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Changes and Transitions in Soil Erosion Intensity Classes in Liangshan Yi Autonomous Prefecture

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Abstract

This study assessed how soil erosion extent and intensity changed in Liangshan Yi Autonomous Prefecture, southwestern China, between 2000 and 2023. The Revised Universal Soil Loss Equation (RUSLE) was used to estimate soil erosion rates for 2000, 2005, 2010, 2015, 2020, and 2023. The estimates were grouped into six intensity classes, and a transition matrix was constructed by overlaying the 2000 and 2023 classifications. Very slight and slight erosion together accounted for more than 90% of the classified area in all six years. The area with slight or greater erosion decreased from 15,748.33 km² in 2000 to 15,038.74 km² in 2023 (4.51%), while the area with moderate or greater erosion declined by 12.47%. Erosion extent reached its lowest recorded value in 2010, increased through 2020, and then declined again by 2023. In the endpoint transition matrix, shifts to lower intensity classes accounted for 64.81% of the area that changed class. Class-specific transitions require further verification because the matrix totals by class differ from the annual area estimates. The results support tracking both overall erosion extent and the area in higher intensity classes when assessing regional erosion trends.

Keywords

soil erosion intensity, RUSLE, temporal variation, transition matrix, Liangshan Yi Autonomous Prefecture

1. Introduction

Soil erosion removes soil and nutrients, reduces soil fertility and land productivity, and contributes to sediment accumulation and water quality deterioration [1]. It can also impair ecosystem productivity and stability, accelerate land degradation, and damage habitats and biodiversity, with consequences for food security, water resources, and regional sustainability [2]. In China, variations in topography, rainfall, and human activity produce substantial regional differences in erosion. Although conservation efforts have made progress and erosion extent and intensity have generally declined in recent years, prevention and control remain challenging, particularly in mountainous areas and ecologically vulnerable regions [3].

Reliable estimates of soil erosion rates and soil loss are fundamental to regional erosion assessment [4]. Field monitoring provides direct measurements, but long observation periods, high costs, and limited spatial coverage restrict its use for large-area assessments. Empirical models generally require fewer parameters and

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more readily available data. The Revised Universal Soil Loss Equation (RUSLE) estimates soil loss from rainfall erosivity, soil erodibility, slope length and steepness, cover and management, and support practices. Its compatibility with geographic information systems (GIS) has supported its use across a range of regions and terrain conditions [5]. For example, Zha et al. [6] used RUSLE to assess erosion changes in the Chaohu Lake Basin during 1992–2013, while Liu et al. [7] examined the spatial distribution of soil erosion in the Wuling Mountains.

In 2023, the General Office of the Communist Party of China Central Committee and the General Office of the State Council issued guidelines on strengthening soil and water conservation, emphasizing erosion prevention and control in priority areas. Liangshan Yi Autonomous Prefecture, southwestern Sichuan Province, lies in the lower Jinsha River region and forms part of a national priority area for erosion control. Its varied natural conditions and human activities create spatial differences in erosion. Assessing changes in erosion intensity classes can help identify areas requiring conservation and restoration. We therefore used RUSLE to estimate soil erosion rates in Liangshan for 2000, 2005, 2010, 2015, 2020, and 2023. Class-area statistics and a transition matrix were then used to examine changes in erosion class composition and transitions between classes over the study period.

2. Materials and Methods

2.1 Study Area

Liangshan Yi Autonomous Prefecture (26°03′–29°27′ N, 100°03′–103°53′ E) is located in southwestern Sichuan Province, along the lower reaches of the Jinsha River, and covers approximately 6.03×10^4 km² [8]. Its complex terrain is predominantly mountainous, with elevations generally decreasing from northwest to southeast. Mountain ranges, including the Daliang and Daxue Mountains, alternate with river valleys, producing substantial topographic relief. The study area has a subtropical monsoon climate with distinct wet and dry seasons. Topographic and elevation differences create pronounced vertical climatic zonation [9]. This complex terrain, seasonal precipitation variability and spatial differences in land cover contribute to spatial variation in soil erosion across Liangshan.

2.2 Data Sources

The data sources are listed in Table 1. Precipitation, land-use and NDVI data were obtained for different years in Liangshan, whereas DEM and soil data were held constant. All spatial datasets were harmonized to the WGS_1984_UTM_Zone_48N coordinate system and a 30 m resolution to ensure consistent spatial references and grid sizes for calculating the RUSLE factors.

Table 1: Data sources and spatial resolutions

Dataset	Resolution	Source
Soil properties	1000 m	Harmonized World Soil Database (https://iiasa.ac.at/models-tools-data/hwsd)
Land use	30 m	Resource and Environment Science and Data Center, CAS (https://www.resdc.cn)
Precipitation	1000 m	National Tibetan Plateau Data Center (https://data.tpdc.ac.cn)
DEM	30 m	Geospatial Data Cloud (www.gscloud.cn)
Slope gradient	30 m	Derived from the DEM in ArcGIS
Slope length	30 m	Derived from the DEM in ArcGIS
NDVI	30 m	National Ecosystem Science Data Center (https://nesdc.org.cn)

2.3 Methods

2.3.1 RUSLE Model

The Revised Universal Soil Loss Equation (RUSLE) was used to estimate soil erosion rates in Liangshan Yi Autonomous Prefecture:

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

Here, A is the soil erosion rate (t ha^{-1} yr^{-1}); R is the rainfall erosivity factor, which represents the erosive potential of rainfall; K is the soil erodibility factor; and LS is the slope length and steepness factor. C and P are the dimensionless cover and management factor and support practice factor, respectively.

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(1) Calculation of the slope length and steepness factor (LS)

Slope gradient and slope length were derived from the DEM. The modified equation proposed by Liu et al. [10] for steep slopes was used to improve the applicability of slope steepness calculations in these areas.

$$L=\left(\frac{\lambda}{22.13}\right)^{m} \tag{2}$$

$$\begin{cases} m=0.5 & \theta\geq 9° \\ m=0.4 & 9°>\theta\geq 3° \\ m=0.3 & 3°>\theta\geq 1° \\ m=0.2 & 1°\geq\theta \end{cases} \tag{3}$$

$$S=\begin{cases} 10.8\sin\theta+0.03 & \theta<9° \\ 16.8\sin\theta-0.50 & 18°>\theta\geq 9° \\ 21.91\sin\theta-0.96 & \theta>18° \end{cases} \tag{4}$$

Here, λ is slope length (m), θ is slope gradient (°), and m is the slope-length exponent.

(2) Rainfall erosivity factor (R)

The R factor represents the effect of rainfall on soil erosion and is primarily related to rainfall amount and erosive potential [11]. Rainfall erosivity was estimated using the following empirical rainfall-based equation [12]:

$$R_j=\alpha P_j^{\beta} \tag{5}$$

Here, R_j is the rainfall erosivity factor in year j, P_j is precipitation in the corresponding year, and α and β are 0.0534 and 1.6548, respectively.

(3) Soil erodibility factor (K)

The K factor describes the susceptibility of soil to detachment and transport by rainfall and surface runoff. It was calculated using the empirical EPIC equation [13] and its correction relationship as follows:

$$\begin{aligned} K_{EPIC}= & \left\{0.2+0.3\exp\left[-0.0256SAN\left(1-\frac{SIL}{100}\right)\right]\right\}\times\left(\frac{SIL}{CLA+SIL}\right)^{0.3} \\ & \times\left\{1-\frac{0.25C}{\left(C+\exp(3.718-2.947C)\right)}\right\}\times\left[1-\frac{0.7\mathrm{S}N_1}{\mathrm{SN}_1+\exp(-5.509+22.899SN_1)}\right] \end{aligned} \tag{6}$$

$$K=(-0.01383+0.51575K_{EPIC})\times 0.1317 \tag{7}$$

$$SN_1=1-\frac{SAN}{100} \tag{8}$$

Here, SAN, C, SIL and CLA are the soil sand, organic carbon, silt and clay contents (%), respectively.

(4) Cover and management factor (C)

Following the method of Cai et al. [14], vegetation cover was estimated from the normalized difference vegetation index, and C was calculated using the following empirical relationships:

$$f=\frac{I-I_{\min}}{I_{\max}-I_{\min}} \tag{9}$$

$$C=\begin{cases} 1 & f=0 \\ 0.6508-0.3436\times\lg f & 0<f<0.783 \\ 0 & f\geq 0.783 \end{cases} \tag{10}$$

Here, f is vegetation cover, and I is the normalized difference vegetation index.

(5) Support practice factor (P)

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The P factor represents the effects of land-use types and soil and water conservation practices on soil erosion and ranges from 0 to 1. It is one of the more difficult model parameters to obtain because field surveys and quantitative measurements are time-consuming and labor-intensive. Values are therefore commonly assigned by land-use type. Using land-use-based assignment as a general framework [15], we set P to 1 for forest and grassland, 0 for water bodies and built-up land, 0.4 for unused land, and 0.2 for cropland.

2.3.2 Soil Erosion Classification

Soil erosion intensity in the study area was classified by soil erosion rate according to the Standards for Classification and Gradation of Soil Erosion (SL 190–2007) [16]. Six classes were defined: very slight, slight, moderate, severe, very severe and extreme. The classification criteria are provided in Table 2.

Table 2: Classification of soil erosion intensity

Erosion intensity class	Soil erosion rate (t ha^{-1} yr^{-1})
Very slight	<5
Slight	5-25
Moderate	25-50
Severe	50-80
Very severe	80-150
Extreme	>150

2.3.3 Transition Matrix

Soil erosion class maps for 2000 and 2023 were overlaid to quantify the areas transitioning between the six classes. A transition matrix was constructed as follows:

$$H = \begin{bmatrix} H_{11} & H_{12} & \cdots & H_{1n} \\ H_{21} & H_{22} & \cdots & H_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ H_{n1} & H_{n2} & \cdots & H_{nn} \end{bmatrix} \tag{11}$$

Here, H is the transition matrix, H_{ij} is the area (km^2) transitioning from class i in 2000 to class j in 2023, and n is the number of erosion classes.

3. Results

3.1 Changes in Erosion Class Composition

Very slight and slight erosion together accounted for more than 90% of the study area in every assessed year (Table 3). Very slight erosion was the most extensive class, followed by slight erosion; moderate and higher classes occupied smaller areas. Between 2000 and 2023, the share of very slight erosion increased from 73.88% to 75.05%, while that of slight erosion decreased slightly from 17.45% to 17.36%. Low-intensity erosion therefore remained dominant, with an overall shift in class composition toward lower severity.

The erosion-affected area, defined here as the area with slight erosion or above, decreased from 15,748.33 km^2 in 2000 to 15,038.74 km^2 in 2023, a net reduction of 709.59 km^2 (4.51%). The area of very slight erosion increased by 709.27 km^2, whereas slight erosion decreased by only 57.50 km^2. Moderate, severe, very severe, and extreme erosion decreased by 237.52, 237.46, 121.29, and 55.82 km^2, respectively. Extreme and severe erosion had the largest relative reductions, at 67.93% and 28.40%. The combined area with moderate or greater erosion decreased from 5,227.64 to 4,575.55 km^2, a decline of 12.47%, exceeding the reduction in the total erosion-affected area.

Erosion severity generally decreased between 2000 and 2010. The area of very slight erosion increased from 44,536.33 to 46,412.94 km^2, and its share rose from 73.88% to 76.99%, the highest among the assessed years. Slight erosion fluctuated modestly but decreased overall, while moderate, severe, very severe, and extreme erosion declined at each successive assessment. Severe erosion decreased from 836.19 to 102.18 km^2, and extreme erosion from 82.17 to 14.27 km^2. The total erosion-affected area reached 13,871.49 km^2 in 2010, a reduction of 1,876.84 km^2 (11.92%) from 2000 and the lowest value recorded in the study.

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This reduction was reversed during 2010–2015. The area of very slight erosion decreased from 46,412.94 to 44,521.22 km². Slight erosion also decreased, whereas all classes from moderate to extreme expanded. Moderate and severe erosion increased by 728.55 and 729.26 km², respectively, while very severe and extreme erosion increased by 245.09 and 82.74 km². The total erosion-affected area rose to 15,482.57 km², 11.61% above the 2010 value. The contraction of very slight erosion and expansion of higher-intensity classes indicated an increase in modeled erosion severity over this interval.

During 2015–2020, the erosion-affected area increased slightly, from 15,482.57 to 15,634.62 km² (0.98%). Changes differed among classes. Very slight erosion increased modestly, slight erosion decreased by 240.16 km², and all classes from moderate to extreme increased. The combined area with moderate or greater erosion grew from 5,226.75 to 5,618.96 km², an increase of 7.50%. Thus, the small change in total erosion extent coincided with an expansion of higher-intensity erosion.

Erosion severity decreased again during 2020–2023. Very slight and slight erosion increased by 599.51 and 447.53 km², respectively, while all higher classes contracted. Moderate, severe, and very severe erosion decreased by 287.16, 398.83, and 284.22 km². Extreme erosion fell from 99.55 to 26.35 km², a reduction of 73.53%. The combined area with moderate or greater erosion decreased by 1,043.41 km² (18.57%), and the total erosion-affected area declined by 595.88 km² to 15,038.74 km². These changes reflected both a reduction in erosion extent and a shift toward lower intensity classes. Nevertheless, the erosion-affected area in 2023 remained larger than in 2010.

Table 3: Areas of soil erosion intensity classes in Liangshan during 2000–2023 (km²)

Erosion class	2000	2005	2010	2015	2020	2023
Very slight	44,536.33	45,515.98	46,412.94	44,521.22	44,646.09	45,245.60
Slight	10,520.69	10,364.83	10,430.38	10,255.82	10,015.66	10,463.19
Moderate	2,624.37	2,287.70	1,859.94	2,588.49	2,674.01	2,386.85
Severe	836.19	543.11	102.18	831.44	997.56	598.73
Very severe	1,684.91	1,541.81	1,464.72	1,709.81	1,847.84	1,563.62
Extreme	82.17	31.25	14.27	97.01	99.55	26.35

3.2 Transitions Between Erosion Intensity Classes

The erosion classifications for 2000 and 2023 were overlaid to construct a transition matrix (Table 4). Most of the study area remained in the same class, although transitions toward both lower and higher severity occurred. In the current matrix, 54,512.88 km² (90.43%) retained the same class at the two endpoints, while 5,771.46 km² (9.57%) changed class. Endpoint class agreement therefore predominated over class transitions. Very slight erosion had the largest unchanged area, at 32,421.56 km². The unchanged areas of slight, moderate, and very severe erosion were 9,191.30, 5,713.15, and 5,078.56 km², respectively, compared with 2,084.07 km² for severe erosion and 24.24 km² for extreme erosion. Very slight and slight erosion together accounted for most of the area retaining its original class. Transitions to lower severity covered 3,740.44 km², or 64.81% of the area that changed class. Transitions to higher severity covered 2,031.02 km² (35.19%). The area shifting to lower classes was 1.84 times that shifting to higher classes, a difference of 1,709.42 km². By area, transitions toward lower erosion intensity therefore predominated, although some locations shifted to higher classes.

Most transitions to lower severity followed a small number of pathways. The largest was from slight to very slight erosion (1,131.74 km²), followed by very severe to slight (975.91 km²), severe to moderate (789.75 km²), and very severe to severe erosion (498.10 km²). Together, these four pathways accounted for 90.78% of the area shifting to lower classes. They included both transitions between adjacent classes and larger changes spanning several classes. A further 52.99 km² shifted from extreme to very severe erosion.

The largest transition toward higher severity was from moderate to very severe erosion, covering 1,177.42 km², or 57.97% of the area shifting to higher classes. Very slight erosion also shifted to higher classes: 246.80 km² became slight, 159.01 km² moderate, and 142.51 km² very severe erosion. Smaller areas became severe (65.45 km²) and extreme erosion (0.79 km²). These transitions from very slight erosion totaled 614.56 km², indicating increased erosion severity in some areas that initially belonged to the lowest class. Transitions also occurred in both directions between individual class pairs. Slight-to-very-slight transitions covered 1,131.74 km², compared with 246.80 km² in the reverse direction, giving a combined exchange of 1,378.54 km². By contrast, transitions between moderate and very severe erosion were dominated by increasing severity:

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1,177.42 km² shifted from moderate to very severe erosion, whereas only 48.47 km² shifted in the opposite direction. These differences show that an overall reduction in erosion extent can coexist with increases in severity at particular locations. The transition matrix adds information on these pathways that is not apparent from net class-area changes alone.

Table 4: Transition matrix of soil erosion intensity classes in Liangshan between 2000 and 2023 (km²)

	Very slight	Slight	Moderate	Severe	Very severe	Extreme	Total
Very slight	32421.56	246.80	159.01	65.45	142.51	0.79	33036.12
Slight	1131.74	9191.30	74.79	26.44	95.60	0.77	10520.64
Moderate	72.65	36.71	5713.15	24.34	1177.42	0.08	7024.35
Severe	33.79	11.87	789.75	2084.07	16.55	0.15	2936.16
Very severe	83.52	975.91	48.47	498.10	5078.56	0.32	6684.89
Extreme	2.33	0.60	1.67	0.34	52.99	24.24	82.17

4. Discussion

4.1 Changes in Erosion Class Composition and Their Regional Implications

Very slight and slight erosion dominated the erosion class composition in Liangshan Prefecture from 2000 to 2023, together accounting for more than 90% of the area in every study year. This indicates relatively low modeled erosion intensity across much of the study area. The predominance of lower erosion classes is consistent with the findings of Zhang et al. [17] for the Sunshui River Basin in Liangshan Prefecture. Erosion control nevertheless remains necessary across the region. In 2023, the erosion-affected area was still 15038.74 km², including 4575.55 km² with moderate or higher erosion, indicating that a portion of the study area continued to face relatively high erosion risk. Regional assessments should therefore consider both the dominant erosion classes and the areas in higher classes, so that the large proportion of very slight erosion does not obscure changes in other classes.

Between the beginning and end of the study period, the area with moderate or higher erosion decreased by 12.47%, compared with a 4.51% decrease in the total erosion-affected area. The overall improvement thus involved both a contraction of the erosion-affected area and a change in erosion class composition. Severe and extreme erosion showed particularly large relative decreases in area, reflecting a reduction in some of the higher erosion classes. Changes in class areas describe the distribution of land among intensity intervals, however, and do not directly imply proportional changes in total soil loss. Further analysis of the mean erosion rate and soil loss contribution of each class could identify classes that occupy small areas but account for large soil losses, allowing more targeted regional assessment.

4.2 Interpreting Temporal Fluctuations in Soil Erosion

Soil erosion in Liangshan Prefecture alternated between improvement and renewed deterioration during the study period. The erosion-affected area decreased from 2000 to 2010, increased from 2010 to 2020, and decreased again from 2020 to 2023. The overall improvement between the first and last years was therefore neither continuous nor uniform. The erosion-affected area in 2023 remained larger than in 2010, showing that improvement could be reversed and that erosion at the end of the study period had not returned to the lowest level recorded among the study years.

The model used static topographic and soil data, so differences in the estimates among years were expressed mainly through rainfall erosivity, the cover-management factor, and land-use-related parameters. These factors provide a basis for interpreting the temporal fluctuations. Changes in precipitation conditions may alter the erosive forcing represented in the model, while changes in vegetation cover and land use may modify the response of the land surface to rainfall and runoff.

Previous studies have also found that long-term changes in soil erosion can coexist with fluctuations between periods. In the Wangmaogou watershed on the Loess Plateau, Shi et al. [18] found that erosion decreased from 2010 to 2015 and increased again in 2020, and discussed these changes using rainfall and vegetation data. This suggests that assessments covering multiple years should consider the environmental conditions in each year and their combinations, rather than infer the entire trajectory solely from the first and last years.

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Land-use change provides another basis for interpreting erosion fluctuations. The global study by Borrelli et al. [19] identified differences in erosion among land-use types and the effects of land-use change on erosion estimates. Future work in Liangshan Prefecture could overlay changes in land use and erosion classes to compare erosion responses among different land-use transitions, and combine these results with precipitation and vegetation data for attribution analysis. Until such evidence is available, the decrease in erosion-affected area found here should be described as an overall improvement in the assessment results. The contribution of specific conservation measures requires further verification.

4.3 Combining Erosion Class Areas With Transition Analysis

Statistics on the area of each erosion class describe regional class composition and changes in class areas, but net area changes do not fully capture transitions between classes. A small change in the area of a class, for example, may coincide with substantial transitions into and out of that class. These opposing transitions can largely offset one another, producing a small net change. Combining class area statistics with a transition matrix can therefore help distinguish unchanged classes from decreases and increases in erosion intensity, and identify the main pathways through which class composition changes.

Class transitions also need to be interpreted in relation to the temporal scale of analysis. The transition matrix in this study was constructed from the erosion classifications for 2000 and 2023 and therefore describes the correspondence between classes at the beginning and end of the study period. A spatial unit assigned to the same class in both years may still have experienced increases or decreases in erosion in the intervening years. Given the fluctuations observed among the study years, transition matrices for successive intervals could help distinguish sustained improvement, sustained deterioration, and repeated changes. Erosion classes are also intervals defined from continuous erosion rates, so changes in class and changes in erosion rate do not correspond exactly. A grid cell close to a classification threshold may cross a class boundary after only a small change in erosion rate, while substantial differences in erosion intensity can occur within the same class. Class transition analysis is therefore suited to describing changes between intensity categories, and its interpretation should also consider the magnitude of erosion rate changes. Where transitions span several classes, the original model factors, land-use changes, and data validity require particular scrutiny to distinguish the effects of environmental changes from those of changes in model parameters.

4.4 Implications for Regional Soil Erosion Control

Lower erosion classes accounted for a large proportion of Liangshan Prefecture, while a considerable area remained subject to moderate or higher erosion. Soil and water conservation should therefore combine preventive protection with targeted treatment. In areas that have remained in lower classes over the long term, maintaining ground cover and limiting human disturbance should help reduce the risk of transition to higher classes. In areas where higher erosion classes have been confirmed through continued monitoring and field surveys, suitable measures for vegetation restoration, hillslope runoff regulation, and conservation tillage should be selected according to slope, land use, and erosion type.

The increases in erosion observed during some periods also indicate the need to assess conservation outcomes through continued monitoring. Areas where erosion has decreased may subsequently be affected by changes in rainfall, fluctuations in vegetation cover, and adjustments in land use. Assessments of conservation outcomes should therefore track the area with moderate or higher erosion, the persistence of higher erosion classes, and areas where erosion classes have increased, alongside the total erosion-affected area. Monitoring these indicators can help detect changes in erosion risk in time to inform adjustments to conservation measures.

4.5 Study Uncertainties and Future Improvements

RUSLE provides a common framework for comparing regional erosion classes among years, but the results remain subject to the model's scope, the input data, and the parameter settings. USLE/RUSLE models primarily estimate hillslope sheet and rill erosion caused by rainfall and surface runoff. The hillslope soil loss estimated by these models also differs from sediment yield at a catchment outlet [20]. In the complex mountainous terrain of Liangshan Prefecture, gully erosion, slope collapse, and landslides require dedicated surveys or other assessment methods. The model results should therefore be interpreted within this scope. Differences in the spatial scales of the input data are another source of uncertainty. Resampling all datasets to a 30 m resolution

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facilitated spatial overlays and calculations, but the original precipitation and soil datasets had a resolution of 1000 m. Resampling does not add local information absent from the original data. In areas of pronounced relief, these scale differences may affect the identification of local erosion intensity and class boundaries. The results are therefore suitable for assessing overall regional changes, while local areas of high erosion risk require validation with finer-resolution data and field observations.

The methods used to estimate model parameters may also affect comparisons among years. Rainfall erosivity was estimated from an empirical relationship with annual precipitation, which provides limited information on rainfall intensity, duration, and concentration within a year and may not fully capture the erosive effects of short-duration, intense rainfall. Assigning the support practice factor by land-use type also limits its ability to represent differences in terraces, tillage practices, and the condition of conservation measures within the same land-use class. In particular, assigning a value of 0 to built-up land produces zero estimated soil loss for that class under the current model settings. Disturbance such as exposed soil during construction requires separate identification when assessing actual erosion risk, which cannot be inferred from land-use type alone.

The assessment covered six selected years and can reveal differences among those years, but it cannot fully describe annual changes from 2000 to 2023. Future work could add data for consecutive years to examine whether unusual precipitation or data conditions influenced the selected years, and conduct parameter sensitivity analysis and independent validation. The study boundaries, valid grid-cell coverage, and class codes should also be consistent across years, so that area statistics and transition matrices use the same spatial extent and support more comparable results across the study years.

5. Conclusions

RUSLE estimates for six selected years, combined with erosion class-area statistics, describe changes in soil erosion intensity in Liangshan between 2000 and 2023. The main findings are as follows.

(1) Very slight and slight erosion together occupied more than 90% of the study area in all assessed years. Very slight erosion was the dominant class, increasing from 73.88% of the area in 2000 to 75.05% in 2023.

(2) The area with slight erosion or above decreased from 15,748.33 to 15,038.74 km², a net reduction of 709.59 km² (4.51%). The area with moderate or greater erosion decreased from 5,227.64 to 4,575.55 km² (12.47%). The larger relative reduction in the higher classes indicates that the overall change involved both a contraction of erosion-affected land and a shift in class composition toward lower severity.

(3) Changes differed among assessment intervals. Erosion extent decreased during 2000–2010, increased during 2010–2020, and decreased again during 2020–2023. The erosion-affected area was smallest in 2010, at 13,871.49 km². Although the 2023 value was below that of 2000, it remained above the 2010 level. Continued monitoring should therefore track both renewed increases in erosion extent and changes in the area with moderate or greater erosion.

References

[1] Pimentel D (2006). Soil erosion: A food and environmental threat. Environment, Development and Sustainability 8(1), 119–137. DOI: 10.1007/s10668-005-1262-8.

[2] Smith P, Poch R M, Lobb D A, et al. (2024). Status of the world's soils. Annual Review of Environment and Resources 49, 73–104. DOI: 10.1146/annurev-environ-030323-075629.

[3] General Office of the Communist Party of China Central Committee and General Office of the State Council (2023). Opinions on strengthening soil and water conservation in the new era. Published 3 January 2023. Accessed 15 November 2026.

[4] Borrelli P, Alewell C, Alvarez P, et al. (2021). Soil erosion modelling: A global review and statistical analysis. Science of the Total Environment 780, 146494. DOI: 10.1016/j.scitotenv.2021.146494.

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[5] Renard K G, Foster G R, Weesies G A, et al. (1997). Predicting soil erosion by water: A guide to conservation planning with the Revised Universal Soil Loss Equation (RUSLE). Agriculture Handbook No. 703. Washington, DC: U.S. Department of Agriculture. Source.

[6] Zha L S, Deng G H, Gu J C (2015). Dynamic changes of soil erosion in the Chaohu Watershed from 1992 to 2013. Acta Geographica Sinica 70(11), 1708–1719. (in Chinese) DOI: 10.11821/dlxb201511002.

[7] Liu H, Yan Y, Zhang W H, et al. (2024). Soil erosion in the Wuling Mountains based on the RUSLE model. Journal of South-Central Minzu University (Natural Science Edition) 43(3), 295–306. DOI: 10.20056/j.cnki.ZNMDZK.20240302.

[8] People's Government of Liangshan Yi Autonomous Prefecture (2022). Master plan for mineral resources in Liangshan Yi Autonomous Prefecture (2021–2025). Published 16 December 2022. Accessed 15 November 2026.

[9] China Weather Network (2020). Why are forest fires frequent in Liangshan, Sichuan, and why is firefighting there so dangerous? Published 31 March 2020. Accessed 15 November 2026.

[10] Liu B Y, Nearing M A, Risse L M (1994). Slope gradient effects on soil loss for steep slopes. Transactions of the ASAE 37(6), 1835–1840. DOI: 10.13031/2013.28273.

[11] Zhang W B, Fu J S (2003). Rainfall erosivity estimation under different rainfall amount. Resources Science 25(1), 35–41.

[12] Yin S, Xie Y, Liu B, et al. (2015). Rainfall erosivity estimation based on rainfall data collected over a range of temporal resolutions. Hydrology and Earth System Sciences 19, 4113–4126. DOI: 10.5194/hess-19-4113-2015.

[13] Zhang K L, Shu A P, Xu X L, et al. (2008). Soil erodibility and its estimation for agricultural soils in China. Journal of Arid Environments 72(6), 1002–1011. DOI: 10.1016/j.jaridenv.2007.11.018.

[14] Cai C F, Ding S W, Shi Z H, et al. (2000). Predicting soil erosion in a small watershed using the USLE model and the IDRISI geographic information system. Journal of Soil and Water Conservation 14(2), 19–24. DOI: 10.13870/j.cnki.stbcxb.2000.02.005.

[15] Yin X H, Sun X H, Xu X L, et al. (2018). The impact of returning farmland on soil conservation function in the western region of farming-pastoral ecotone of northern China. Journal of Geo-information Science 20(12), 1721–1732. DOI: 10.12082/dqxxkx.2018.180341.

[16] Soil and Water Conservation Department, Ministry of Water Resources (2008). Standards for classification and gradation of soil erosion: SL 190–2007. Beijing: China Water & Power Press.

[17] Zhang S, Xiong D H, Wu H, et al. (2021). Research on spatial variation of soil erosion in Sunshui River Basin based on RUSLE model. Journal of Soil and Water Conservation 35(5), 24–30. DOI: 10.13870/j.cnki.stbcxb.2021.05.004.

[18] Shi X J, Zhang B, Guo J L, et al. (2024). Spatial-temporal evolution of soil erosion in a typical watershed of the Loess Plateau. Acta Geographica Sinica 79(7), 1787–1803. DOI: 10.11821/dlxb202407010.

[19] Borrelli P, Robinson D A, Fleischer L R, et al. (2017). An assessment of the global impact of 21st century land use change on soil erosion. Nature Communications 8, 2013. DOI: 10.1038/s41467-017-02142-7.

[20] Food and Agriculture Organization of the United Nations (n.d.). Universal Soil Loss Equation. Accessed 15 November 2026. Source.

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Conflicts of Interest

The author(s) declare no conflicts of interest.

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