSLE model compares soil loss concerning specific types of vegetation cover. It evaluates the efficacy of a crop or vegetation and its management system in curbing soil loss. In the RUSLE model, empirical equations by Wischmeier and Smith (1978) determine the crop or vegetation and management factor. Hence, this factor was derived from the vegetation and land use map of the region, as detailed in Table. 2.

Table 2. The *C* factor in different land use types for the study area (Rokhbin et al., 2014).

Land use	Area (ha)	C-Factor
Residential areas	164	0.15
Garden	1881	0.2
Irrigated farming	472	0.19
Dry farming	3948	0.32
Space and moderate rangelands	7075	0.1
Dense rangelands	5099	0.03

- Support practices factor (*P*)

The support practice factor evaluates the ratio of soil loss attributed to a specific conservation practice against the soil loss from conventional straight-row farming conducted along up and down slopes. In this study, a ratio of 1 was chosen, indicating the use of straight-row farming as the baseline for comparison (Kim and Maidment, 2014).

- Overlying layers and erosion mapping

The RUSLE model was employed to obtain essential input parameters for the modeling procedure. The erosion map of the study area was created by overlaying the input layers following the RUSLE model through ArcGIS platform.

2.2.2 Measured sediment discharge

This study utilized data from the Kalhor sedimentation station for eight years spanning from 2006 to 2013 using sediment rating curves through examining the relationship between sediment and flow data. In this research, the (Lawrence, 1996; "National Engineering Handbook, Sedimentation, Chapter 6: Sediment sources, yields, and delivery ratios.," 1971) sediment delivery ratio (SDR) methods were used to determine the erosion and sedimentation rates (Becvar, 2006; Asadi-Nalivan et al., 2013). Based on the analysis of the station data and assessment of various SDR calculation methods, the (Lawrence, 1996) method has been selected as most appropriate Eq. 7.

$$SDR = A^{-0.2} \quad (7)$$

where, A is the area study (km^2).

2.2.3 Development of land use and crop/vegetation management scenarios

Using a scenario-based approach, land use scenarios were developed considering diversity and erosion reduction potential (Sadoddin et al., 2010; Dymond et al., 2010). Different management scenarios for erosion-prone areas were identified using land use maps and relevant guidelines, implemented through the ArcGIS platform (Ronford et al., 2011).

The study area and land use condition were used to develop twenty land use-based management scenarios for the watershed, in addition to the existing scenario (current condition), taking into account restoration and degradation approaches and soil conservation against erosion (Table. 3). As the parameters K (soil erodibility), L (slope length), and S (slope) within a defined region remain stable in the short term within the RUSLE model, variations in rainfall patterns significantly impact the R parameter. Hence, alterations in the C and P parameters are crucial for assessing the impacts of agricultural practices and soil conservation efforts. The land use information, in conjunction with the combined table, was employed to extract C and P values for each land use type, applied in the RUSLE model to compute soil erosion for various management scenarios within a 10×10 meters cell size.

The correlation between changes in the amount of land use erosion in different management scenarios and the factor C and P values was evaluated using SPSS software through correlation analysis. A significant correlation indicates that changes in factors C and P will significantly affect the amount of soil erosion.

3. Results and discussion

3.1 Soil erosion and sediment estimation

The factors that impact soil erosion estimation in the RUSLE model were classified based on the study area conditions and mapped using layer overlap expressed in t/ha/yr in the ArcGIS10.1 environment. Upon computation of the R, K, LS, C, and P factors within the RUSLE model, the average values for each factor were determined, yielding an annual soil erosion average of 17.22 t/ha/yr. Furthermore, Table 4 exhibits the sediment yields recorded at the Kalhor river gauge station situated in the Rozehchai watershed.

Table 4 displays the observation sediment amount calculated using sediment rating curves, which is equivalent to 0.687 t/ha/yr. Additionally, the average watershed erosion, estimated using the (Lawrence, 1996) method and considering SDR, was found to be 1.96 t/ha/yr.

3.2 Land use management scenario analysis

The management activities were prepared based on the ecological conditions of the study area, land suitability, constraints, and reclamation activities, using existing standard guidelines and resources, as described in the research

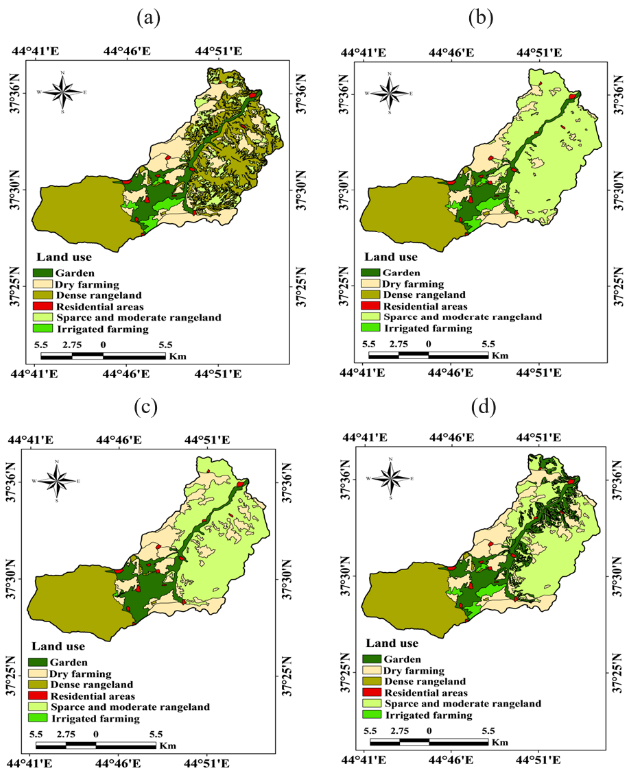

Figure 2. Land use management scenarios in the study area, a) conservation and restoration of rangeland, b) conservation and restoration of plowed rangelands, , c) soil conservation and water construction measures, d) soil conservation and construction of the vineyard.

Table 3. Rules for management scenarios development to restore degraded area.

Management scenarios	Title of activity	Rules of codification and description
Existing condition	Current land use	Baseline scenario (existing condition)
1	Restoration and improvement of rangeland	Conversion of space and moderate rangelands into dense rangelands (Faro at a slope of less than 20%, fertilization and planting pile at a slope of more than 25%)
2	Restoration of plowed rangelands	Restoration of plowed rangelands located in rangelands or adjoining areas with a slope of more than 25% (27% of dry farming), a 50-meter buffer of dense rangelands and space and moderate rangelands
3	Garden construction	The construction of apple and walnut gardens in the lands (slope of less than 20%)
4	Construction of vineyards	The construction of vineyards in space and moderate rangelands around the villages (slopes 30 to 60%) , 1500-meter buffer of residential areas
5	Conservation and improvement of rangeland	Performance conservation operations in scenario 1
6	conservation and restoration of plowed rangelands	Performance conservation operations in scenario 2
7	Soil conservation and garden construction	Performance conservation operations in scenario 3
8	Soil conservation and construction of the vineyard	Proper economic operation, conservation of sloping areas through the construction of vineyards
9 9	Soil low conservation in existing rangelands	Observe the grazing season, suitable grazing intensity
10	Soil low conservation in existing dry farming	Convert of low-yielding farms into dense rangelands and space and moderate rangelands, changing of crops cultivation in every year
11 11	Soil low conservation in existing irrigated farming	Conservation the remnants of vegetation after of crops harvesting
12	Soil low conservation in existing garden lands	Fertilization, planting of appropriate trees to the local conditions of the region
13 13	Soil high conservation in existing rangelands	Enclosed rangeland, fertilization
14	Soil high conservation in existing dry farming	Planting of trees with shallow water requirements, fertilization
15 15	Soil high conservation in existing irrigated farming	Periodic cultivation
16	Soil high conservation in existing garden lands	Deep soil, appropriate water quality, use of understory trees for alfalfa cultivation
17	Rangeland plow in existing land use	Conversion of space and moderate rangelands and dense rangelands into dry farming (slope of less than 15%)
18	Degradation and overgrazing of the rangelands	Conversion of moderate rangelands into space rangelands (low vegetation, low palatability plants, inappropriate time for entering and leaving livestock from rangeland)
19	Severe degradation and overgrazing of the rangelands	Conversion of dense rangelands into moderate rangelands (inappropriate soil, non-compliance with the grazing season, the inappropriate balance between livestock and rangeland, high grazing intensity)
20	overgrazing of the rangelands	Conversion of moderate and dense space rangelands (excessive grazing intensity, rangelands into livestock imbalance in the rangeland, fragile soil surface)

Table 4. Measured sediment and soil erosion values (t/ha/yr) in the Kalhor river gauge station.

Annual sediment average (t/ha/yr)	(SDR) Sediment delivery ratio	Area (km^2)	Soil erosion average (t/ha/yr)
0.687	0.35	186.41	1.96

methodology. The current condition of the Rozechai watershed was considered as the base-case scenario), as presented in Figure 2a, b, c, d, e, f.

3.3 Effects of management scenarios on soil erosion and sediment rate

Table 5 present the average soil erosion and sediment yield (t/ha/yr) for each of the management scenarios.
The results presented in Table 5 show that the observed values of soil erosion in the current land use scenario range from zero to 17.22 t/ha/yr. Scenario 20, characterized by severe rangeland degradation and overgrazing, exhibited the highest estimated erosion at 30.42 t/ha/yr, marking a substantial increase of 13.20 t/ha/yr (76.66%) compared to the present land use scenario. Conversely, scenario 6, involving the conservation and rehabilitation of rangelands previously converted from dry farming areas, demonstrated the lowest erosion at 9.75 t/ha/yr, showcasing a notable reduction of 7.47 t/ha/yr (43.38%) compared to the current land use scenario. The most significant and least sediment values were observed in scenario 20 (extreme rangeland degradation and overgrazing) and scenario 6 (restoration of plowed rangelands), respectively. Dry farming notably influenced erosion and sediment yield in contrast to the other scenarios.
Conservation operations in dry agricultural lands that are converted into rangelands (scenario 6), high soil conservation in existing rangelands (scenario 13), and conservation and restoration of rangelands (scenario 5) have resulted in erosion reduction of 43.38%, 40.19%, and 34.09%, respectively.
Yousefifard et al. (2007) and Talebikhiavi et al. (2017) have also referred to the productive erosion importance of sloping lands in their study areas. Mixed management scenarios usually have a more significant impact on reducing erosion. Participatory planning of soil conservation should consider implementing extension programs to educate farmers on the positive effects of erosion control operations and proper tillage. The proposed management operation can be combined with traditional and native methods in the region, as suggested by Villarreal et al. (2017). Based on results, it is possible to adapt to watershed conditions and the location and area of different land uses by implementing ecology plans based on the principles of landscape ecology. This approach aims to control runoff and reduce sediment flow, which is similar to the findings of Ronford et al. (2011) and Semmahasak (2014) regarding the importance of assessing the results of surface runoff reactions in the form of land use change scenarios for local planning and policymaking. The findings of this study align with the results of Singh et al. (2023) and Mekonnen et al. (2023), both of which used RUSLE models to assess soil erosion and prioritize conservation efforts. However, the results in the study watershed incorporated a scenario analysis of various land management practices and their impact on soil erosion rates. This study emphasizes the restoration and conservation of rangelands as a more effective strategy, demonstrating up to a 43.38% reduction in erosion. This study advances the understanding of erosion control by providing specific, actionable management scenarios tailored to the ecological conditions of the Rozechai watershed, offering a appropriate approach to mitigating soil loss that could be adapted to similar regions.
In examining the competitive land uses, it is evident that the Rozechai watershed has undergone significant changes in land use, as indicated by field surveys and the previous land use conditions. On the other hand, given the high population density in the region, the intensity of land use in

Table 5. The soil erosion and sediment yield (t/ha/yr) in different management scenario.

Management scenarios	Title of activity	Soil erosion (t/ha/yr)	Sediment (t/ha/yr)	Soil changes (t/ha/yr)	Soil changes (%)
Base	Current land use	17.22	6.05	0	0.00
1	Restoration and improvement of rangeland	14.03	4.93	-3.19	-18.52
2	Restoration of plowed rangelands	15.34	5.39	-1.88	-10.92
3	Garden construction	17.23	6.06	0.01	0.06
4	Construction of vineyards	18.15	6.38	0.93	5.40
5	Conservation and improvement of rangeland	11.35	3.99	-5.87	-34.09
6	conservation and restoration of plowed rangelands	9.75	3.43	-7.47	-43.38
7	Soil conservation and garden construction	16.44	5.78	-0.78	-4.53
8	Soil conservation and construction of the vineyard	17.02	5.98	-0.2	-1.16
9	Soil low conservation in existing rangelands	13.71	4.82	-3.51	-20.38
10	Soil low conservation in existing dry farming	15.46	5.43	-1.76	-10.22
11	Soil low conservation in existing irrigated farming	17.14	6.02	-0.08	-0.46
12	Soil low conservation in existing garden lands	16.75	5.89	-0.47	-2.73
13	Soil high conservation in existing rangelands	10.3	3.62	-6.92	-40.19
14	Soil high conservation in existing dry farming	13.74	4.83	-3.48	-20.21
15	Soil high conservation in existing irrigated farming	17.07	6.00	-0.15	-0.87
16	Soil high conservation in existing garden lands	16.3	5.73	-0.92	-5.34
17	Rangeland plow in existing land use	17.68	6.21	0.46	2.67
18	Degradation and overgrazing of the rangelands	18.49	6.50	1.27	7.38
19	Severe degradation and overgrazing of the rangelands	26.5	9.31	9.28	53.89
20	Very severe degradation and overgrazing of the rangelands	30.42	10.69	13.2	76.66

agricultural areas is high, and practices leading to further degradation exacerbate erosion problems. Additionally, the high number of livestock in pastures is an indicator of the pressure caused by grazing on natural areas. Also, the watershed, characterized by a diverse range of elevations and slopes, experiences various climatic influences which affect soil erosion dynamics.

3.4 Changes in rusle factors and soil erosion rate

Figure 3 illustrates the correlation between the values of factors C and P and soil erosion in different land use scenarios.

The correlation results displayed in Figure 3 reveal a noteworthy relationship between the C-factor and soil erosion amounts. Higher C-factor values correspond to increased soil erosion, while elevated vegetation cover and residue tend to reduce the C-factor, subsequently reducing soil erosion rates. Meanwhile, the P-factor, ranging from zero to one, exhibits a direct relationship with soil erosion rates, where higher P-factor values result in increased erosion rates. Furthermore, Table 6, obtained through SPSS software and Pearson's correlation test, demonstrates a significant positive correlation between the C-factor and soil erosion values ($r=0.79$, $p<0.01$), as well as between the P-factor and soil erosion values ($r=0.65$, $p<0.01$). These results highlight the importance of considering both the C and P-factors when formulating land use management strategies to address soil erosion. Such studies emphasize the pivotal role of effective land management practices, including bolstering vegetation cover and minimizing soil disturbance, in reducing soil erosion and sediment yield.

3.5 Management implications

Evaluating the influence of management scenarios on reducing erosion and sediment yield suggests the potential advantages of restorating poor and moderate rangelands through fertilization, seeding, and planting initiatives, and converting them into high-quality rangelands, subject to the region's natural conditions. Moreover, reinforcing vegetation for livestock purposes can notably diminish erosion rates. Therefore, operations can be prioritized based on the severity of erosion in each land use scenario or the extent to which operations can be carried out. These studies support the idea that proper land management practices, including conservation and rehabilitation of rangelands, can play a crucial role in reducing soil loss and sediment production. However, both studies highlight the importance of identifying the contribution of different land use practices in preventing soil erosion and prioritizing land management activities. Furthermore, the importance of proper land management practices, including the regeneration of poor and medium rangelands and strengthening vegetation for livestock purposes, is emphasized as a means of reducing soil erosion rates.

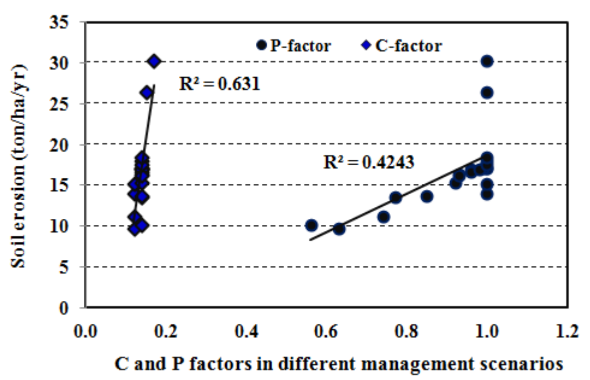

Figure 3. Relationship between factors C and P with soil erosion in different management scenarios.

Table 6. Pearson correlation coefficient r between factor C and P with soil erosion in different management scenarios.

Factor	Se	C	P
Se	1.00	-	-
C	**0.794	1.00	-
P	**0.651	0.313	1.00

Se:Soil erosion (t/ha/yr)

4. Conclusions

The soil erosion intensity mapping in a mountainous watershed was examined using the RUSLE model and GIS, employing a scenario-based approach that accounted for both restoration and degradation conditions in an area with intensive land use. The analysis revealed an average annual soil loss of 17.22 t/ha/yr in the watershed, which was subsequently categorized into six groups, with the greatest proportion of erosion observed in the shallow, low, and moderate categories. The total observed sediment was estimated to be 0.687 t/ha/yr based on discharge-sediment and sediment rating curves. Management activities were then developed based on the ecological conditions, land suitability, and available resources and guidelines. A range of management scenarios was codified, including restoration and degradation scenarios, in order to project future conditions in the region. The scenario-based approach in the GIS environment enabled spatial estimation of erosion changes and management planning, in addition to assessing erosion severity. These studies emphasize the significance of adopting management practices tailored to the ecological characteristics and land use patterns of the study area to decrease soil erosion and sediment yield. Implementing management measures in areas with severe erosion and critical locations can be a practical approach to reducing erosion and sediment discharge from watersheds. The baseline scenario shows an erosion rate of 17.22 tons/ha/yr, whereas scenario 20, which involves severe degradation of grazing pastures, results in a 66.67% increase in erosion, in line with Pajoohesh et al. (2011) findings on increased erosion in rangelands due to the interaction between slope and excessive grazing of livestock during early spring. The increase in erosion production in rangelands can be attributed to the interaction between slope and excess grazing of livestock in

the early spring. Plant cover is crucial in mitigating runoff and erosion, and enclosing rangelands is a suitable approach for enhancing vegetation, which diminishes the effect of raindrops on the soil, leading to reduced soil structure disruption and facilitating water infiltration.
The study's results emphasize the significance of recognizing the impact of various land uses in preventing soil erosion and prioritizing land management efforts. They emphasize the effectiveness of implementing conservation practices in arid agricultural settings, especially on steep lands, as demonstrated by scenario 6 (conservation and restoration of plowed rangelands). These practices led to a significant reduction in erosion, underscoring the importance of prioritizing strategies for soil and water management.
To determine the acceptance of the developed scenarios in the area, interviews or surveys can be conducted among watershed communities, ranchers, and farmers. It is important to note that a suitable scenario should not only reduce erosion but also increase farmers' income. The results of scenario analysis can help decision-makers and stakeholders to better understand the potential impacts of different land use options and make more informed and sustainable decisions. The development of suitable soil and water management measures to address the effects of climate change can aid in reducing soil erosion and safeguarding the ecological integrity of the watershed.

4.1 Limitations

In this research, we have focused on predicting the effect of scenarios on erosion, but it should also be considered a factor in runoff production and hydrological response. One limitation of this research is that the land use scenarios evaluated are based on static GIS data and may not fully account for dynamic changes in land use patterns and climate conditions over time. Additionally, the RUSLE model's reliance on input parameters that are subject to spatial variability and measurement uncertainty could affect the accuracy of erosion estimates and their generalizability to different regions or future conditions.

4.2 Future directions

Future research should explore the long-term effectiveness of scenario-based land use management in restoring natural areas. Additionally, investigating how different combinations of support practices and vegetation management can be optimized for various environmental and socio-economic contexts will be crucial in enhancing the resilience and sustainability of these strategies. Also, further research could explore the effectiveness of various soil and water management strategies in mitigating soil erosion and sediment production.

Authors Contributions
All authors contributed to the study conception and design.

Availability of Data and Materials
All data generated or analysed during this study are included in this published article.

Conflict of Interests
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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