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1-km Raster Dataset of Annual Soil Erosion Modulus on the Loess Plateau (2001–2015)

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Abstract: Soil erosion modulus is an important index to measure the quality of ecological environment, and its temporal and spatial distribution is an important scientific basis for soil erosion control. The Loess Plateau is an ecologically fragile area in China with severe soil erosion. At present, the region still lacks a fully shared dataset of soil erosion modulus with long-term sequence and uniform format. In order to effectively support the soil erosion control on the Loess Plateau, the authors produced the dataset of soil erosion modulus with 1-km resolution from 2001 to 2015 based on the RUSLE (Revised Universal Soil Loss Equation) model, through the standardized processing of precipitation data, soil texture data, DEM (digital elevation model) data, and vegetation index data, etc. This dataset, which is stored in TIFF format, contains data of soil erosion modulus with 1-km resolution of the Loess Plateau from 2001 to 2015, and consists of 60 data files with a total data size of 105.0 MB.

Keywords: Loess Plateau; soil erosion modulus; RUSLE model

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Dataset Availability Statement:

The dataset supporting this paper was published and is accessible through the *Digital Journal of Global Change Data Repository* at: https://doi.org/10.3974/geodb.2021.11.06.V1 or https://cstr.escience.org.cn/CSTR:20146.11.2021.11.06.V1.

1 Introduction

With a serious impact on human life, soil erosion is a severe environmental problem facing China and the whole world[1–3]. The Loess Plateau region has complex topography, steep slopes and deep gullies, low vegetation coverage, loose soil and frequent water seepage. In addition, the heavy rainfall in summer, coupled with unreasonable exploitation by humans,

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has led to extremely serious soil erosion in the Loess Plateau region[4,5]. At present, the research on soil erosion in the Loess Plateau region is mainly focused on a single year, small watershed or city/county scale, while lacks long-term series, complete spatial scope and systematic research, which seriously affects the development of soil erosion control and soil conservation in the Loess Plateau region.

Data of soil erosion modulus can help people grasp the pattern of regional soil erosion and provide an important basis for soil erosion control. In order to accurately calculate the soil erosion modulus, scholars at home and abroad have proposed different simulation calculation methods, among which the Revised Universal Soil Loess Equation (RUSLE) model proposed by the U.S. Department of Agriculture in 1997 has been the most widely used[6]. Chinese scholars introduced this model and conducted localized research, optimized the calculation method of the related factors to make it more suitable for China’s national conditions, so that the RUSLE model has played a good role in China’s soil erosion control work, and also produced many open and shared data on soil erosion.

At present, published soil erosion data covering the complete Loess Plateau region include the Dataset of soil erosion intensity with 1-km resolution in Pan-TEP 65 countries (2015) [7] of the National Tibetan Plateau Data Center[1], which includes the raster data of soil erosion intensity in Pan-TEP 65 countries in 2015; the Soil erosion map in the Loess Plateau region (2010) of the National Earth System Science Data Center[2], which is the raster data of Loess Plateau region in 2010; the Soil erosion change dataset of China (1985–2011)[8,9] of the Global Change Research Data Publishing & Repository[3], which mainly includes statistics of classified areas by province in China in 1985, 1995, 2000 and 2011; and also the National soil erosion data of the Geographic Information Monitoring Cloud Platform[4], which is the data of soil erosion modulus in each provinces in China in 2005. At the same time, a large number of existing studies have also produced a series of data related to soil erosion of different years and regions on the Loess Plateau[10–12]. However, the existing data sharing platforms and related research data are relatively single-year and lack long time series, and the data production methods, spatial resolutions and data types are not unified, so it is impossible to make a more systematic evaluation of soil erosion on the Loess Plateau. Therefore, based on the RUSLE model, this paper produced a dataset of soil erosion modulus of 1 km per year in the Loess Plateau region from 2001 to 2015. The data can be used to analyze the characteristics of the temporal and spatial changes of soil erosion in the Loess Plateau region and its typical watersheds and soil erosion types, reveal the effectiveness of ecological construction on the Loess Plateau, and support the evaluation of the temporal and spatial dynamic changes of soil erosion and the evaluation of ecological environment quality.

2 Metadata of the Dataset

The metadata of 1-km Raster dataset of annual soil erosion modulus on the Loess Plateau (2001–2015)[13] is summarized in Table 1. It includes the dataset full name, short name, authors, year of the dataset, temporal resolution, spatial resolution, data format, data size, data files, data publisher, and data sharing policy, etc.

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[1] The National Tibetan Plateau Data Center. http://data.tpdc.ac.cn/en/

[2] National Earth System Science Data Center. http://www.geodata.cn/.

[3] Global Change Research Data Publishing & Repository. http://www.geodoi.ac.cn/.

[4] Geo-graphic Information Monitoring Cloud Platform. http://www.dsac.cn/.

Table 1 Metadata summary of the 1-km raster dataset of annual soil erosion modulus on the Loess Plateau (2001–2015)

Items	Description
Dataset full name	1-km raster dataset of annual soil erosion modulus on the Loess Plateau (2001–2015)
Dataset short name	SoilErosionLoessPlateau_2001–2015
Authors	Geng, W. G., Shandong University of Technology, gengwg@lreis.ac.cn Zhu, Y. Q., Institute of Geographic Sciences and Natural Resources, Chinese Academy of Sciences, zhuyq@igsnrr.ac.cn Chen, P. F. D-7136-2019, Institute of Geographic Sciences and Natural Resources, Chinese Academy of Sciences, pengfeichen@igsnrr.ac.cn
Geographical region	Loess Plateau, 100°E–114°E, 33°N–41°N
Year	2001–2015
Temporal resolution	year
Spatial resolution	1 km
Data format	.tif
Data size	105.0 MB (36.2 MB compressed)
Data files	The data set consists of 60 files. The file name consists of SELP + year, and the last four digits show the year
Foundation	Chinese Academy of Sciences (XDA23100100)
Data publisher	Global Change Research Data Publishing & Repository, http://www.geodoi.ac.cn
Address	No. 11A, Datun Road, Chaoyang District, Beijing 100101, China
Data sharing policy	***Data*** from the Global Change Research Data Publishing & Repository includes metadata, datasets (in the *Digital Journal of Global Change Data Repository*), and publications (in the *Journal of Global Change Data* & *Discovery*). ***Data*** sharing policy includes: (1) ***Data*** are openly available and can be free downloaded via the Internet; (2) End users are encouraged to use ***Data*** subject to citation; (3) Users, who are by definition also value-added service providers, are welcome to redistribute ***Data*** subject to written permission from the GCdataPR Editorial Office and the issuance of a ***Data*** redistribution license; and (4) If ***Data*** are used to compile new datasets, the 'ten per cent principal' should be followed such that ***Data*** records utilized should not surpass 10% of the new dataset contents, while sources should be clearly noted in suitable places in the new dataset[14]
Communication and searchable system	DOI, CSTR, Crossref, DCI, CSCD, CNKI, SciEngine, WDS/ISC, GEOSS

3 Methods

3.1 Algorithm Principle

The soil erosion modulus in the RULSE model is calculated from precipitation data, soil data, DEM (Digital Elevation Model) data, NDVI (Normalized Difference Vegetation Index) data and land cover data, as shown in equation (1):

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

where A is the soil erosion modulus per unit area ($t\cdot hm^{-1}\cdot a^{-1}$); R is the rainfall erosivity factor ($MJ\cdot mm\cdot hm^{-1}\cdot h^{-1}\cdot a^{-1}$); K is the soil erodibility factor ($t\cdot h\cdot MJ^{-1}\cdot mm^{-1}$); LS is the slope length and slope factor; C is the vegetation coverage and management factor; and P is the conservation practices factor.

The rainfall erosivity factor can characterize the impact of rainfall on soil erosion. This study uses Wischmeier empirical formula[15] to calculate the rainfall erosivity using monthly rainfall. Soil erodibility factor is a comprehensive index that reflects the sensitivity of soil to precipitation and surface runoff, as well as the ease of soil erosion[16]. In this paper, the EPIC model method[17], a commonly used method at present, is used to calculate the soil erodibility factor, taking into account the soil properties. The K value calculated by this model is in American unit, which needs to be converted into international metric unit by multiplying by the constant 0.1317[18]. The slope length and slope factor are important indicators to reflect the effect of topography on soil erosion. The slope length and slope factor of this study adopt the research results of McCool *et al*. and Liu *et al*[19–21]. The vegetation cover management factor represents the effect of vegetation cover and management measures on soil erosion. This study is based on the method of Cai *et al*[22] and uses the dimidiate pixel mode when calculating the vegetation fraction. The factor of soil and water conservation measures is the ratio of the soil loss under specific conservation measures to the soil loss of the corresponding sloping cultivated plot without conservation measures[23]. In this paper, based on the existing literature research[24–26] on the Loess Plateau region, the factor of water and soil conservation measures is assigned a value of 0.8 for the forest land, and 1 for the bare land, water body, construction land, and grassland. Since the effect of soil and water conservation measures on cultivated land is proportional to the slope, *P* is assigned according to the slope range (Table 2).

Table 2 P value of cultivated land with different slopes

Slope range	*P* value
<5°	0.1
5°–10°	0.221
10°–15°	0.305
15°–20°	0.575
20°–25°	0.705
>25°	0.8

3.2 Technical Route

The technical route of producing data of soil erosion modulus on the Loess Plateau is shown in Figure 1, which mainly includes: data collection, data preprocessing, calculation of various factors and calculation of soil erosion.

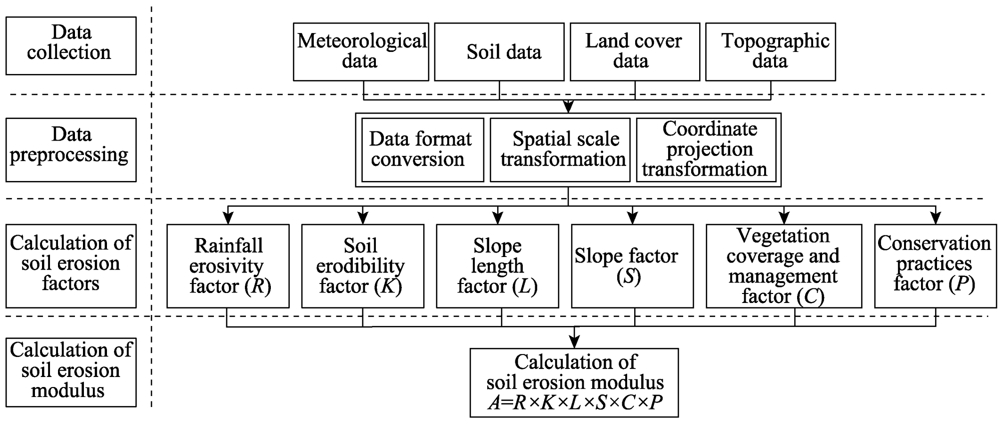

Figure 1 Technical route of the dataset development

3.2.1 Data Collection and Preprocessing

(1) The precipitation data come from China meteorological forcing dataset (1979–2018)[27,28] of the National Tibetan Plateau Data Center, with a spatial resolution of 1-km and a temporal resolution of 3 hours. In this study, the data of time period from 2001 to 2015 are selected and converted into monthly data of average precipitation through calculation.

(2) The soil data come from the China soil map based harmonized world soil database (HWSD) (v1.1) (2009)[29] of the National Tibetan Plateau Data Center. The spatial projection of the data is WGS84 coordinate system with a spatial resolution of 1 km.

(3) The DEM data are obtained using the Shelter Radar Topography Mission[5] (SRTM) data, with a spatial resolution of 30 m.

(4) The NDVI data were derived from NASA's[6] 1-km resolution product (MOD13A3)

[5] CGIAR - Consortium for Spatial Information (CGIAR-CSI). https://srtm.csi.cgiar.org/.
[6] National Aeronautics and Space Administration. https://www.nasa.gov/.

based on the inversion of MODIS data.

(5) The land cover data are obtained using NASA's land cover data product[7] (MCD12Q1) based on MODIS interpretation. When using this dataset, we adopt the land cover classification method of the University of Maryland.

(6) The boundary data of the Loess Plateau come from the Boundary data of the Loess Plateau region[30,31] of the Global Change Research Data Publishing & Repository.

3.2.2 Data Preprocessing

The above data are not unified in data format, coordinate projection system, and spatial resolution, etc. In order to facilitate the calculation, data format transformation, coordinate projection transformation, data resampling, spatial registration, clipping and other techniques are adopted in this study to unify data at the same scale, namely spatial resolution of 1 km, reference ellipsoid of Krasovsky, projection method of Albers, and data format of TIFF.

3.2.3 Calculation of Data of the Soil Erosion Modulus

Using the preprocessed data, we calculate the rainfall erosivity factor, soil erodibility factor, slope length factor, slope factor, vegetation cover and management factor, and factor *P* of soil and water conservation measures based on the RUSLE model, and finally calculate the soil erosion modulus of the whole Loess Plateau region from 2001 to 2015 year by year to form the relevant datasets.

4 Data Results and Validation

4.1 Data Composition

The dataset includes data of soil erosion modulus of the Loess Plateau for 15 years from 2001 to 2015. The spatial resolution of the data is 1 km, the projection is Alberts, the data format is TIFF.

4.2 Data Results

The annual average soil erosion modulus of the Loess Plateau from 2001 to 2015 was 37.05 $t\cdot hm^{-2}\cdot a^{-1}$, and the annual average amount of soil erosion was 65.89 $t\cdot hm^{-2}\cdot a^{-1}$ in 2013 and 20.31 $t\cdot hm^{-2}\cdot a^{-1}$ in 2015. The average annual amount of soil erosion showed an overall decreasing trend, of which the average annual amount of soil erosion decreased significantly from 2001 to 2012, and the amount of soil erosion increased due to excessive precipitation in 2013. Among the types of land cover, the soil erosion of cultivated land, forest land and grassland showed a decreasing trend, with the most significant decrease in the soil erosion of forest land from 2001 to 2010. According to the Standards for classification and grading of soil erosion[32], the annual amount of soil erosion is graded, and the data of soil erosion of each year are compared. The spatial distribution patterns of soil erosion on the Loess Plateau are roughly the same. Among them, the spatial distribution of soil erosion modulus on the Loess Plateau in 2010 is shown in Figure 2. From the figure, it can be seen that most parts on the Loess Plateau are in a state of slight or mild soil erosion, but a considerable part suffers from moderate or more severe soil erosion. The areas with severe soil erosion are mainly located in the northern part of Shanxi province and the eastern part of Qinghai province, while the areas with moderate soil erosion are mainly located in the central part of the Loess Plateau.

[7] Level-1 and Atmosphere Archive & Distribution System Distributed Active Archive Center. https://ladsweb.modaps.eosdis.nasa.gov/.

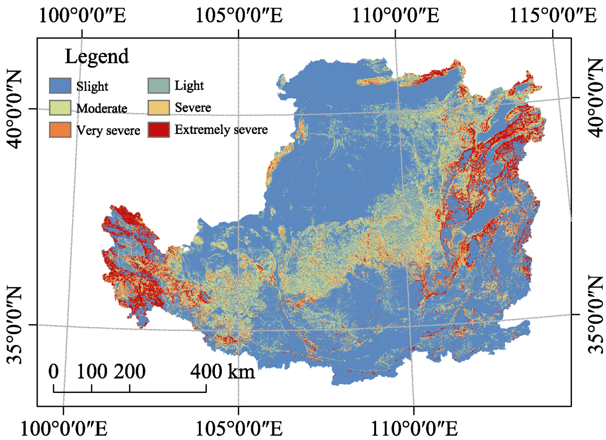

Figure 2 Spatial distribution of soil erosion in the Loess Plateau in 2010

4.3 Data Validation

At present, two methods are generally used to verify the data results of the model: one is to compare with the measured data, and the other is to compare with the existing research results[33]. Due to the limited sampling size and high cost of the measured data, and the difficulty of spatially matching the representative areas with the data calculated based on the model, this study uses the result data in the published literature and the published statistics for validation.

Based on the RUSLE model, the average annual soil erosion modulus of the Loess Plateau from 2001 to 2015 was 20.18–65.89 t·hm^{-2}·a^{-1}, and it was 4.87 t·hm^{-2}·a^{-1} for forest land, 51.45 t·hm^{-2}·a^{-1} for grassland, 6.03 t·hm^{-2}·a^{-1} for cultivated land, and 25.36 t·hm^{-2}·a^{-1} for urban and construction land. Compared with the previous studies (as shown in Table 3), the soil erosion modulus estimated in this study is within the normal fluctuation range.

Table 3 Comparison of the data of soil erosion on the Loess Plateau and the data of this study in the existing research results (t·hm^{-2}·a^{-1})

Research Area	Year	Research methods	Soil erosion	Source Literature	Modulus of soil erosion in this dataset
Changwu county	1997–2017	RUSLE	13.05–18.91	Yu *et al.*[34]	5.47–37.51
Yulin city	2000–2013	RUSLE	12.18–89.69	Yang *et al.*[35]	13.99–86.68
Loess Plateau	2010	RUSLE	33.55	Gao *et al.*[10]	35.38
Loess Plateau	Annual average	RUSLE	38.25	Dang *et al.*[11]	37.05
Loess Plateau	2000– 2010	RUSLE	34.08	Sun *et al.*[12]	36.40

Note: The results of Sun *et al* are in American units. After conversion, the data in the table are obtained, and the conversion coefficient is 2.242[36].

In addition, from the perspective of the spatial distribution of soil erosion modulus, the results of this study show that the northwestern and southeastern parts of the Loess Plateau are mainly in a state of slight and mild erosion, the central part is mainly moderately eroded, and the northern part of Shanxi province and the eastern part of Qinghai province are heavily eroded. These patterns are consistent with the existing research results[10,12]. The above results show that the data of soil erosion modulus produced in this study are of good accuracy.

5 Discussion and Conclusion

The Loess Plateau is an important ecological environment reserve in China, and it is of great significance to study its soil erosion pattern. The RUSLE model, which is commonly used to calculate the soil erosion modulus, has obvious advantages, such as simple structure, strong practicability and high prediction accuracy. In addition, its applicability in China has been improved through the continuous improvement by a large number of domestic scholars. Nevertheless, the individual factors in the RUSLE model are still empirical values, which may sometimes deviate from the actual situation and are vulnerable to the influence of a single factor. For example, the amount of soil erosion in this dataset in 2013 was affected by precipitation data, resulting in large numbers in local areas. This dataset is based on meteorological, soil, DEM, vegetation index and land cover data, and uses the modified soil loss model to sort out and calculate the annual dataset of soil erosion modulus with a resolution of 1 km on the Loess Plateau. Compared with previous datasets, this dataset has a longer time series and a more complete spatial range. This dataset can be used to grasp the severity and temporal and spatial distribution of soil erosion on the Loess Plateau, and can also provide a data basis for the ecological construction and environmental management of the Loess Plateau.

Author Contributions

Chen, P. F. designed the algorithms of the dataset. Geng, W. G. contributed to the data processing and analysis and wrote the data paper, and Zhu, Y. Q. revised the data paper.

Conflicts of Interest

The authors declare no conflicts of interest.

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