Land Science; Vol. 6, No. 1; 2025
ISSN 2690-5418 E-ISSN 2690-4802
https://doi.org/10.30560/ls.v6n1p11

Soil Erosion in Important Agricultural Areas of Haidong City, Qinghai Province, China

Qi Jigui[1,2], Jia Wei[1,3], Xie Huichun[4] & Ma Yujun[1,3*]

[1] Qinghai Provincial Key Laboratory of Physical Geography and Environmental Process, College of Geographical Science, Qinghai Normal University, Qinghai, China

[2] QumaLai County Meteorological Bureau, Yushu, Qinghai, Qinghai, China

[3] Key Laboratory of Tibetan Plateau Land Surface Processes and Ecological Conservation (Ministry of Education), Qinghai Normal University, Qinghai, China

[4] College of Life Science, Qinghai Normal University, Qinghai, China

Correspondence: Ma Yujun, Qinghai Provincial Key Laboratory of Physical Geography and Environmental Process, College of Geographical Science, Qinghai Normal University, Qinghai, China; Key Laboratory of Tibetan Plateau Land Surface Processes and Ecological Conservation (Ministry of Education), Qinghai Normal University, Qinghai, China. E-mail: Yujunma@qhnu.edu.cn

Received: April 18, 2025 Accepted: May 3, 2025 Online Published: May 7, 2025

Abstract

Haidong City is located in the eastern region of the Tibetan Plateau and the upper reaches of the Yellow River, which is an important agricultural area in Qinghai Province. Surface soil erosion in this area not only reduces soil quality, but also leads to the pollution of the Yellow River water and the increase of sand transport.The soil erosion status of Haidong City in 2022 was assessed using the modified soil loss equation (RUSLE model), combined with landsat8 OLI imagery, DEM, rainfall and land use data, and RS and GIS techniques. The results show that soil erosion in Haidong City is dominated by slight and mild erosion, with an area of 7,835 km^2 and 2,735 km^2 respectively.Among the districts (counties), Ledu District and Mutual aid County have the largest area of strong erosion, with an area of 633 km^2 and 144 km^2 respectively; Ping'an District and Minhe County have a smaller area of strong erosion, with an area of 11 km^2 and 30 km^2 respectively.Between the different land-use types. grassland erosion area was the largest, with an area of 7449km^2, accounting for 59.83%. The results of the above study can provide a scientific basis for soil degradation management in the region to meet the challenges of fragile ecological environment and increasing land use.

Keywords: multispectral remote sensing, land use types, soil erosion, RUSLE, Haidong City

1. Introduction

Soil erosion is a global ecological and environmental problem that poses a serious threat to land quality and productivity[1]. It not only leads to soil quality degradation and surface soil underdevelopment, but also further triggers soil degradation and land productivity decline[2]. Therefore, quantitative analysis of regional soil erosion status and clarification of its occurrence intensity and type are of great significance for the implementation of effective soil and water conservation measures and optimisation of land use. With the wide application of GIS and RS technologies, soil erosion research has entered a new stage[3]. Among them, the RUSLE model has been widely used in regional soil erosion research in China because of its versatility[4,5]. As the most important agricultural production base in Qinghai Province, the eastern agricultural area of Qinghai Province has a more serious soil erosion problem, which accounts for a larger area of soil erosion, leading to a decrease in soil soil fertility and affecting agricultural production capacity[6]. In view of this, this paper intends to use the modified soil erosion equation (RUSLE model), combined with various data sources such as Landsat 8 OLI images, DEM data, and monthly rainfall data, to extract the five factors of *R, K, LS, C,* and *P*, and carry out the algebraic operation using ArcGIS software in order to obtain the soil erosion situation in Haidong City in 2022. By deeply analysing the factors of soil erosion changes, this paper aims to provide scientific basis and theoretical support for soil degradation management in agricultural areas of Haidong City.

2. Materials and Methods

2.1 Overview of the Study Area

Haidong City is located in the eastern part of the Qinghai-Tibetan Plateau (35°26′~37°05′N, 100°41′~103°04′E), which is the second most populous area and the main industrial and agricultural production and development area of Qinghai Province, with a total area of 13200 km^2. It has a semi-arid continental climate, with a large difference in the geographical distribution of the climate and obvious vertical changes [7]. The region is a transition area from the Loess Plateau to the Tibetan Plateau, with dry soil layers, diverse soil types and high soil fertility, and sparse natural vegetation on the surface of the region, coupled with the abundant precipitation in the region, the surface soil erosion is serious, and the scene of thousands of gullies has been formed in part of the region, and it is also the main source area of sand transport in the upper reaches of the Yellow River[8]. With the construction of Lanxi urban agglomeration, the land use process in the region has intensified, the land ecological environment is fragile, and the contradiction between man and land is more prominent[9].

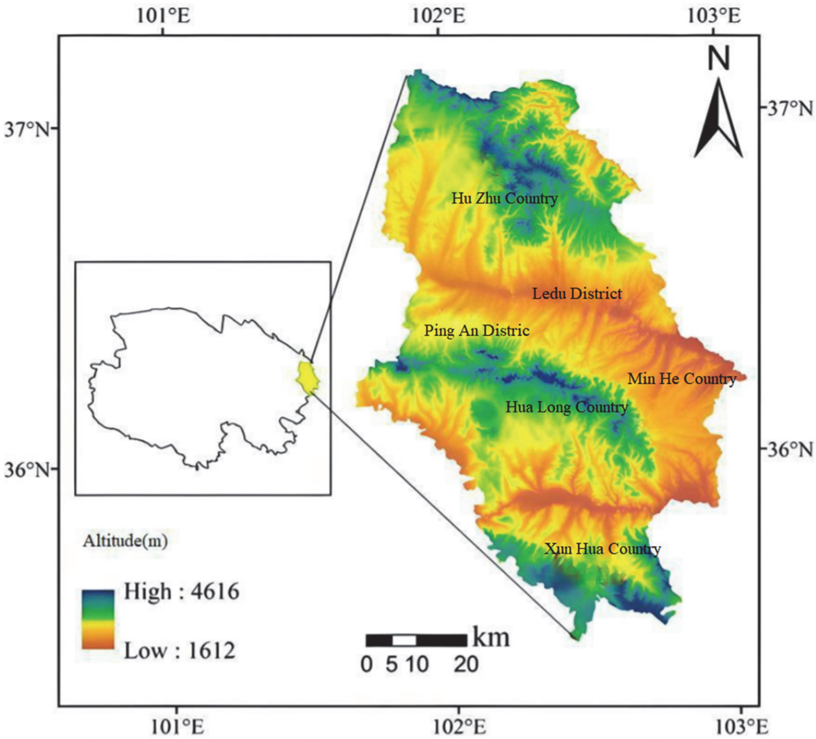

Figure 1. Location map of the study area

2.2 Data Source and Pre-Processing

Taking Landsat8 OLI as the main data source, by downloading Landsat8 OLI remote sensing images of Haidong City in May 2022, and DEM data, after processing through radiometric calibration, atmospheric correction and radiometric enhancement, image stitching was carried out, and the NDVI value of the study area was calculated as a backup; using the DEM data to extract the slope gradient and the slope length of the study area, combined with the data of the land-use type, the The slope length slope factor LS was calculated; month-by-month data and soil type erodibility factor of meteorological stations in six counties and districts in Haidong City in 2022 were obtained. Using ArcGIS 10.6 software, the spatial distribution maps of rainfall erosivity factor R, soil erodibility factor K, cover and management factor C and soil and water conservation factor P in the study area were calculated respectively.

2.3 Research Methods

In this paper, five soil and water conservation factors R, K, LS, C and P were calculated; the soil and water conservation factor P was assigned a value of 1 for unused, arable land, forest land and grassland, 0 for water bodies and marshes, 0 for residential and construction land, and 1 for sandy and saline land according to the land use data; and the amount of soil erosion in the study area was quantitatively assessed by combining the modified general RUSLE model and the data of rainfall from meteorological stations [10]. The formulas are as follows:

$$A = R \times K \times Ls \times C \times P \tag{1}$$

Where: *A* is the soil erosion modulus (unit:t/km^2/a); *R* is the rainfall erosivity factor (unit:MJ·mm·km^2/h/a); *K* is the soil erodibility factor (t·h·km^2/MJ/mm), *LS* is the slope length and slope gradient factor, dimensionless; *C* is the land cover and management factor (range of values [0 - 1]); *P* is the soil and water conservation factor (range of values [0 - 1]).Referring to the national standard 'Soil Erosion Classification and Grading Standard' (*SL190-2007*), the study area was divided into six soil erosion classes as follows (Table 1):

Table 1. Classification of soil erosion intensity class in the study area

Erosion Intensity（t/km/a）	Erosion class
＜10	Minor erosion
10～25	Mild erosion
25～50	Moderate erosion
50～80	Strong erosion
80～150	Very strong erosion
＞150	Intense erosion

2.3.1 Rainfall Erosivity Factor *R*

The rainfall erosivity factor *R* is an indicator that has been used to assess the degree of soil separation and transport caused by rainfall, which can also reflect a potential ability of rainfall to strip the soil[11]. The formula is given below:

$$\sum_{i=1}^{12} \left\{1.735 \times 10^{(1.5 \times log_{10}(pi^2/p) - 0.8188)}\right\} \tag{2}$$

Where: *Pi* stands for rainfall per month (unit: mm); P represents annual rainfall (unit: mm).

2.3.2 Soil Erodibility Factor *K*

In this paper, we chose to adopt the model proposed by Williams et al[12] regarding the calculation of the value of soil erodibility factor K-EPIC model, which is calculated as follows.

$$K = 0.1317\{0.2 + 0.3\, exp\left[-0.0256\, SAN\left(1 - \frac{SIL}{100}\right)\right] \times \left(\frac{SIL}{CLA+SIL}\right)^{0.3} \times \left[1 - \frac{0.25C}{C+exp(3.72-2.95C)}\right] \times 1 - \frac{0.75SN}{SN+exp(22.95SN-5.51)}\right]\} \tag{3}$$

Where: *SAN* (%) is the percentage of sand content; *SIL* (%) is the percentage of chalk content; *CLA* (%) is the percentage of clay content; *C* (%) is the percentage of organic matter content; where: SN = 1-SAN/100.

2.3.3 Slope Length Slope Factor *LS*

Slope length slope factor (*LS*) is the product of both slope length factor *L* and slope factor *S*. It is a measure of the erosive power of rainfall. It is an accelerating factor of rainfall erosive force, which can reflect the influence of topographic and geomorphological features on soil erosion in the region[13,14]. In this paper, the following slope length factor calculations are used, the following formula:

$$L = \left(\frac{I}{22.1}\right)^m \tag{4}$$

Where: *L* is the slope length factor and I is the slope length value.

2.3.4 Cover and Management Factor C

The value of cover and management factor C it reflects the influence of vegetation cover and management of the region on the amount of soil erosion, the value of C is taken between 0-1. In this paper, the relationship model between vegetation cover and C value established by Cai Chongfa et al [15] is used, and the formula is as follows:

$$C = \begin{cases} 1 & f = 0 \\ 0.6508 - 0.3436\, log_{10}(f) & 0 < f \le 78.3\% \\ 0 & f > 78.3\% \end{cases} \tag{5}$$

Where: *C* is the cover and management factor; *f* is the vegetation cover (unit: %).

3. Results and Analyses

3.1 Soil Erosion Factor Results

By using the land use data, combined with the topographic data extracted from Landsat8 OLI and DEM data, as well as the month-by-month precipitation data of the six stations, the results of soil and water conservation factors P, R, K, LS and C were calculated as shown below (Fig. 2): from the spatial map of slope length and slope gradient factor LS of the study area, it can be seen that the high values of LS factor are mainly distributed in the northern part of the study area near the section of Daban Mountain and the eastern slope section of Riyue Mountain in the south, with lower LS factor values in the central region; from the spatial distribution map of the C value of the cover and management factor in the study area, the spatial distribution of the high C factor value is consistent with the distribution trend of the high LS factor value, and the high C factor value is mainly distributed in the gently sloping area between the mountains; from the spatial distribution map of the R value of the rainfall erosive force factor in the study area, it can be seen that the maximum value of the rainfall in the study area is 73.71 mm, and the minimum value is 23.17mm, from the spatial point of view, the rainfall in the study area shows a high - low - high - low strip distribution; from the spatial distribution map of soil and water conservation factor P value in the study area, it can be seen that the spatial distribution of the factor P value is consistent with the spatial distribution of the factor LS value, and the low-value area is mainly distributed in the intermountainous plains of the gently sloping terrain, and the LS value of this area is also lower; from the spatial distribution map of soil erodibility factor K value in the study area, it can be seen that in the northern part of the study area, the soil erosion factor K value is mainly distributed in the intermountainous plains. From the spatial distribution map of K value of soil erodibility factor in the study area, it can be seen that soil erodibility is stronger in the northern and southern regions of the study area, which is consistent with the spatial distribution of P, R, LS and C. The spatial distribution map of K value of soil erodibility factor in the study area was overlaid with the land use map of the study area, and soil erosion was analysed for different land use types (Table 2). From a comprehensive point of view, each factor in the study area shows a positive correlation, and the areas where soil erosion occurs in the study area are mainly located in high-altitude areas.

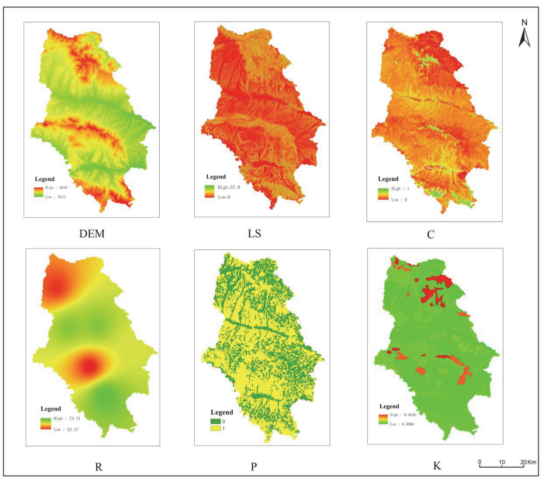

Figure 2. DEM and calculation of soil erosion factors in the study area

3.2 Soil Erosion Results

Using ArcGIS 10.6 software, the raster data of the five factors of soil and water conservation factor *P*, rainfall erosivity factor *R*, soil erodibility factor *K*, slope length and gradient factor *LS*, and cover and management factor *C* in the study area were multiplied to obtain the soil erosion modulus raster data of Haidong City, and the soil erosion intensity of Haidong City was calculated according to soil erosion grade classification in 2022 (Figure 3). class (Figure 3).

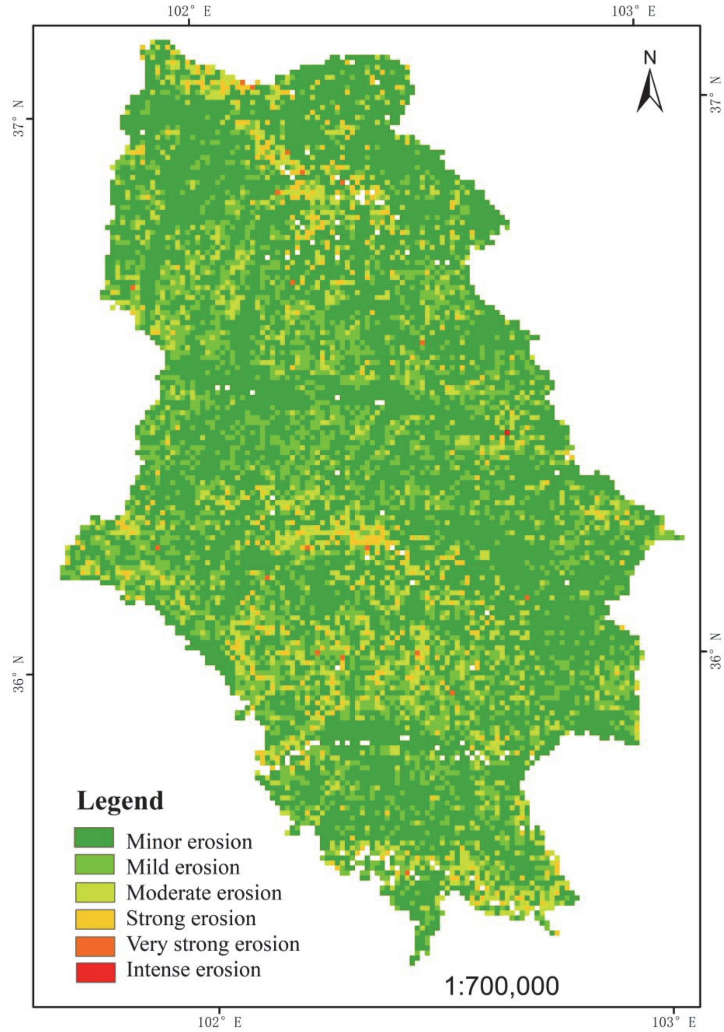

Figure 3. Spatial distribution of soil erosion intensity in the study area

From the spatial distribution of soil erosion intensity in the study area, it can be seen that soil erosion occurs throughout the study area, and the spatial difference in bedding intensity is not obvious, and the soil erosion grade in the study area presents: slight erosion > mild erosion > moderate erosion > strong erosion > very strong erosion > intense erosion, and slight and mild erosion grades are the largest in the whole area. By counting the area where soil erosion occurred in the study area, the area where micro-erosion occurred in the study area was the largest, with 7,835 km², accounting for 62.3 % of the total erosion area in Haidong City; mild erosion was the second largest, with an area of 2,735 km², accounting for 21.7 % of the total erosion area in Haidong City; moderate erosion covered an area of 1,531 km², accounting for 12.2 % of the total erosion area in Haidong City; and intense erosion covered an area of 456 km², accounting for 3.60 % of the total erosion area in Haidong City; the area of very strong erosion is 19 km², accounting for 0.15 % of the total erosion area in Haidong City; and the smallest area of intense erosion is 1 km², accounting for 0.05 % of the total erosion area in Haidong City. It can be seen that the soil erosion situation in Haidong City is not serious, most of the area belongs to weak erosion (slight erosion and mild erosion), accounting for 84% of the total erosion area: moderate erosion is second, accounting for 12.2% of the erosion area; a small portion of the area belongs to strong erosion, accounting for 3.60% of the total erosion area; a very small portion of the area belongs to very strong and intense erosion, accounting for 0.15% and 0.05% of the total erosion area, respectively. A few areas are strongly eroded, accounting for 3.60 % of the total erosion area; very few areas are very strongly eroded and intensely eroded, accounting for 0.15 and 0.05 % of the total erosion area respectively. From a spatial point of view, the areas where strong erosion occurs are mainly located in the study area at high altitude and with large slopes.

3.3 Results of Soil Erosion in Sub-Districts

In order to further analyse the erosion grade status of each district (county) in Haidong City, the soil erosion area of Haidong City was statistically subdivided into regions, and the results are shown in the following table (Table 2):

Table 2. Statistics of soil erosion area in the study area (unit: km^2).

Strength Classification	Le Du District	Ping An District	Min He Country	Hua Long Country	Xun Hua Country	Hu Zhu Country	Total erosion area
Minor erosion	1495	473	1338	1328	1019	2182	7835
Mild erosion	639	184	327	699	363	523	2735
Moderate erosion	239	25	132	403	205	248	1351
Strong erosion	633	11	30	151	57	144	456
Very strong erosion	1	-	1	8	1	8	19
Intense erosion	1	-	-	-	-	-	1

In the area of slight erosion: Mutual aid county has the largest erosion area, 2182 km^2, accounting for 27.8 % of the total area of slight erosion; Ping'an district has the smallest erosion area, only 473 km^2, which is less than 6 % of the total area of slight erosion; in the area of mild erosion: Hualong county and Ledu district have the largest erosion area, 699 km^2 and 639 km^2, respectively, which account for 25.6 % and 25.3 % of the total area of mild erosion; Ping'an district has the largest area of mild erosion; Huilong county and Ledu district have the largest area of mild erosion. and 25.3 %; Ping'an District has the smallest erosion area of 184 km^2, accounting for only 6.7 % of the total area of mild erosion; in moderate erosion: Hualong County has the largest erosion area of 403 km^2, accounting for 29.8 % of the total area of moderate erosion; Ping'an District has the smallest erosion area of 45 km^2, accounting for only 1.9 % of the total area of moderate erosion; in strong erosion: Ledu District has the largest erosion area of 633 km^2, reaching a level of strong erosion; in strong erosion: Ledu District has the largest erosion area of 633 km^2, reaching a level of strong erosion. 633 km^2, accounting for 52.4% of the total area of strong erosion; Ping'an District has the smallest erosion area, accounting for only 2.4% of the total area of strong erosion; among the very strong erosion: Hualong and Mutual aid counties have the largest erosion area and the same area, which is 8 km^2, accounting for 42% of the total area of very strong erosion; and there is only one area in Ledu District where the severe erosion occurs, with an erosion area of 1 km^2.

3.4 Soil Erosion Results of Different Land Use Types

The spatial distribution map of soil erodibility factor *K* value in the study area will be used to calculate the data with the land use type map of the study area, and the combination shows that the soil erosion status of different land use types varies greatly. Grassland has the largest soil erosion area, 7449 km^2, accounting for 59.83 % of the total erosion area; dryland is the second largest, with an erosion area of 2604 km^2, accounting for 20.92 % of the total erosion area; woodland has a larger erosion area of 1922 km^2, accounting for 15.44 % of the total erosion area; residential construction land and unused land have a smaller erosion area of 192 km^2 and 193 km^2, accounting for 192 km^2 and 193 km^2, respectively, of the total erosion area. 193 km^2 , accounting for 15.4 % and 1.55 % of the total erosion area respectively. In the future comprehensive regional management, grassland, dryland and forest land should be the focus, and the artificial management of these three major land use types should be increased to reduce the amount of soil erosion in the region.

Table 3. Statistical results of soil erosion area under different land use modes

Land use	Soil erosion area /km^2	Percentage of erosion / %
Dryland	2604	20.92
Woodland	1922	15.44
Grassland	7449	59.83
Residential land	192	1.54
Unutilised land	193	1.55

4. Discussion

By integrating the raster data of the five major soil and water conservation factors (*P, R, K, LS, C*), the soil erosion intensity in Haidong City was analysed in detailed spatial distribution and classified. This study not only revealed the overall condition of soil erosion in Haidong City, but also further subdivided the erosion characteristics of various districts (counties), which provided a scientific basis for subsequent soil and water conservation and ecological environment management.

From the results of the study, the overall soil erosion condition in Haidong City is dominated by slight and mild erosion, which occupy 84 % of the total erosion area. This finding indicates that although soil erosion occurs throughout the region, soil and water conservation is relatively good in most areas. Moderate erosion is the next most common, accounting for 12.2 % of the total erosion area, while strong, very strong and severe erosion account for only a small proportion of the total erosion area. In terms of spatial distribution, strong erosion occurs mainly in areas with high altitude and large slopes. This is because these areas usually have a more fragile ecological environment and are more vulnerable to erosion by natural factors. Therefore, in future soil and water conservation work, we should focus on these high-risk areas and take targeted treatment measures.

From the erosion status of each district (county), Mutual aid county has the largest area in micro erosion, while Ping'an district has a low bedding area in all types of erosion. Hualong County and Ledu District have a large area distribution in mild, moderate and strong erosion, which may be related to the geographic location, climatic conditions and intensity of human activities in these areas. Especially in Ledu District, the area share of strong erosion is as high as 52.4%, and although the area share of very strong erosion and intense erosion is relatively small, their destructive power to the ecological environment cannot be ignored. Hualong and Mutual aid counties have the largest areas of very strong erosion, indicating that these two areas also have high erosion risks under specific conditions. Ledu District is the only area where intense erosion occurs, and even though the area is only 1 km², it should be paid enough attention to avoid further aggravation of erosion.

From the statistical results of soil erosion area in the study area under different land use modes, it can be seen that there is a significant difference in soil erosion status among different land use types in the study area. Grassland, with its vast area and relatively fragile ecological structure, is the most serious area of soil erosion, accounting for nearly 60%. Dry land and forest land also face the same erosion problem, accounting for 20.92 % and 15.44% of the total erosion area, respectively. In contrast, the erosion area of residential construction land and unutilised land is relatively small.

5. Conclusion

With the support of RS and GIS technology, the soil erosion modulus of Haidong City in 2022 was calculated by combining the five influencing factors of *R, LS, K, C* and *P* in the RULSE model equation:

(1) Soil erosion in Haidong City in 2022 is mainly dominated by slight and mild erosion. The soil erosion class status is: slight erosion > mild erosion > moderate erosion > strong erosion > very strong erosion > intense erosion, and the eroded areas are 7,835 km², 2,735 km², 1,531 km², 456 km², 19 km² and 1 km², respectively, which account for 62.3%, 21.7 %, 12.2%, 3.6%, 0.15% and 0.05%.

(2) From the viewpoint of sub-districts, Ping'an District has the smallest area where soil erosion occurs, with an area of 693 km², while Ledu District and Mutual aid County have the largest areas where soil erosion occurs, with erosion areas of 3008 km² and 3105 km², respectively, and it should be noted that Ledu District, in particular, has a region with an area of 1 km² where intense erosion occurs.

(3) Different land use types have different soil erosion status: the size of soil erosion area of different land use types is in the following order: grassland>dryland>forestland>unutilised land>residential construction land, and unreasonable land use will directly lead to the increase of soil erosion.

Project Number

This work was supported by funds from the Qinghai 'Kunlun Talents - High-end Innovation and Entrepreneurial Talents' Project (Qing Talents [2024]). No. 1); Construction of R&D and Innovation Base for Highland Selenium-rich Qinghong Apricot Deep Processing, 2024ZY020.

References

Cai, C., Ding, S., & Shi, Z., et al. (2000). Study of applying USLE and Geographical Information System IDRISI to predict soil erosion in small watershed. *Journal of Soil and Water Conservation, 14*(2), 19–24.

Jia, W., Gao, X., & Gu, X. (2020). Analysis on environmental carrying capacity of land resources in Huangshui Basin. *The Administration and Technique of Environmental Monitoring, 32*(6), 13–17.

Jiang, G., Kang, J., Cao, G., et al. (2022). Study on soil erosion of Lancang River Basin in Qinghai based on RUSLE model. *Plateau Science Research, 6*(4), 1–13.

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. https://doi.org/10.13031/2013.28273

Liu, B., Zhang, B., Liao, J., et al. (2022). Ecological status evaluation of ecological function area of water and soil conservation based on RS and GIS. *The Administration and Technique of Environmental Monitoring, 34*(3), 35–39.

Liu, F., Qu, W., & You, X., et al. (2019). Calculation of slope factor taking into consideration forest-grass cover. *Surveying and Mapping, 42*(1), 42–46.

Ma, J. (2023). *The response of ecosystem services to changing landscape patterns on the Qinghai-Tibet Plateau: A case study from eastern Qinghai* [Doctoral dissertation, Chang'an University].

Ma, Y., He, H., & Zhao, H. (2023). Spatiotemporal change of soil erosion in Gannan Tibetan Autonomous Prefecture based on GIS and RUSLE. *Research of Soil and Water Conservation, 30*(3), 37–46.

Song, Q., Gao, X., Gu, X., et al. (2024). Estimation of soil organic carbon content in farmland based on UAV hyperspectral images: A case study of farmland in the Huangshui River basin. *Remote Sensing for Natural Resources, 36*(2), 160–172.

Wang, S., Fang, H., & He, J. (2021). Effects of variation in vegetation cover and rainfall on soil erosion in Black Soil Region, Northeastern China. *Bulletin of Soil and Water Conservation, 41*(2), 66–75.

Wang, T., Lu, Z., Ning, J., et al. (2023). Temporal and spatial characteristics of soil erosion in typical counties of Black Soil Region based on RUSLE. *Bulletin of Soil and Water Conservation, 43*(5), 227–234.

Williams, J. R., & Arnold, J. G. (1997). A system of erosion-sediment yield models. *Soil Technology, 11*(1), 43–55.

Xu, X., Zhang, F., Zeng, C., et al. (2024). Advances in erosion and sediment generation processes and related model algorithms in cold region. *Science of Soil and Water Conservation, 22*(4), 1–13.

Zhang, W., Shi, P., Zhao, W., et al. (2022). Spatiotemporal variation and obstacle factor diagnosis of resource and environment carrying capacity of Lanzhou-Xining urban agglomeration in the upper Yellow River, Northwest China. *Chinese Journal of Applied Ecology, 33*(9), 2501–2510.

Zhu, C., Fan, X., & Bai, Z., et al. (2021). Spatiotemporal differentiation in water erosion on topsoil disturbed area of production and construction in China based on RUSLE model. *China Land Science, 35*(9), 105–115.

Copyrights