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Development of Ecological Vulnerability Classification 1-km Raster Dataset in Qinghai Province of China (2015)

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Abstract: Qinghai province, an important part of the Qinghai-Tibet Plateau, plays a critical role in establishing China's ecological security barrier and is of great ecological strategic importance. In this study, we apply the "SPR" (ecological sensitivity-ecological pressure-ecological resilience) model to Qinghai province, whose data is based on three criterion levels of environmental concern, including ecological sensitivity, ecological pressure, and ecological resilience. Collectively, these conceptual ideas generate a total of 12 indicators. Among these indicators, slope, elevation, and topographic relief have a resolution of 30 m × 30 m; while the indicators with a 1 km × 1 km resolution include: soil erosion sensitivity, land degradation sensitivity, NDVI, average annual temperature, average annual precipitation, population density, GDP density, road density, and grazing intensity. The random forest method is used to determine the weighting of these indicators to assess the ecological vulnerability of Qinghai province. The study area was then divided into five vulnerability levels: slight, mild, moderate, severe, and extreme. The final dataset has a resolution of 1 km × 1 km and a .tif format, consisting of five files with 1.30 MB of data.

Keywords: Qinghai province; ecological vulnerability; random forest; SPR 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.2022.01.04.V1 or https://cstr.escience.org.cn/CSTR:20146.11.2022.01.04.V1.

1 Introduction

In recent years, with the intensification of global climate change and rapid socio-economic development, the role of humans in the transformation of the natural environment has

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[2] Zhi, Z. M, Liu, F. G., Chen, Q., *et al*. Ecological vulnerability classification 1-km raster dataset in Qinghai province of China (2015) [J/DB/OL]. *Digital Journal of Global Change Data Repository*, 2022. https://doi.org/10.3974/geodb.2022.01.04.V1. https://cstr.escience.org.cn/CSTR:20146.11.2022.01.04.V1.

increased rapidly. The human impact on the ecological environment has become increasingly significant, and the relationship between humans and nature has become tenser. Therefore, the assessment of ecological vulnerability and its management has gradually received more attention from scholars in ecology[1]. Currently, there are several definitions of ecological vulnerability, but it is generally recognized that ecological vulnerability mainly refers to the degree of internal response of an ecosystem to external disturbances[2]. Ecological vulnerability can also be thought of as the sensitive response and recovery state of a landscape system or ecosystem under the conditions of external action at a specific temporal and spatial scale and is represented by the performance of the properties possessed by the system itself when subjected to disturbing effects[3]. The assessment of regional ecological vulnerability can therefore provide an effective reference for regional development and the promotion of healthy and sustainable regional economic development.

Qinghai province is located in western China, an important part of the Qinghai-Tibetan Plateau, belonging to the Qinghai-Tibet alpine region. It is the source region of the Yangtze River, the Yellow River, and the Lancang River, and its strategic ecological position is very important. Since 2017, Qinghai province has been adhering to the "ecological province" strategy and building an "ecological civilization highland" with a clear purpose. Therefore, the ecological vulnerability assessment of the entirety of Qinghai province is of great importance. Based on the "SPR" (ecological sensitivity-ecological pressure-ecological resilience) model, this dataset is based on the three levels: ecological sensitivity, ecological pressure, and ecological resilience, which have relevant and measurable parameters of slope, elevation, topographic relief, soil erosion sensitivity, land degradation sensitivity, NDVI, etc. The spatial distribution of ecological vulnerability in Qinghai province is obtained through ArcGIS spatial overlay analysis, which effectively clarifies the spatial distribution of ecological vulnerability in Qinghai province. This dataset can illustrate the spatial distribution of the ecological fragility in Qinghai province and provide a base reference for the regional economic development direction of Qinghai province.

2 Metadata of the Dataset

The metadata from the Ecological vulnerability classification 1-km raster dataset in Qinghai province of China (2015)[4] are summarized in Table 1, which includes the dataset full name, short name, authors, year of the dataset, spatial resolution, data format, data size, data files, data publisher, and data sharing policy, etc.

3 Methods

The ecological vulnerability grading data of Qinghai province is mainly based on the "SPR" model to build the index system, which mainly includes an ecological sensitivity layer, ecological pressure layer, and an ecological resilience layer. Based on previous studies and taking into account the actual environmental characteristics of Qinghai province and the availability of data, 12 indicators were selected, including slope, elevation, topographic relief, soil erosion sensitivity, land degradation sensitivity, NDVI, average annual temperature, average annual precipitation, population density, GDP density, road density, and grazing intensity, to build an ecological vulnerability assessment system[6–9]. The random forest method was used to determine the weights of assessment indicators. Then the data were superimposed by the ArcGIS spatial superposition analysis tool to obtain the ecological vulnerability distribution data for Qinghai province. Finally, the vulnerability was classified into five levels: slight, mild, moderate, severe, and extreme, using the ArcGIS natural breakpoint method consistent with the previous studies in the alpine region of the Tibetan Plateau[10].

Table 1 Metadata summary of the Ecological vulnerability classification 1-km raster dataset in Qinghai province of China (2015)

Items	Description
Dataset full name	Ecological vulnerability classification 1-km raster dataset in Qinghai province of China (2015)
Dataset short name	EcoVul.Qinghai_2015
Authors	Zhi, Z. M. ABG-7100-2020, School of Geographic Science, Qinghai Normal University, zhizemin@126.com Liu, F. G. L-8795-2018, School of Geographic Science, Qinghai Normal University, lfg_918@163.com Chen, Q. AAB-3346-2021, School of Geographic Science, Qinghai Normal University, qhchenqiong@163.com Zhou, Q. AAB-3351-2021, School of Geographic Science, Qinghai Normal University, zhouqiang729@163.com
Geographical region	Qinghai province (31°36′N–39°19′N，89°35′E–103°04′E)
Year	2015
Temporal resolution	Year
Spatial resolution	1 km ×1 km
Data format	.tif
Data size	1.30 MB
Foundation	Ministry of Science and Technology of P.R. China (2019YFA0606902)
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[5]
Communication and searchable system	DOI, CSTR, Crossref, DCI, CSCD, CNKI, SciEngine, WDS/ISC, GEOSS

3.1 Study Area

Qinghai province (31°36′N–39°19′N, 89°35′E–103°04′E) is located in western China and in the northeastern part of the Qinghai-Tibet Plateau. The topography is higher in the west and lower in the east, higher in the north and south, and lower in the middle, with an overall trapezoidal downward trend. The eastern part of the province transitions from the Loess Plateau to the Qinghai-Tibet Plateau. The northeastern part is an important agricultural area in Qinghai province, while the terrain is complex and diverse to the south, with more than 80% of the area characterized as plateau or mountainous; the western part is mainly a plateau and basin, and the Qaidam Basin, one of the four major basins in China, is located in the western part of Qinghai province. The entire province has a continental climate with many rivers, including the Yellow River, Lancang River, Yangtze River, Huangshui River, and Hei River. It is also home to the headwaters of the Yellow River, Yangtze River, and Lancang Rivers. There are several nationally protected areas in Qinghai province, including the "Three Rivers Source" Nature Reserve, Coco Cili Nature Reserve, and Qaidam Nature Reserve. As a result, the ecological environment of Qinghai province is very fragile due to its geographical location and climate. Due to the importance of its strategic ecological position, the ecological security of Qinghai province directly affects the ecological security of the entire country, so it is very important to evaluate the ecological vulnerability of this region.

3.2 Methods

The data mainly refers to the ecological vulnerability assessment model developed by previous authors[2,3], localizes the assessment indicators involved in the model, calculates the weights for each criterion layer indicator separately, based on the random forest model, and uses the ArcGIS spatial overlay analysis tool to overlay the indicator and criterion layers to obtain the spatial distribution dataset of ecological vulnerability in Qinghai province.

3.2.1 The SPR (Sensitivity- Pressure-Resilience) Model

The SPR model was proposed by Qiao *et al*. in 2008[11], and the model is mainly used to comprehensively assess ecological vulnerability in a given region. For a specific time period in a certain region, the internal frame structure of the system has instability which is expressed as sensitivity when it is disturbed by the outside environment. Such sensitivity develops in a direction unfavorable to the system's stability due to the lack of sufficient coping capacity, and the system is subjected to pressure within the system to show resilience. The SPR model contains three criterion layers, ecological sensitivity, ecological pressure, and ecological resilience, and the selection of indicators can be determined according to the actual characteristics of the region. Its basic operational method is centered on the actual environmental characteristics of the study area. In this way, the model indicators under the three criterion layers are localized. The regional ecological vulnerability index is obtained by assigning weights to the different indicators and spatially superimposing different indicators based on the weighted values. Finally, vulnerability classification is carried out according to the classification method.

Ecological vulnerability is obtained from the graded ecological frangibility index (EFI), which is calculated from ESI (ecological sensitivity index), EPI (ecological stress index), and the ERI (ecological resilience index), where ESI and EPI are positive indicators and ERI is a negative indicator. Its calculation formula is given as follows:

$$EFI=ESI\cdot Ws+EPI\cdot Wp-ERI\cdot Wr \tag{1}$$

where Ws represents the weight of ecological sensitivity, Wp represents the weight of ecological pressure, and Wr represents the weight of ecological resilience.

3.2.2 Random Forest Model

The random forest (RF) model, a commonly used machine learning method, is a comprehensive deep learning method[12], which has distinct advantages for solving nonlinear problems[13] and serves as a data mining method using categorical regression trees[12]. Its operating principle is to obtain categories by integrating multiple decision trees and categorical voting. At the same time, the method requires fewer arithmetic data. For the study of multi-factor classifications, it can quantitatively provide the degree of importance of the elements for the results, which is relatively more objective and more accurate than other machine learning algorithms[14]. In particular, the RF method has a certain resistance to overfitting, as it can reduce the risk of overfitting by averaging the decision trees, and it has a high tolerance for noise and outliers generated in the model operations[13,14]. It can also measure the degree of importance of variables, which is a great advantage for solving weighting class problems. Therefore, this study uses the RF method to evaluate ecological vulnerability, mainly using the R studio compiler in the R 3.3.3 environment to call the RF package for iterative operations. The importance of each factor provided by the random forest method determines the index's weight, allowing for the processed data to be integrated using the ArcGIS spatial superposition analysis tool to obtain the ecological vulnerability grading data of Qinghai province.

3.3 Technology Line

In this dataset, the three sub-goals of ecological sensitivity, ecological pressure, and ecological resilience were constructed by selecting 12 indicators: slope, elevation, topographic relief, soil erosion sensitivity, land degradation sensitivity, NDVI, average annual temperature, average annual precipitation, population density, GDP density, road density and grazing intensity, and the weights of the sub-goals were determined based on the random forest model. The ArcGIS spatial analysis tool was used to calculate the ecological sensitivity, ecological pressure, and resilience of the three sub-objectives. Then the random forest model was used to determine the weights of the three sub-objectives for the main objective. Finally, ArcGIS spatial superposition analysis was used to obtain the spatial distribution of the ecological vulnerability index in Qinghai province, which was classified into extreme, severe, moderate, mild, and slight based on the ArcGIS natural fracture classification method (Figure 1).

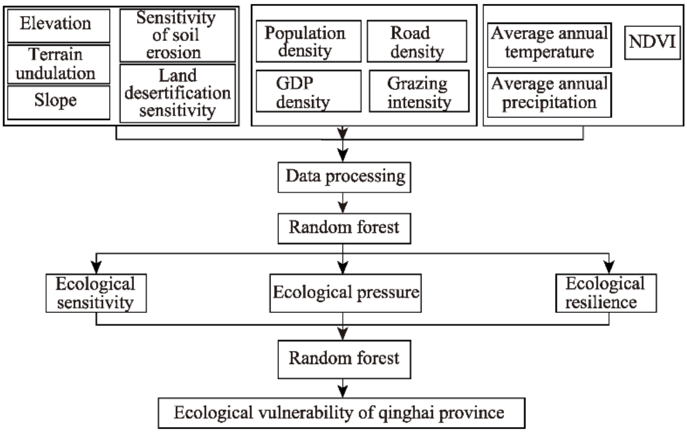

Figure 1 The flowchart of dataset development

4 Data Results and Validation

4.1 Data Composition

The original format of this data was mostly raster. The administrative division data and road data (vector) of Qinghai province are from the 2017 national geographic resources directory service system (https://www.webmap.cn/main.do?method=index). The road density data (raster), also from 2017, are obtained from the ArcGIS "density analysis" tool, with a spatial resolution of 1 km × 1 km. The year-end livestock data came from the statistical yearbook of Qinghai province cities (states) and the statistical bulletin of national economic and social development (2016), where the grazing intensity is defined as the number of livestock per unit grassland area. The elevation data are obtained from the geospatial data cloud platform (http://www.gscloud.cn/home), and the slope and topographic relief are obtained through elevation data extraction, with a data resolution of 30 m × 30 m, sampled by "resampling" tools to 1 km × 1 km. The 2015 soil erosion sensitivity and land desertification sensitivity data (resolution of 1 km × 1 km) were obtained from the Ecological Environment Research Center of the Chinese Academy of Sciences (http://www.rcees.ac.cn/). The 2015 data for the normalized vegetation index (NDVI), average annual precipitation, average annual temperature data, population density data, and GDP density were obtained from the Resource and Environment Science Data Center of the Chinese Academy of Sciences (https://www.resdc.cn/) with a 1 km ×1 km resolution.

4.2 Data Products

Based on the temporal distribution of the original data, the ecological fragility grading assessment data of Qinghai province is defined for the year 2015, and the spatial domain is the entirety of Qinghai province. The fragility grading assessment results show that the ecological fragility grading of Qinghai province has the highest proportion of light fragility, mainly distributed in the Qinghai Plateau and the T'ang- ku-la Mountain region, whose area accounts for 36.33% of the area of Qinghai province. The smallest proportion consisted of extremely fragile areas, mainly distributed in the Yellow River-Huangshui River Valley agricultural area and the Qaidam Basin. Coincident with the most intense human activities in Qinghai province, human interference in the Yellow River-Huangshui River Valley has a greater impact on the ecological environment; thus, the ecological pressure is more prominent. This is followed by the poor natural environment of the Qaidam Basin, with an annual precipitation shortage and serious desertification, which has also become an extremely fragile ecological area, compromising 8.51% of extremely fragile areas. The remaining slightly fragile and moderately fragile areas have similar proportional areas, accounting for 19.69% and 21.43%, respectively, and the percentage of the area of the severely vulnerable areas is relatively small at 14.05%[15] (Figure 2).

Overall, the ecological vulnerability of Qinghai province shows a distribution characteristic of high in the north and low in the south; high in the east and low in the west. In the east, the population density is relatively high; consequently, the intensity of human activities is high. Thus, the conflict between humans and land is significant, and the ecological pressure on the system is high. However, in the west, the Qaidam Basin is an important energy supply base for Qinghai province and even for the whole country. While the GDP density is relatively high, the environment is harsher, so the vulnerability level is higher. In the south, the area is mainly pastoral; therefore, the population densities less within a relatively healthy natural environment, justifying a relatively low vulnerability level.

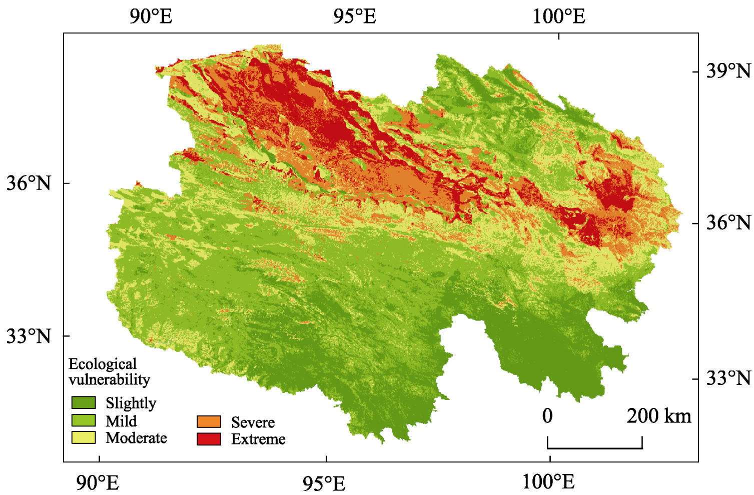

Figure 2 Ecological vulnerability classification in Qinghai province

4.3 Data Validation

The overall accuracy of the random forest model served as the main focus for data validation. In terms of the three sub-goals of ecological stress, ecological resilience, and ecological sensitivity in the model iteration and the final ecological vulnerability target calculation, the R^2 of the random forest model was above 0.95, and the overall error was less than 0.05. Therefore, the model's overall accuracy is high, and the data results are reliable to a certain extent.

5 Discussion and Conclusion

We applied a random forest model to construct the ecological vulnerability classification data of Qinghai province based on three index layers of ecological sensitivity, ecological pressure, and ecological resilience. The following parameters drove the model: altitude, slope, topographic relief, soil erosion sensitivity, land desertification sensitivity, NDVI, average annual temperature, average annual precipitation, population density, GDP density, road density, and grazing intensity, each of which was assigned weights by the random forest method. The ecological vulnerability distribution data of Qinghai province were obtained by superimposing the indicators through an ArcGIS spatial analysis.

With the deepening of ecological vulnerability evaluation research, the selection of vulnerability evaluation indicators has gradually matured. Still, due to the accessibility of some indicators, this dataset can only calculate the spatial distribution characteristics of ecological vulnerability in Qinghai province for 2015. The effectiveness of future research can be improved if some indicators with poor accessibility are replaced by other proxy indicators or prepared by certain methods to improve the effectiveness of the research.

Author Contributions

Liu, F. G. first proposed the ideas and thoughts of the paper; Chen, Q., and Zhou, Q. adjusted the general framework of the paper; Zhi, Z. M. designed the dataset's development and collected, processed the original underlying data, and wrote the paper.

Conflicts of Interest

The authors declare no conflicts of interest.

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