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Comprehensive evaluation of ecosystem health in pastoral areas of Qinghai–Tibet Plateau based on multi model

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ABSTRACT

In order to solve the problem that the existing ecosystem health assessment methods are affected by many uncertain factors, resulting in inaccurate assessment results, a comprehensive assessment method of ecosystem health in pastoral areas of Qinghai–Tibet Plateau was proposed based on multi model combination method, taking pastoral areas of Qinghai–Tibet Plateau as an example. Remote sensing technology is introduced to obtain the relevant information of the study area and analyze the ecological and environmental problems of the Qinghai–Tibet Plateau. The remote sensing image of plateau pastoral area is corrected and fused, and the multi model is established by using the common Kriging interpolation method, and the response evaluation index system is obtained. Analysis of forest vegetation coverage, temperature vegetation drought index, leaf area index, vegetation primary productivity, surface temperature and precipitation, calculation of index weight, complete the design of evaluation method. The experimental results show that the designed evaluation method is closer to the actual situation, which verifies the effectiveness of the evaluation method.

1. Introduction

Located in the middle of the Asian continent, the Qinghai–Tibet Plateau is a unique ecological environment area on the earth with steep mountains and rivers and rich natural resources. It is the birthplace of major rivers in China and Southeast Asia, known as the "China water tower", which promotes the derivation of ancient Yellow River civilization and Indian civilization. Up to now, the Qinghai–Tibet Plateau, with its rich resources and environmental advantages, has a very special position in the development of the Chinese nation and human living environment (Gładysz et al., 2018; Jiang et al., 2018). The domestic investigation of the ecological environment of the Qinghai–Tibet Plateau began in the 1930s and 1940s. At first, it was the personal exploration and investigation of some scientists, such as botanists, meteorologists, geologists, etc. up to the 1940s, most of the subjects of the Qinghai–Tibet Plateau were still in a state of scientific emptiness. Since the founding of the people's Republic of China, the scientific investigation of the Qinghai–Tibet Plateau has mainly gone through three stages: development, expansion and in-depth study. The large-scale scientific investigation began in the early 1950s after the founding of new China. The comprehensive investigation and scientific

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research on the Qinghai–Tibet plateau for more than 50 years can be roughly divided into three stages: from the beginning of 1950s to the end of 1960s, the first stage is nearly 20 years. Some regional and special scientific investigation and research work have been completed, and important first-hand materials have been obtained for the future science the investigation and research laid the foundation. The second stage is from 1970s to the end of 1980s. The Chinese Academy of Sciences organized scientific and technological personnel from relevant departments in China to carry out a large-scale comprehensive scientific investigation of the Qinghai–Tibet Plateau, and obtained millions of words of original first-hand scientific investigation data (Palomba et al., 2018; Edegbene et al., 2019). The comprehensive evaluation of ecological environment quality is a multi-level, multi-objective and multi task system engineering. It follows the principles of ecology, environmental science, economics, system engineering, etc. the comprehensive evaluation methods and theoretical research of ecological environment are very strong and exploratory and pioneering at present, especially the large-scale comprehensive evaluation of regional ecological environment is still in the initial stage.

Scholars at home and abroad have done a lot of research on the hot issues of ecological evaluation, such as the change of natural elements of ecological environment, the relationship between human activities and ecological environment, global change and regional ecological environment change. For example, some scholars have assessed the long-term impact of coniferous forests (cypress, loblolly pine, slash pine) on Ecological Restoration in the Andean highlands of Colombia. In order to determine the degree of restoration, we assessed whether there were differences in the structure or density of understory vegetation or soil ecological characteristics between plots established in plantations and plots established in other vegetation cover types (secondary forests, ferns, pastures and abandoned mining areas). In addition, researchers have studied the accumulation of PAHs in sediments and river water samples from two rivers. The spatial distribution, composition and sources of polycyclic aromatic hydrocarbons (PAHs) in sediments were studied.

The toxic equivalent quotient (TEQ CARC) of potential carcinogenic polycyclic aromatic hydrocarbons (PAHs) and sediment quality index were used to evaluate the impact of PAHs on ecosystem. The average concentrations of PAHs in Luofu River and Hejin River are 2161 ng/g and 160 ng/g respectively. This may be due to higher population density and pyrolytic activity in the lov River Basin. However, because the above methods only focus on the plant characteristics of specific areas, the comprehensive evaluation of ecosystem health in pastoral areas of the Qinghai–Tibet Plateau is uncertain, and the evaluation results have large errors. Therefore, a comprehensive evaluation method of ecosystem health in pastoral areas of Qinghai–Tibet Plateau Based on multi model combination was designed. Uncertainty is an inherent attribute of the objective world and exists in all disciplines. The uncertainty of various hydrogeological conditions such as seepage structure should be taken as the object of multi model analysis.

2. Comprehensive evaluation of ecosystem health in pastoral areas of the Qinghai Tibet Plateau

2.1. Analysis of ecological environment problems in the study area

Most parts of the Qinghai–Tibet Plateau still maintain the original landscape. Due to the lack of heat, the soil layer is young, the soil is poor, the ability of anti erosion is weak, the plant growth is slow, the natural production capacity is low, and the ecosystem is in the young development stage, showing great vulnerability and strong change characteristics. The ecological environment is in a state of turbulence, and all kinds of physical and geographical processes are still young and unstable. The main ecological problems can be divided into the following categories:

A. Crisis of water resources change. Under the influence of global warming, snowline rising, glacial retreat, multi-year glaciers, melting of frozen soil or increasing of seasonal melting depth, and decrease of snow cover all year round may lead to the development of climate towards "warm wet" in the short term. In the long term, with the depletion of various types of water resources, the Qinghai–Tibet Plateau, as the "water tower" of China and Southeast Asia, has an impact on water resources and peripheries the function of environmental impact is gradually weakened, and the area radiated by "water tower" will lead to disastrous consequences (Peláez-Silva et al., 2019).

B. With the aggravation of land desertification, the problem of soil erosion is becoming more and more serious. Land is the basis of survival, which maintains the basis of agriculture and animal husbandry in the vast inland areas of Qinghai–Tibet. The soil development in most parts of the Qinghai–Tibet Plateau is relatively primitive, especially in the arid and alpine areas in the hinterland of Qinghai–Tibet, which are affected by the scarcity of vegetation, drought and windy, and the soil wind erosion and salinization desertification are more and more serious. Since the 1980s, the global climate change has increased, and the natural conditions of the plateau itself are poor As a result, the grassland vegetation and soil restoration function are poor, and overgrazing and unreasonable cultivation of human beings aggravate the land desertification.

C. Wetlands are shrinking. The wetlands in the Qinghai–Tibet Plateau belong to the inland wetlands in the alpine and arid regions, which not only account for a large proportion of the wetlands in China, but also are mostly distributed in the river source area, oasis, river beach, inland lakeside and other ecologically sensitive areas (Tu et al., 2018). In the past 30 years, under the influence of global change and human activities, the wetlands in the Qinghai–Tibet Plateau have been shrinking, resulting in the decrease of lake water level, the decrease of river water supply, the degradation of grassland, and even the impact of local climate change.

D. Geological disasters are frequent. The plateau is located in the area adjacent to the Eurasian plate and the Indian plate, where the geological movement is extremely active, especially in the area with large topographic relief and steep

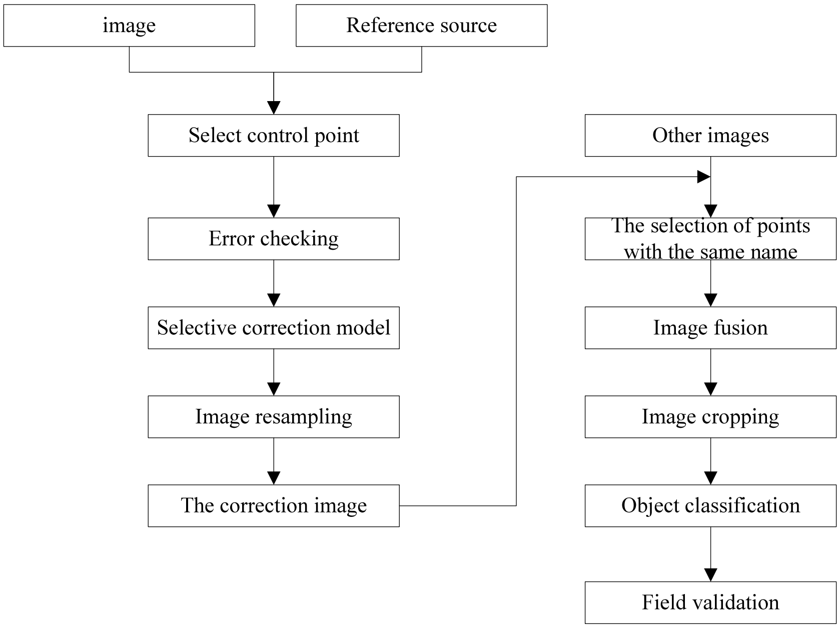


Fig. 1. Remote sensing image processing flow.

slope, strong soil and water loss, frequent geological disasters such as collapse, landslide and debris flow, which pose a more and more serious threat to the agricultural production, traffic construction and people's life and property safety in the Qinghai–Tibet Plateau.

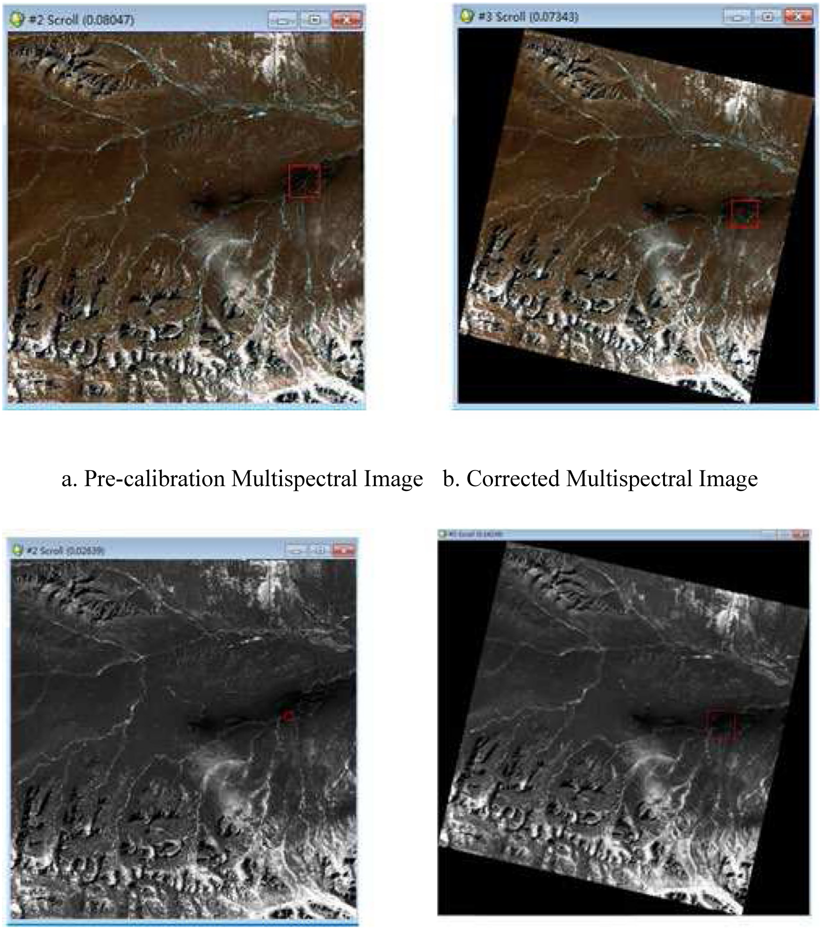
E. The rapid and disordered growth of population. Since the founding of the people's Republic of China, the population growth rate of the Qinghai–Tibet Plateau has been too fast, while the regional environmental and resource carrying capacity is relatively low. Since the 1980s, the dry and warm effects have magnified the impact and damage of human activities on the ecological environment. The contradiction between the rapid and disordered population growth and the relatively low environmental and resource carrying capacity of the Qinghai–Tibet Plateau is obvious (Ling et al., 2019).

Therefore, in view of the particularity and main problems of the ecological environment of the Qinghai–Tibet Plateau, remote sensing technology is used to obtain its geographical information, so as to obtain the status quo investigation and change data of the ecological environment related factors of the Qinghai–Tibet Plateau, find out the distribution, and carry out a large-scale and long-term ecological environment evaluation and monitoring on the evolution law of the main ecological factors in the region, so as to provide reference for the rational utilization, development and utilization of the ecological environment To protect all kinds of ecological resources, provide decision support, and realize the coordinated and sustainable development of nature, economy and society.

2.2. Processing remote sensing image data

After obtaining the target image, it needs to be processed. In this paper, the image processing includes the steps of image geometric precision correction, image fusion, resampling, image registration, image clipping, ground feature classification and so on. Now, the image is preprocessed and the required ground feature categories are interpreted. Finally, field verification is carried out according to the classification results. The specific flow chart is shown in Fig. 1:

In the process of acquiring remote sensing image, due to satellite attitude, orbit height, earth rotation, curvature of earth surface, terrain fluctuation, system error of sensor itself and other reasons, remote sensing image will have geometric distortion to a certain extent. Geometric correction is to eliminate these distortions (Smeds et al., 2018; Duncan et al., 2018). Geometric correction is divided into geometric fine correction and geometric coarse correction. Geometric coarse correction has been completed by the ground workstation before the image is purchased. Geometric fine correction is to establish the mathematical model between image coordinates and geodetic coordinates by selecting control points, and to relocate the image to a certain map projection plane coordinate system, so as to eliminate the row and column errors caused by the geometric position errors of remote sensing image pixels Uniformity, inaccurate correspondence between pixel size and actual figure size, and irregular change of figure shape. The image is processed with envis. 1 software, and the high-resolution No.1 image is corrected with the corrected TM image. In the geometric correction, the selection of control points is the key to control the correction accuracy. The accuracy of control points directly affects the point accuracy and area accuracy of the corrected image (Richter, 2018; Wu et al., 2019; Shi et al., 2018). In this paper, 51 control points are selected for multispectral image correction. 52 control points are selected for panchromatic



a. Pre-calibration Multispectral Image b. Corrected Multispectral Image

c. Pre-calibration Panchromatic Image d. Panchromatic Image After Correction

Fig. 2. Comparison before and after image correction. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

band image correction (Xun and Hu, 2019). The double linear interpolation method is selected for resampling method, which can improve the brightness discontinuity of image and the blocky phenomenon of linear features, and improve the accuracy. Fig. 2 is the contrast before and after image correction:

It can be distinguished from the red box marked in the corrected image. The changes before and after image correction, the ore area in the image before correction is inclined, and the ore area in the image after correction is approximate level.

Using the simultaneous interpreting technology of the same sensor or different sensors, the information of single remote sensing image can be fused to improve the spatial resolution of multispectral images and improve the recognition degree of image information, so that the fused images can meet the needs of users (Li et al., 2019; Wang et al., 2018). As shown in Fig. 3, 'a' is the area before fusion of GF-1 multispectral image, 'b' is the area before fusion, 'c' is the result after fusion of 1 multispectral image, and 'd' is the same area as B after fusion.

In this paper, data fusion is used to enhance the visual effect and classification effect of the image, so as to improve the visual interpretation accuracy of the image. There are four bands in GF-1 multispectral data. The spectral information is rich, but the spatial resolution is only 8 m. Panchromatic data has only one band, the spectral information is weak, and the spatial resolution is 20 m. Through the pixel level fusion of GF-1 multispectral image and panchromatic band image, the spatial resolution of the fused image can be improved while the multispectral information is retained, and the interpretation accuracy can be improved in the mine ecological environment interpretation. Remote sensing image needs two steps of preprocessing before fusion: A. Image spatial registration: the control points are selected for image registration, and resampled to the same spatial resolution, and the spatial registration error shall not exceed one pixel; B. Image matching: the histogram of panchromatic image is transformed into the histogram of multispectral image to be fused, so that the brightness distribution of the two images is as close as possible, so as to reduce the spectral distortion of the fused image. In this paper, principal component analysis (PCA) is used to fuse GF-1 image. In the above figure,

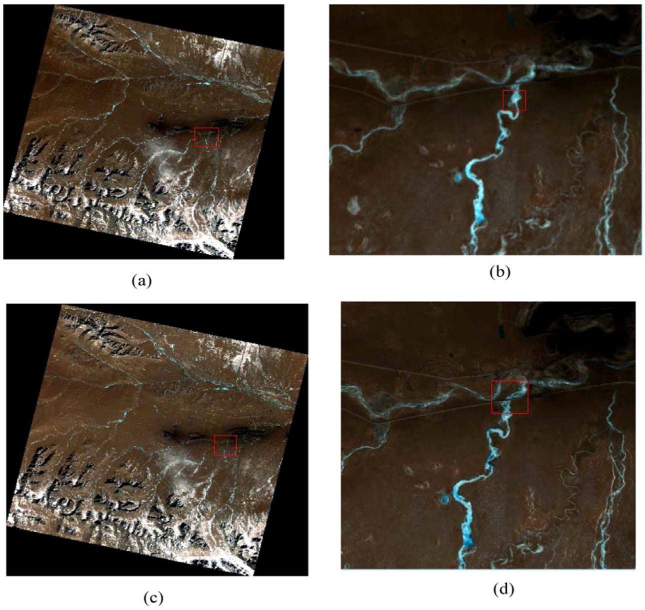


Fig. 3. Comparison before and after multispectral image fusion of Gaofen-1. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

figure a is a region of GF-1 multispectral image before fusion, B is a region of GF-1 multispectral image, C is a region of GF-1 multispectral image after fusion, and D is a region of GF-1 multispectral image. The spatial resolution of the fused GF-1 multispectral image is significantly higher than that of the fused multispectral image, and the change of resolution can be observed from the marked area in the red frame, which also provides a better condition for the ground object interpretation. There are three most commonly used classification methods for surface feature classification, which are supervised classification, unsupervised classification and decision tree classification. Feature classification is to distinguish different features in remote sensing image according to different colors, so as to facilitate the implementation of the subsequent evaluation process.

2.3. Multi model construction

Kriging method is a commonly used interpolation method in geostatistics, and the parameter values of the variogram model determine the interpolation results, which are usually determined by fitting the variogram with the sample data. In this numerical experiment, ordinary kriging method was used for interpolation, and spherical model was used as the variogram model according to the fitting situation. The expression is as follows:

$$C(h) = \begin{cases} C_0 & h = 0 \\ C_0 + C\left(\dfrac{3h}{2a} - \dfrac{h^3}{2a^3}\right) & 0 < h < a \\ C_0 + C & h > a \end{cases} \tag{1}$$

where, a is Range, representing the autocorrelation Range of the regionalized variable space; C_0 is the block gold constant, which means that when h is equal to 0, $C(h)$ is equal to a constant C_0, which is called the block gold effect. On the one hand, it comes from internal variation smaller than the sampling scale, on the other hand, it comes from sampling analysis error. The base station value $C_0 + C$ reflects the maximum variation of regionalized variables in space. Regional variables often have anisotropy, which is reflected by the directional assignment of variable range. The ratio of the long axis variable range to the short axis variable range reflects the degree of spatial anisotropy. Kriging interpolation is performed using software sge-ms developed at Stanford university. R. Nicholas et al. of Stanford university's department of energy engineering, developed sge-ms to address the lack of an easy-to-use graphical interface for GSLIB. The software integrates a large number of geostatistical algorithms, including traditional kriging methods, multivariable collaborative kriging, indicative kriging, and a variety of random simulation algorithms. Another advantage of sge-ms is that you can pull script files into the software to perform the evaluation, which can save users a lot of time when doing the same calculation multiple times. After establishing a number of alternative models, the model is firstly corrected according to the observed data to optimize the model parameters. UCODE is a common groundwater model parameter inversion program, which is nested in the commercial groundwater numerical simulation software Processing MODFLOW, Visual MODFLOW and GMS. It can be used for parameter sensitivity analysis, parameter optimization, prediction, data demand evaluation, uncertainty analysis of parameters and predicted values, etc. The objective function is the sum of squares of the residual differences between the simulated value and the observed value. The purpose of the correction is to optimize the parameters to minimize the objective function value:

$$S(b) = \sum_{i=1}^{n} \omega_i \left[y_i - y_i' (b) \right]^2 \tag{2}$$

where, n is the number of observed data; b is the parameter vector; y_i is the observation vector. When the parameters of model $y_i' (b)$ are b, the simulation values corresponding to the observed data are obtained; ω_i is the weight of response uncertainty corresponding to the observed data y_i. This completes the construction of multiple models.

2.4. Constructing the index system of ecological evaluation

Vegetation coverage is an important indicator to measure the ecological environment of a region. Domestic scholars have done a lot of research on the vegetation coverage of high altitude and high latitude areas in China. At present, there are many indexes used to retrieve vegetation coverage, most of which are based on band calculation, such as enhanced vegetation index evi, global environmental monitoring index Gemi, vegetation condition index VCI, etc. The NDVI product data derived from satellite are widely used in large-scale ecological research. The growth and development of vegetation cannot be separated from soil and water. The low soil moisture content will lead to the early drying of soil, the weakening of photosynthesis ability of vegetation, and the withering and death of vegetation due to water shortage. As an important index of monitoring soil degradation, soil moisture plays an important role in the material and energy conversion of soil vegetation atmosphere. The TVDI formula calculated by NDVI-Ts features is as follows:

$$\begin{cases} TVDI = \dfrac{Ts - Ts_{\min}}{Ts_{\max} - Ts_{\min}} \\ Ts_{\max} = a1 + b1 \times NDVI \\ Ts_{\min} = a2 + b2b1 \times NDVI \end{cases} \tag{3}$$

where Ts represents the land surface temperature, $Ts_{\min}$ represents the minimum pixel unit in the wet edge equation, and $Ts_{\max}$ represents the maximum pixel unit in the dry edge equation. The higher *TVDI* value is, the lower the soil moisture is; the lower *TVDI* value is, the higher the soil moisture is. The distribution of *TVDI* in Tibet can be obtained by the combination of band superposition. *LAI* has a close relationship with photosynthesis, transpiration and productivity of vegetation. It has gradually become an important botanical parameter and is widely used in ecological evaluation. With the help of remote sensing technology to retrieve leaf area index, it has been verified in the research of many scholars. Based on MODIS products, this paper obtains the distribution of *LAI* in Tibet. According to MODIS Product Description: *DN* value is 253, indicating bare land or low vegetation coverage: *DN* value is 254, indicating snow area; *DN* value is 255, indicating water area. The non special *DN* value is expressed by the following formula:

$$LAI = 0.1 \times DN \tag{4}$$

where *DN* is the gray value of the leaf area index image. Through pretreatment and grid calculation, the *LAI*was dimensionless, and the *LAI* was controlled at [0,1], and the distribution of *LAI* in Tibet was obtained. Under the condition of photosynthesis, the total primary productivity (GPP) of vegetation is the total amount of organic carbon fixed by green vegetation in a unit time, which determines the material and energy in the process of vegetation growth and development, and can reflect the efficiency of vegetation photosynthetic utilization. GPP is a common index m for studying the growth quality of regional vegetation and crops. At present, the GPP of total primary productivity can be calculated by MODIS, Lands at and meteorological station monitoring data, and the distribution of GPP can be retrieved by combining relevant models. The relationship between temperature, precipitation and ecology can effectively predict the response of ecosystem to climate change. Based on the above index processing method, lst of land surface temperature in Tibet area is processed, and the distribution of land surface temperature in Tibet area is obtained by mask. In this paper, Kriging spatial interpolation method is used to obtain precipitation data. Kriging spatial interpolation provides a linear unbiased estimation method. By analyzing the variation distribution of attribute values in spatial geometry, the appropriate distance range that can act on the points to be inserted is determined. Based on the sampling points in this range, the attribute values of each interpolation point are estimated.

After the selection of indicators, the weight of each indicator needs to be determined. In this paper, the proposed ecological index should integrate the characteristics of the above five indicators, so the principal component analysis (PCA) method of objective weight confirmation is used to build the ecological comprehensive index (P). The principle of principal component analysis (PCA) is to transform a number of relevant indicators or elements into uncorrelated comprehensive indicators. On the basis of the principle of ensuring the least information loss, the original indicators are reduced in dimension. Its advantages lie in simplifying complex research, improving research precision and efficiency. At the same time, the weight of PCA is determined objectively according to the characteristics of the data itself and the contribution rate of each index to the principal component, so as to improve the accuracy of the results and avoid the calculation deviation caused by different people and methods.

Table 1
Index characteristic value and contribution rate.

Particular year	Index	PC1	PC2	PC3
2008	FVC	0.940	−0.042	−0.067
	LAI	0.933	0.014	−0.24
	GPP	0.966	0.022	−0.194
	LST	0.335	0.885	0.323
	PRE	0.628	0.455	0.617
	Characteristic value	3.208	0.993	0.599
	Variance contribution rate	64.156%	19.585%	11.591%
	Cumulative contribution rate	64.1156%	84.512%	95.455%
2018	FVC	0.901	−0.103	−0.051
	LAI	0.912	0.071	−0.254
	GPP	0.924	0.024	−0.187
	LST	0.219	0.905	0.364
	PRE	0.428	−0.402	0.776
	Characteristic value	2.773	0.991	0.836
	Variance contribution rate	55.465%	19.941%	16.718%
	Cumulative contribution rate	55.465%	75.406%	92.124%

Table 2
Comprehensive weight value of each index.

Index	2008	2018
FVC	0.227	0.223
LAI	0.221	0.226
GPP	0.233	0.230
LST	0.167	0.172
PRE	0.152	0.149

With the help of SPSS data analysis tool and principal component transformation, the normalized FVC, Lai, gpplst are analyzed, the data of five pre indexes are summarized and synthesized into ecological comprehensive index. According to the principle of principal component analysis, the correlation coefficient matrix of each index is calculated, and the variance contribution rate of each principal component is obtained. The first k characteristic roots whose cumulative contribution rate is more than 85% are selected as the principal components to determine the index weight. In this paper, the values of 2008 and 2018 are selected for reference, as shown in Table 1:

It can be seen from the above table that in the first principal component (PC1), the loads of FVC, LAI and GPP are relatively large, and the data of both phases are above 0.9. In the second principal component (PC2), the load of LST is large, and in the third principal component (PC3), the load of PRE is large, and the data of two periods are 0.617 and 0.776 respectively. Therefore, we can conclude and extract three principal components: (1) the first principal component: vegetation factor represented by FVC, LAI and GPP; (2) the second principal component: heat factor represented by LST; (3) the third principal component: humidity factor represented by PRE. In principal component analysis, five indexes with high correlation coefficient are extracted as three independent factors, which are used to represent the ecological comprehensive situation, and weighted sum them to calculate the weight value of each index (Table 2). The weighted summation formula is expressed as:

$$PC = \sum_{i=1}^{3} (e_i \times pc_i) \tag{5}$$

where, PC represents the comprehensive weight of each index, e_i represents the variance contribution rate corresponding to the principal component, and pc_i represents the load of each principal component on the original index. The weight values of each index can be obtained as Table 2:

According to the weight value of each index, the ecological distribution of Tibet in 2008 and 2018 is obtained by superposition analysis. In order to facilitate the measurement and comparison of indicators, the results are standardized and the ecological comprehensive index p value is obtained. In order to better analyze the representativeness of P value of ecological index, according to the existing classification standard, with 0.2 as the rank interval, P value of ecological index is divided into five grades, representing poor, poor, medium, good and excellent respectively. The higher P value is, the better the ecological condition is.

3. Experiment

3.1. Experiment preparation

In order to verify the effectiveness of this evaluation method, we need to design experiments. The first choice is to determine the evaluation index system of the ecological environment of the Qinghai–Tibet Plateau.

Table 3
Evaluation index system of ecological environment in Qinghai–Tibet plateau.

Target layer A	Criteria layer B	Index layer C
Comprehensive evaluation of the ecological environment of the Qinghai–Tibet Plateau	Topographical and geological conditions B_1	Altitude.C_1. Topographic relief C_2 Fracture density C_3
	Natural resources B_2	Annual average temperature C_4 Annual average precipitation C_5 Land suitability C_6 NDVI index C_7
	Surface water resources B_3	Glacier density C_8 Wetland density C_9 River network density C_{10}
	Socio economic conditions B_4	GDPC_{11} Population density C_{12} Road density C_{13}
	Ecological degradation B_5	Geological disaster density C_{14} Land desertification index C_{15} Grazing overload C_{16}

As shown in Table 3, in the topographical and geological conditions, the altitude data is analyzed with the DEM data of 1:250000 Qinghai–Tibet Plateau; the topographic relief is calculated with the DEM data of 1:250000 Qinghai–Tibet Plateau, using the topographic relief formula and through the window analysis; the fracture density data is provided by the research group of remote sensing investigation and monitoring of Qinghai–Tibet Plateau Ecological and geological environment, and the line is conducted with ArcGIS software Density analysis. In the natural resources criterion layer, the annual average temperature data is interpolated by "regression equation calculation + spatial residual"; The multi-year average precipitation data is provided by Institute of Geosciences and resources, Chinese Academy of Sciences, and the software ANUSPLIN issued by Canberra research center of resources and environment, Australian National University is used 4.3 the precipitation data of 1 km × 1 km in Qinghai–Tibet Plateau are obtained by interpolation with thin disk smooth spline method; the land suitability data are vectorized with 1:1 million land resource map data, and the land suitability class layer is extracted, and the grid point data is calculated by interpolation method; ndti index data is synthesized by MVC method with the annual average maximum month of 8 km × 8 km NDVI index. In the criteria layer of surface water resources, the data are all from the "remote sensing investigation and monitoring of the ecological geological environment of the Qinghai–Tibet Plateau" research group, and are obtained through grid and weighted calculation. As a special water resource, glacier has certain regional environmental effects on its existence and change, so it is considered as a distribution variable in the basin. In the criteria layer of social and economic conditions, the GDP and population density are provided by the resource and environment data center of the Institute of Geosciences and resources of the Chinese Academy of Sciences; the road density data comes from the 1:500000 national traffic map vector data of the national basic geographic data center, which is calculated and processed by weighting different levels of roads. In the criteria layer of ecological degradation, the data of geological disaster and land desertification come from the subject of "remote sensing investigation and monitoring of ecological geological environment of Qinghai–Tibet Plateau", and are calculated according to the type and level of disaster and desertification; the data of grazing overload comes from the data of grassland livestock capacity in the third national grassland resource survey and the data of animal husbandry in 2000 statistical yearbook.

Based on the comprehensive evaluation of data volume, data processing ability of professional software, computer configuration level and other factors, the above index data are passed through ArcGIS software to generate 10 km × 10 km research grid, and 26 473 evaluation units are generated in the whole region. Using ArcGIS to extract the vector data in the grid through 10 km × 10 km Qinghai–Tibet Plateau grid or spatial analysis and other means to generate excel Microsoft spreadsheet file, which lays the data foundation for the next step of weighting processing and the application of SPSS (statistical program for Social Sciences) for principal component analysis. In fact, it is a weighted combination of hierarchical single ranking to calculate the relative importance ranking of layer C to layer A through the hierarchical total ranking of the established index system,

$$c_{mn} = \sum_{j=1}^{n} b_j \cdot c_{1j} \tag{6}$$

In the above formula, $b_1, b_2, \ldots, b_n$ is the sort of layer B to layer A, and $c_{m1}, c_{m2}, \ldots, c_{mn}$ is the total sort of layer C to layer A. In the SPSS software, the data is normalized according to the range standardization, the data of the standardized evaluation samples are weighted, and the variance of the relatively important index samples is expanded, so as to synthesize the subjective and objective weight of the evaluation factors, the weight of the quantity value relationship and the weight of the relative importance, and the experimental results are obtained,

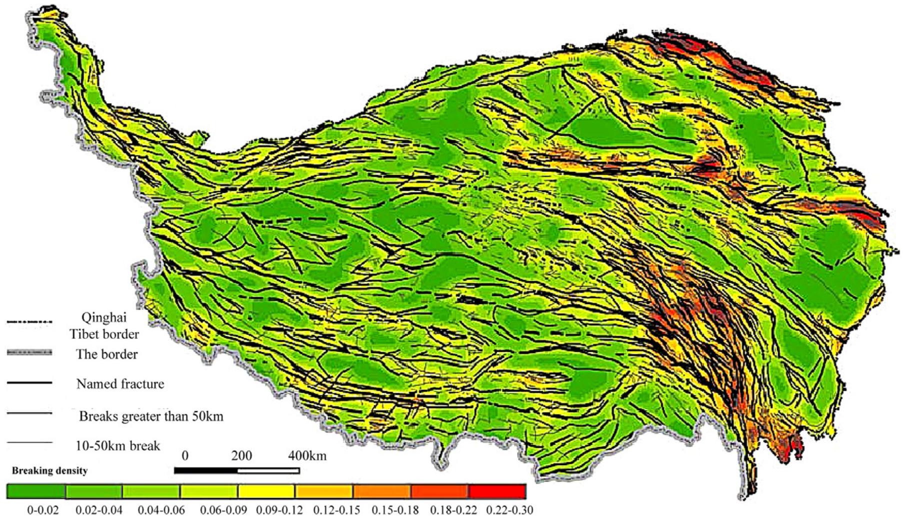


Fig. 4. Distribution of fracture and fracture density in the Qinghai–Tibet Plateau.

3.2. Analysis of experimental results

3.2.1. Fracture structure density analysis

The development of faults in the Qinghai–Tibet Plateau has an important influence on the development of regional structures, magmatism, sedimentary formation and changes, and mineralization. The data of fault distribution in the Qinghai–Tibet Plateau is provided by the project team of remote sensing investigation and monitoring of the eco-geo environment of the Qinghai–Tibet Plateau. The faults are mainly divided into named faults, faults larger than 50 km and faults 10–50 km. The named fault is the dividing line of the main structural units, such as the deep fault zone in the southern margin of Kunlun Mountain, the deep fault zone of lazhulong Jinshajiang, and the Altun fault zone. According to the length of the fault, it can be divided into more than 50 km fault and 10–50 km fault again, which represents the development scale of the fault. The geological fracture density is estimated by the linear density of ArcGIS software spatial distribution, unit: fracture length per square meter, as shown in Fig. 4:

The fracture density is used to evaluate the development degree of the faults in the Qinghai–Tibet Plateau. The fracture density is closely related to the geological stability of the engineering construction, the seismic region and intensity, the development of geological disasters (avalanche flow), especially the hot springs and volcanic activities in the neotectonics and some active fault zones. The areas with high fracture density are generally vulnerable to the ecological environment. In the study area, the area with the highest fault density is located in the north–south direction fault zone of Hengduanshan area. The main part of the fault is the deep fault zone of lazhulong Jinshajiang River, which forms the area with the highest South–North slow s-direction fault density, followed by the East Kunlun Mountain and the Gangdise mountain of Qilian Mountain. The Qinghai–Tibet Plateau has experienced three major tectonic events: plate subduction zones, suture zones and deep faults in different geological periods. The uplift of the Qinghai–Tibet Plateau and the geological and geomorphic pattern formed after the uplift. The plateau area has experienced the changes of different types of ecological environment from tropical and subtropical forests with low altitude to alpine meadows, arid grasslands and deserts. Moreover, in the near future, the plateau is still under the strong influence of the uplift and new tectonic movement, and the ecological environment is in a state of turbulence, especially the fracture model is large The natural and geographical processes in the junction zone of the internal units of the Tibetan Plateau with high density are still young and unstable, which may be the fragile zone of geological environment and ecological environment.

3.2.2. Annual average temperature interpolation

Add the two parts of the results of regression equation interpolation and residual interpolation to get the grid data of annual average temperature in the whole region, as shown in Fig. 5:

It can be seen from the interpolation results that the regression equation interpolation and residual interpolation accurately reflect the macro distribution characteristics of the annual average temperature of the Qinghai–Tibet Plateau, and are suitable for the comprehensive evaluation of the ecological environment based on the grid evaluation unit. In the further analysis of Precipitation Interpolation of the Qinghai–Tibet Plateau, it is found that the precipitation of the Qinghai–Tibet Plateau is affected by more complex factors such as monsoon circulation, slope direction, topography and so on. Through experiments, the method of spatial precipitation interpolation has a large error, which is difficult to be applied to the study, and the data obtained by other methods or software are needed to be processed.

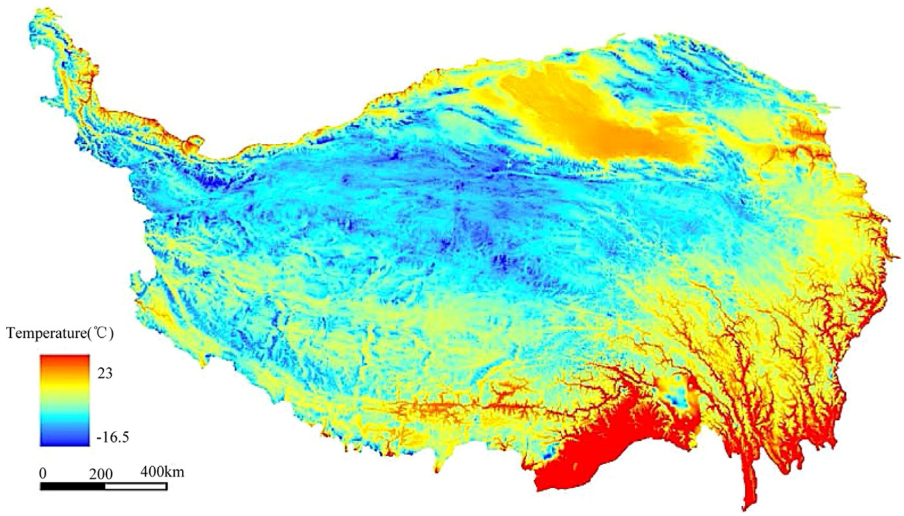


Fig. 5. Annual average temperature interpolation map of Qinghai–Tibet Plateau.

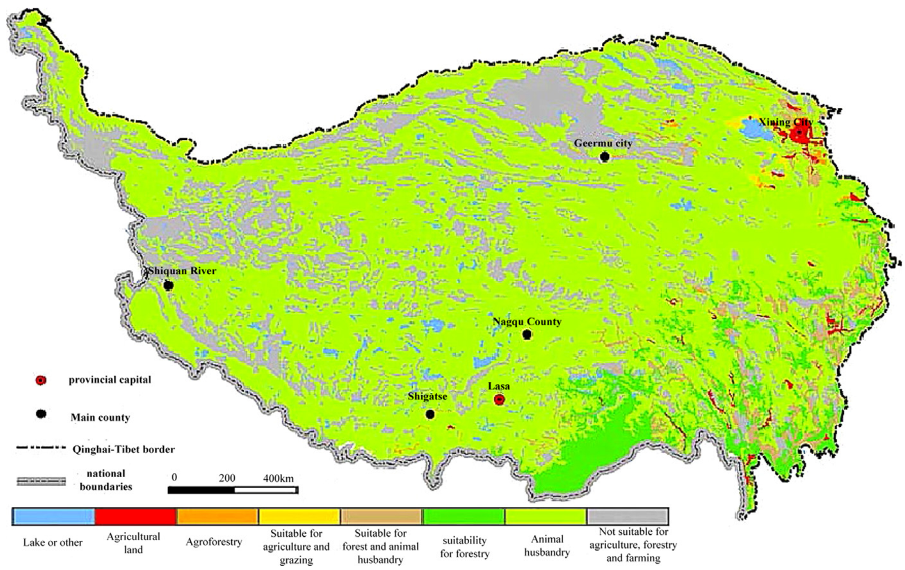


Fig. 6. Vegetation coverage of the Qinghai–Tibet Plateau.

3.2.3. Vegetation coverage

Land suitability refers to the suitability of a certain land type for a specific purpose. Generally, it is divided according to the suitability of land for agricultural, forestry and animal husbandry production to reflect the quality and production capacity of land. The land suitability classification data of the Qinghai–Tibet Plateau mainly comes from the result map series of the national "Seventh Five Year Plan" key scientific and Technological Projects — the remote sensing data set of resources and environment in the Loess Plateau. According to the suitability, the land of Qinghai–Tibet Plateau is divided into 8 categories, including farmland, forest, animal husbandry, forest, animal husbandry, lake or others. The distribution of various types of land is shown in Fig. 6:

The cultivated land suitable for agriculture in Qinghai–Tibet Plateau is mainly distributed in Xining city and surrounding counties of Hehuang Valley, followed by the relatively concentrated cultivated land in the valley of Western Sichuan, which is generally distributed in a strip along the valley direction, accounting for only 0.65% of the plateau area; The land suitable for agriculture and animal husbandry is mainly distributed in Qinghai Province, such as the surrounding area of Qinghai Lake, Hainan Tibetan Autonomous Prefecture, etc.; the land suitable for forestry and animal husbandry is mainly distributed in the valley of West Sichuan and East Tibet, where the lower part of the valley slope is mostly shrub grass slope, the middle and upper part of the valley slope and both sides of the tributary Valley, where there are dense forests

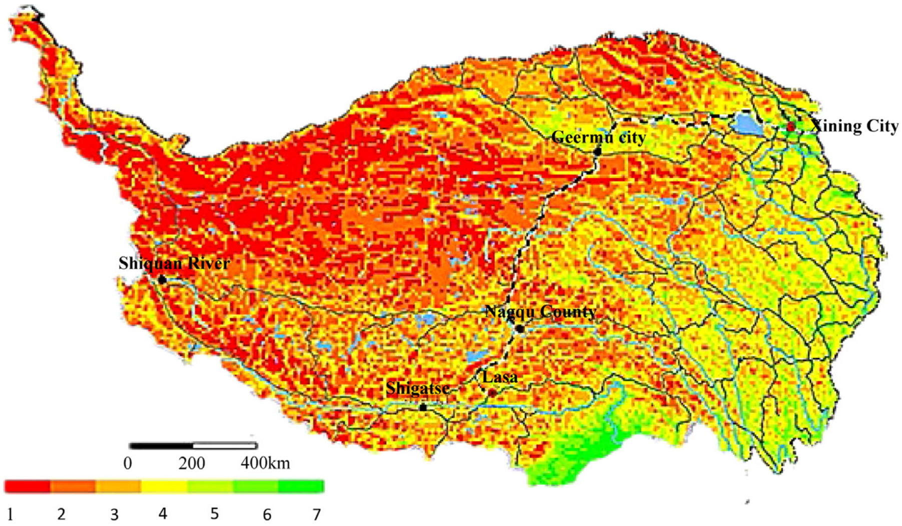


Fig. 7. Evaluation results obtained by the evaluation method in this paper. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Table 4
Comparison of evaluation results.

Ecological evaluation	Results of the evaluation method in this paper		Method results of literature (Edegbene et al., 2019)	
	Number of units	Area ratio	Number of units	Area ratio
Range	4923	18.4	4013	15.0
Poor	7285	27.3	4638	17.4
Bad	6710	25.1	5628	21.1
Intermediate	4381	16.4	5681	21.3
Good	2116	7.9	4344	16.3
Preferably	931	3.5	1475	5.5
Excellent	351	1.3	918	3.4

and lots of Alpine Grassland on the mountain front. These natural conditions form a widely distributed land suitable for animal husbandry Forest and animal husbandry land accounts for 2.87% of the plateau area; The suitable forest land is mainly distributed in the eastern edge and southeast of the plateau, such as the tropical evergreen broad-leaved forest zone in Southeast Tibet and the coniferous forest zone in the mountains and valleys in East Sichuan and Tibet. The suitable forest land accounts for about 6.32% of the total area. The suitable grazing land is the most widely distributed land type in the study area. Except for the Southeast Tibet and the Qaidam Basin, it is widely and continuously distributed, accounting for about 66.74% of the total area; Land that is not suitable for agriculture, forestry and animal husbandry temporarily, including Alpine desert land and soil with high salinity, are distributed in Qaidam Basin and northwest of Qiangtang plateau.

3.2.4. Comprehensive evaluation results

On the basis of the above, the comprehensive assessment results of ecosystem health in the pastoral areas of the Qinghai–Tibet Plateau are as Fig. 7:

The different colors in the legend above represent different overall levels of ecological environment. 1. 2, 3, 4, 5, 6 and 7 respectively correspond to very poor, poor, poor, medium, good, good and very good. Based on the multi model comprehensive evaluation method of ecosystem health in pastoral areas of Qinghai–Tibet Plateau designed in this paper and the establishment method of multi-scale index of macro invertebrates for ecological evaluation of rivers in central and northern Nigeria in reference (Edegbene et al., 2019), the evaluation results are analyzed and compared. The results are shown in Table 4

It can be seen from the above table that there will be some deviation between the two evaluation results. According to the actual situation of the Qinghai–Tibet Plateau, the extremely poor ecological environment is mainly distributed in the western part of the Qiangtang plateau, the western part of the Kunlun Mountains, the KEXILI region, the Karakoram mountains, the Qilian Mountains and the Gangdise mountains, etc. the type of ecosystem is from the desert grassland in the hinterland of the plateau to the northwest, and the extremely poor ecological environment is embodied in cold, extreme drought and lack of oxygen As its main feature. The poor ecological environment accounts for the largest proportion of the total number of ecological environment assessment units, and its distribution is the most extensive.

Except for the eastern part of Qinghai and the western part of Sichuan, there are large areas of distribution, among which the central part of Qiangtang plateau, the northern part, the source area of the Yangtze River and the Yellow River are the most concentrated. The main climate types are cold semi-arid and arid climate, and the ecosystem types are mainly alpine grassland. The number of "poor" eco-environmental units is only inferior to that of poor units, which are mainly distributed in the middle and north of Qaidam Basin, the south of Qiangtang plateau, the Yarlung Zangbo River Basin, and the upper reaches of rivers (Yangtze River, Yellow River and Liancang River). The medium ecological environment quality is mainly distributed in the west of Sichuan, Hengduanshan area, the east of Tibet, the south of Gansu, and the south of Qaidam Basin, with an average elevation of 3500–4000 m. It is dominated by the temperate semi-arid climate type. The main ecosystem types are alpine meadow, alpine grassland and partial temperate grassland. The "good" ecological environment is mainly distributed in the west of Sichuan Province, around the Nieshui Valley in the east of Qinghai Province, in the south of Gansu Province, in the south of Tibet, in the valley area of Hengduan Mountain Area and in the oasis area in the south of Qaidam Basin. The average altitude of these areas is about 3000–3500 m (among which, the altitude of Qaidam Basin is about 2500–3000 m). Except Qaidam Basin, these areas are under the influence of southwest monsoon. The climate type is semi humid and semi-arid, and the main ecosystem types are deciduous broad-leaved forest, coniferous forest, temperate grassland, etc. The areas with "good" and "very good" ecological environment are concentrated in the tropical and subtropical humid mountains in the southeast of the plateau, and in the area of Nieshui valley. The average altitude of this area is between 2500 m. affected by the monsoon, the water and heat are sufficient. The main ecosystem types are the primary tropical and subtropical evergreen broad-leaved forest and the River Valley agricultural area of Nieshui valley with sufficient water sources. In conclusion, it can be concluded that the results of the evaluation method designed in this paper are closer to the real situation.

4. Conclusion

Based on multi-model technology, combined with the actual situation in Tibet, this paper studied the ecological environment quality of the Qinghai–Tibet plateau region with the help of ENVI, ArcGis, SPSS and other software, and obtained the following results:

A. In this paper, remote sensing technology is applied to effectively monitor the ecological environment in Tibet, which can significantly improve the accuracy of ecological evaluation and enhance the accuracy of evaluation results.

B. Based on remote sensing technology and various models, the density of fault structure, annual average temperature and vegetation coverage of the Qinghai–Tibet Plateau are comprehensively analyzed, and a comprehensive and reliable evaluation result is obtained. That is to say, the climate type is semi humid and semi-arid, and the main ecosystem types are deciduous broad-leaved forest, coniferous forest, temperate grassland, etc. the areas with "good" and "very good" ecological environment are concentrated in the tropical and subtropical humid mountainous areas and muddy river valley areas in the southeast of the plateau.

In the future, how to collect more diversified index data while reducing human interference is worthy of further exploration in future ecological research.

CRediT authorship contribution statement

Ruxia Shi: Methodology, Software, Data curation, Writing - review & editing. **Qinyi Jia:** Methodology, Validation, Writing - review & editing, Validation. **Fenzi Wei:** Writing - review & editing, Validation. **Guozhen Du:** Conceptualization, Methodology, Software, Data curation, Writing - original draft, Writing - review & editing, Validation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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