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Methodology for 1-km Raster Dataset of Annual Soil Erosion Modulus in Southwestern Mountainous Region of China (2000–2015)

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Abstract: The southwestern mountainous region of China covers Sichuan, Chongqing, Yunnan, and Guizhou provinces and cities and is an ecologically fragile area in this country. The construction of a long-term soil erosion dataset in the southwestern mountainous region is of great significance for analyzing changes in the ecological environment under long-term human-natural interactions and the formulation of sustainable development policies. However, there is still a lack of long-term sequences, unified formats, and fully shared datasets for soil erosion in the southwestern mountainous region. Therefore, the author collected precipitation data, soil data, digital elevation data, land-cover data, and vegetation index data from 2000 to 2015 and unified them to the same scale after a format conversion, projection conversion, and spatial scale matching. A revised soil-loss model (The Revised Universal Soil Loss Equation, RUSLE) was used to calculate an annual soil erosion dataset (2000–2015) with a 1-km grid in the southwestern mountains (Yunnan, Guizhou, Sichuan, and Chongqing); this dataset can provide support for relevant research. The dataset is in .tif and .shp format, and the data size is 109 MB.

Keywords: the southwestern mountainous region of China; mountainous region; soil erosion modulus; RUSLE model; 1 km

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.2021.04.04.V1.

1 Introduction

The southwestern mountainous region of China (Sichuan, Chongqing, Yunnan, and Guizhou) is located in the hinterlands. Due to its special topography, geological conditions and human

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activities, the ecological environment of this region is fragile and faces the problem of "rocky desertification" caused by severe soil erosion[1–3]. Current research on soil erosion has mainly focused on a single year at the county scale, and there is a lack of studies at the medium- and long-term scales. Dynamic and systematic studies on areas with large spatial spans have seriously affected the planning of the regional ecological environment[4].

The soil erosion modulus is an important indicator used to measure the status of soil erosion. Wischmeier *et al*. established the estimation model of the soil erosion modulus USLE (Universal Soil Loss Equation,1958)[5]. The model is relatively simple and contains only two independent variables, namely, the slope length and slope. The USLE model only considers single-factor effects and has a defect in that it is only suitable for gentle slopes and cannot describe the physical process of soil erosion[6]. With the development of artificial rainfall test technology, people's understanding of the mechanisms of soil erosion continues to improve. In 1992, Rernard *et al*. proposed an improved soil erosion modulus estimation model called the Revised Universal Soil Loss Equation (RUSLE, 2019)[7] by integrating the USLE and the erosion conceptual model established by Meyer and Forester. The RUSLE model has a clearer physical meaning than the USLE, and the prediction accuracy of the RUSLE is greatly improved. It is currently the most widely used soil erosion modulus estimation model[8,9].

At present, the only soil erosion modulus dataset covering the southwestern mountain area that has been shared is the soil erosion data product provided by the cloud platform from the geographical monitoring of national conditions; however, this dataset only contains the soil erosion modulus data of each province in China in 2005 in its number of data. This dataset cannot meet the needs of analyses concerning soil erosion changes in the southwestern mountainous areas regarding ecological engineering construction, regional economic development or climate change. Therefore, based on the RUSLE model, this paper produced a raster dataset with a soil erosion modulus of 1 km in the southwestern mountainous region from 2000 to 2015.

2 Metadata of the Dataset

The metadata of 1 km raster dataset of annual soil erosion modulus in southwestern mountainous region of China (2000–2015)[10] is summarized in Table 1. It includes the full name, short name, authors, year, temporal resolution, spatial resolution, data format, data size, data files, data publisher, and data sharing policy of the dataset, etc.

3 Methods

3.1 Algorithm Principle

The soil erosion modulus in the RULSE model is calculated by using precipitation data, soil data, topography data, NDVI data and land-cover data [12], as shown in Equation (1):

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

where A is the soil erosion modulus ($t\cdot hm^{-2}\cdot a^{-1}$); R is the rainfall erosivity factor ($MJ\cdot mm\ hm^{-2}\cdot h^{-1}\cdot a^{-1}$); K is the soil erodibility factor ($t\cdot h\cdot MJ^{-1}\cdot mm^{-1}$); LS is the slope length and slope factor (dimensionless); C is the surface vegetation cover and management factor (dimensionless); and P is the water and soil conservation measure factor (dimensionless).

(1) Determination of the rainfall erosivity factor

The rainfall erosivity factor is calculated using Wischmeier's Eqution[13]. This equation considers both the total annual precipitation and monthly precipitation intensity, as shown in Equation (2).

Table 1 Metadata summary of 1 km raster dataset of annual soil erosion modulus in southwestern mountainous region of China (2000–2015)

Item	Description
Dataset full name	1 km raster dataset of annual soil erosion modulus in southwestern mountainous region of China (2000–2015)
Dataset short name	SoilErosionSouthWestChina_2000-2015
Authors	Wang, J. Y., Shandong University of Technology, wangjy766@sina.com Zhu, Y. Q. L-6116-2016, Institute of Geographic Sciences and Natural Resources Research，Chinese Academy of Sciences, zhuyq@igsnrr.ac.cn Chen, P. F. D-7136-2019, Institute of Geographic Sciences and Natural Resources Research，Chinese Academy of Sciences, pengfeichen@igsnrr.ac.cn
Geographical region	The mountainous region of southwestern China: 21°N–35°N, 97°E–111°E
Year	2000–2015 Temporal resolution year
Spatial resolution	1 km Data format .tif, .shp
Data size	109 MB (52.5 MB after compression)
Data files	The dataset consists of 72 files. The file name is composed of a+year, and the last four digits are the year
Foundation(s)	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 freely 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 percent 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[11]
Communication and searchable system	DOI, DCI, CSCD, WDS/ISC, GEOSS, China GEOSS, Crossref

$$R=\sum_{i=1}^{12}\left(1.735\times 10^{\left(1.5\times lg\frac{P_i^2}{Pa}-0.8188\right)}\right) \tag{2}$$

The above equation contains the monthly precipitation and annual precipitation representing each month.

(2) Determination of the soil erodibility factor

The soil erodibility factor is a comprehensive manifestation of soil resistance to erodibility, and different soil types have different values. The greater the value of the soil erodibility factor is, the greater the possibility of soil erosion, and vice versa. This study chooses the EPIC model formula proposed by Sharply and Williams to calculate the soil erodibility factor[14]. This algorithm considers both the soil organic carbon content and soil type, as shown in Equation (3):

$$K=\left\{0.2+0.3\exp\left[-0.0256m_s\left(1-\frac{m_{silt}}{100}\right)\right]\right\}\times\left[\frac{m_{silt}}{m_c+m_{silt}}\right]^{0.3}\times\left\{1-\frac{0.25\,org\,C}{[org\,C+\exp(3.72-2.95org\,C)]}\right\}\times\left\{1-\frac{0.7\left(1-\frac{m_s}{100}\right)}{\left\{\left(1-\frac{m_s}{100}\right)+\exp\left[-5.51+22.9\left(1-\frac{m_s}{100}\right)\right]\right\}}\right\} \tag{3}$$

where, m_s, m_{silt}, m_c, and *orgC* are the contents of sand, powder, clay and organic carbon, respectively, in units of %.

(3) Determination of the slope factor

The slope factor is calculated using the formulas of McCool *et al*.[15] and Liu Baoyuan[16], as shown in Equation (4):

$$S = \begin{cases} 10.8 \sin\theta + 0.03 & (\theta < 5°) \\ 16.8 \sin\theta - 0.05 & (5° \leqslant \theta \leqslant 10°) \\ 21.92 \sin\theta - 0.96 & (\theta > 10°) \end{cases} \tag{4}$$

where θ is the slope of the ground.

$$L = (\lambda / 22.13)^m \tag{5}$$

$$m = \begin{cases} 0.5 & \theta \geqslant 3 \\ 0.4 & 1.5 \leqslant \theta < 3 \\ 0.3 & 0.5 \leqslant \theta < 1.5 \\ 0.2 & \theta < 0.5 \end{cases} \tag{6}$$

(4) Determination of the vegetation cover management factor *C* and soil and water conservation measure factor *P*

The related research results of other scholars [17] was consulted to determine the *C* and *P* values of various types of land cover, as shown in Table 2.

The *C* factor refers to the assignment of surface vegetation coverage factors[18], and the *P* factor refers to the assignment of soil and water conservation measure factors[19].

Table 2 Assignment of *C* and *P* factors for different land-cover types

Land-cover type	*C* factor assignment	*P* factor assignment
Woodland	0.006	1
Grassland	0.03	0.8
Dry land	0.31	0.4
Paddy field	0.12	0.01
Water body	0	0
Other land	0	0

3.2 Technical Route

The technical route of the dataset construction is shown in Figure 1. The route mainly includes two parts: data collection and preprocessing, and data simulation.

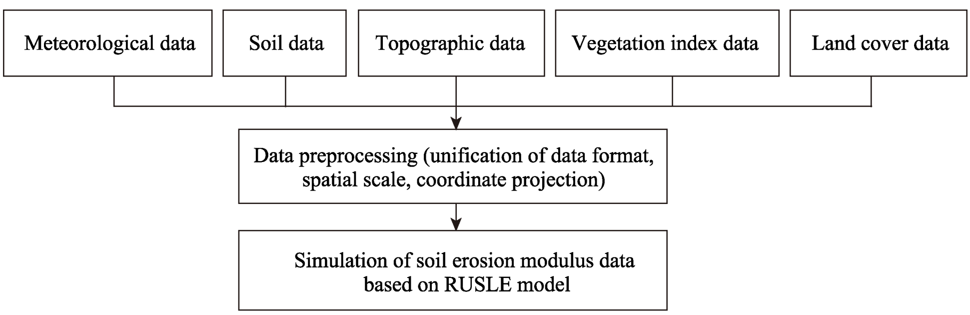

Figure 1 Technology roadmap of the dataset development

3.2.1 Data Collection and Processing

(1) The precipitation data come from the "China regional high temporal and spatial resolution ground meteorological factor driven dataset"[20] of the National Qinghai-Tibet Plateau Science Data Center[1], with a spatial resolution of 1 km and a temporal resolution of 3 hours. This study converts the data into 1-km monthly average precipitation data through calculations.
(2) The soil data in 1 km resolution is taken from the China Soil Data Set (v1.1)[21] of the World Soil Database (HWSD) of the National Qinghai-Tibet Plateau Science Data Center[2] and is spatially resolved.
(3) The DEM data adopt 30-m resolution SRTM data[3].
(4) The NDVI data come from the 1-km resolution product (MOD13A3)[4].
(5) The 2000 land-cover data are taken from the AVHRR land-cover data product, which is based on AVHRR data from 1981 to 1994. The land-cover classification method used is the classification method of the University of Maryland[5]. After 2000, the land-cover data use the land-cover data product corresponding to MODIS (MCD12Q1)[4]. When using MODIS data, the University of Maryland classification method is also used.
(6) The boundary data come from 2015 China provincial boundary data from the Resource and Environmental Science and Data Center[6] of the Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences.
3.2.2 Data Modeling
The above preprocessed data are used as input and the production of related datasets based on the RULSE model is realized.

4 Data Results and Validation

4.1 Data Composition

The dataset consists of the soil erosion modulus data of the southwestern mountainous region from 2000 to 2015 and contains 1-km raster data of annual soil erosion in the southwestern mountainous region from 2000 to 2015.

4.2 Data Products

Comparing the soil erosion modulus data of various years, the distribution of the soil erosion modulus in southwestern mountainous areas is approximately the same, taking 2010 as an example (Figure 2). According to the SL 190—2007 "Soil Erosion Classification and Grading Standard"[22], the annual soil erosion modulus data are divided into 6 grades: slight erosion, light erosion, moderate erosion, severe erosion, extreme erosion and severe erosion. As shown in Figure 1, most soil erosion in the southwest is in a state of slight or light erosion. However, the degree of erosion in eastern Sichuan Province, western Guizhou Province, and northwestern Yunnan Province is relatively serious and is basically in a state of intensity, extreme intensity and severe erosion.

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1 National Qinghai-Tibet Plateau Science Data Center. http://westdc.westgis.ac.cn/.
2 National Qinghai-Tibet Plateau Science Data Center. https://data.tpdc.ac.cn/.
3 http://srtm.csi.cgiar.org/.
4 http://reverb.echo.nasa.gov/.
5 http://glcf.umd.edu/data/landcover/.
6 http://www.resdc.cn/.

4.3 Data Validation

Since the measured data of the soil erosion modulus are small and difficult to obtain and the representative area of the measured data differs from the representative area of the soil erosion modulus calculated based on the RUSLE model, it is difficult to verify the accuracy of the soil erosion modulus based only on the measured data. Therefore, this study combines the published measured data with simulated data in published articles to verify the soil erosion modulus data of this study.

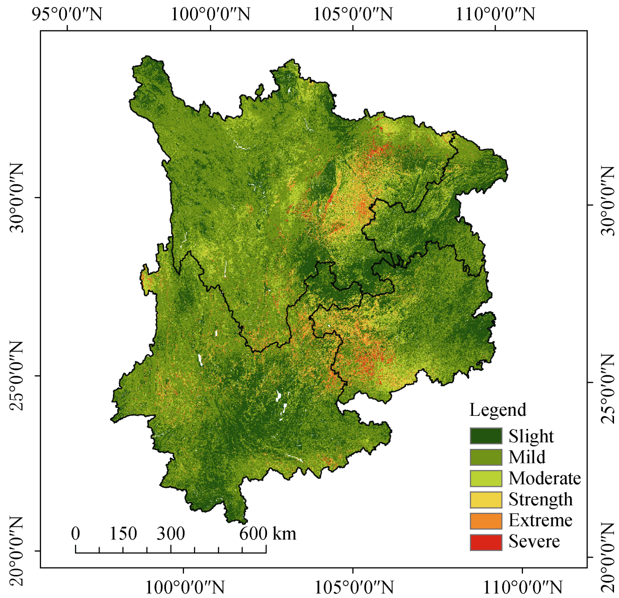

Figure 2 Spatial distribution map of soil erosion modulus in 2010

This study is based on the RUSLE model simulation of annual average soil erosion modulus of southwestern mountainous region from 2000 to 2015, which is 13.25–24.60 (t·hm^{-2}·a^{-1}). Compared with existing studies, the soil erosion modulus estimated in this study is within the normal fluctuation range (Table 3). Table 4 lists the ranges of the soil erosion modulus for different land-use types simulated by some models in existing studies. Compared with them, the average annual soil erosion modulus of forestland simulated in this study is 15.92 t·hm^{-2}·a^{-1}, average annual soil erosion modulus of grassland is 19.84 t·hm^{-2}·a^{-1}, average annual soil erosion modulus of cultivated land is 21.97 t·hm^{-2}·a^{-1}, and annual average soil erosion modulus of residential land is 0.37 t·hm^{-2}·a^{-1}. The data obtained in this study are in good agreement with the existing data, which shows that the soil erosion modulus data generated in this study are more reliable.

Table 3 Comparison of soil erosion modulus of different studies in different regions in southwestern region with this dataset (t·hm^{-2}·a^{-1})

Study area	Years	Research method	Soil erosion modulus	References	Soil erosion modulus calculated in this dataset
Chengdu	The annual average	SCSLE	2.93	Liu, B, T., *et al.* [23]	1.70–28.86
Yuanyang County	2005–2015	RUSLE	6.54–17.81	Chen, F., *et al.* [24]	12.36–50.59
Karst trough area	2000–2015	CA-Markov	1.04–21.61	Cao, Y., *et al.*[25]	18.49
Jianchuan County	The annual average	RUSLE	12.56	Wei, X, L., *et al.*[26]	9.47–38.01
Guizhou Province	The annual average	RUSLE	23.50	Niu, L, N., *et al.* [27]	23.48

Table 4 Comparison of soil erosion modulus of various land-cover types in this dataset with the simulation results of other studies ($t \cdot hm^{-2} \cdot a^{-1}$)

Research method	Land-cover type				Period	Area
	Woodland	Grassland	Arable land	Residential land		
CSLE model[28]	4.59	5.23	35.36	3.73	1981–2010	Guizhou province
RUSLE model[29]	5.99	–	43.75	0	1962–2012	Lingjiaotang small watershed in the Three Gorges Reservoir area
^{137}Cs Tracer[30]	–5.22–5.16	9.91–16.16	7.27–24.89	–	2018	Small watershed in southern Yunnan
^{137}Cs Tracer[31]	9.29	–	25.37	–	Annual average	Sangyong valley
this research	12.61	20.01	32.51	0.37	Annual average	Southwestern mountains

5 Discussion and Conclusion

This dataset is based on integrating data on meteorological, soil, topography, vegetation index and soil cover data, using a modified soil-loss model to sort out and calculate the annual soil erosion modulus dataset with a resolution of 1 km in southwestern mountainous region.

Author Contributions

Chen, P, F. designed the methodology of the dataset. Wang J, Y. contributed to the data processing and analysis and wrote the data paper. Zhu, Y, Q. revised the data paper.

Conflicts of Interest

The authors declare no conflicts of interest.

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