Geological environment evaluation of river valley slope projects based on remote sensing technology

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Abstract: The method to evaluate the geological environment of river valley slope projects has a small precision in determining the weight of geological environment evaluation index, which leads to a large error between the results of geological environment evaluation and the actual value of river valley slope projects. Therefore, the reverse research of the geological environment evaluation of river valley slope projects based on remote sensing technology is proposed. Remote sensing technology is used to build the projects' geological environment evaluation framework of river valley slope, on this basis, the Delphi method is used to preliminarily determine the geological environment evaluation index, the cluster analysis is used to screen the evaluation index, the evaluation system of projects' geological environment is constructed, the AHP method is used to calculate the evaluation index weight, and the corresponding remote sensing image number is obtained according to the projects' geological environment evaluation system. According to the data, the

corresponding software is used to preprocess it, and the remote sensing data of projects' geological environment is obtained. The grey evaluation method is constructed based on AHP to realize the evaluation of geological environment of river valley slope projects. The experimental results show that compared with the existing methods, the evaluation error of the proposed method is smaller, which fully proves that the application performance of the proposed method is better.

Keywords: Remote sensing technology; River valley slope engineering; Geological environment; Evaluation; Evaluation index;
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1. Introduction

River is the birthplace of human civilization and the basis of human survival and development. Rivers play a leading role in social development and economic construction. Under normal circumstances, regional economic development along rivers is better. In addition to the basic flood control and drainage functions, the river also carries many functions, such as improving water quality, stabilizing climate, water supply and so on. However, in the process of river upgrading, human beings pay more attention to the benefits of river for economic development, ignore the balance of river ecosystem, and implement large-scale interference. In the early stage, the river revetment mainly adopted hardening, channelization and other methods, which led to the disappearance of the original river, resulting in "Two or three sides of light" river revetment, which greatly damaged the organisms in the water land interface zone, reduced the living space of animals and plants, and also reduced the self-purification capacity of river water. Therefore, the implementation of river valley slope project is put on the agenda [1].

In river valley slope engineering, there will be some physical and geological phenomena, mainly including: landslides, collapses, rock heaps and other surface deformation under the action of gravity. They are the result of spatial displacement of surface materials, leaving traces of displacement on the surface. Therefore, we can infer the process and characteristics of the surface material's spatial displacement according to the displacement traces reflected in the remote sensing images. The most direct interpretation marks of physical geological phenomena are morphological marks and tonal marks, the most important of which is morphological marks. In addition, lithological characteristics, hydrogeological conditions, vegetation distribution and human activities can provide clues for interpretation of physical and geological phenomena. Geological structures, especially active structures, are often the direct cause of disastrous physical geological phenomena. They are often concentrated along the edge of fault structural belt and structural uplift belt. The physical and geological phenomena in these river valley slope projects have a certain impact on the river and the surrounding geological environment [2].

Geological environment is a part of human natural environment, which refers to the sum of geological bodies and geological processes that interact with human life and production activities. It is a dynamic system, which, together with water environment, atmospheric environment, ecological environment and other systems, constitutes a natural environment system that affects human survival and development. Geological environment evaluation is an important part of environmental evaluation. In a broad sense, it is to evaluate and analyze the conditions, structure, state, quality and function of geological environment, to predict the possible change trend under the influence of natural conditions and human activities, and to qualitatively or quantitatively evaluate the coordination between geological environment and social and economic development activities [3].

As far as the existing research results are concerned, due to the low accuracy of the weight determination of the geological environment evaluation index, the error between the evaluation result and the actual value of the geological environment evaluation method for river valley slope projects is large, which can not meet the needs of the current projects' geological environment research and restoration. Therefore, the paper puts forward the geological environment evaluation method of river valley slope projects based on remote sensing technology. Remote sensing technology refers to the use of visible light, infrared, microwave and other electromagnetic wave detection instruments to scan, photograph and sense information from remote sensing platform and outer space, and transmit the acquired information to the ground, so as to study the shape, size and position of objects on the ground. Remote sensing image is the real reflection of various landscape elements and their correlation of in situ objects, and it is the basis of a series of thematic mapping. According to the image characteristics and distribution rules of various ground objects on remote sensing images, the process of making the judgment of the nature and quantity of the ground object and studying its development rules is called image interpretation. The image is interpreted, the interpretation results are converted into digital information according to different utilization status, and the corresponding information database is established. In a word, the rapid development and application characteristics of remote sensing technology provide good technical support and evaluation ideas for the geological environment evaluation of complex structural areas in China. We hope to improve the existing problems through the application of remote sensing technology.

2. Study on projects' geological environment evaluation method of river valley slope

2.1 Construction of projects' geological environment evaluation framework for river valley slope

The basic idea and technical route of using remote sensing technology to evaluate geological environment of river valley slope projects are as follows:

Based on the geological survey on the geological environment of river valley slope projects, the main evaluation objectives and corresponding evaluation index system are established. The remote sensing image data (multi band TM data) of the evaluation area are selected, and the remote sensing image is visually interpreted and computer-aided interpreted by using appropriate remote sensing technology to extract the special information of geological environment of river valley slope projects (image loop information). The corresponding geological units are concluded by using remote sensing geoscience analysis method. Based on the interpretation results and field investigation verification, the current situation of geological environment of river valley slope projects and the prediction and evaluation of geological environment on this basis are given [4].

In conclusion, the geological environment evaluation framework of river valley slope projects based on remote sensing technology is shown in Figure 1.

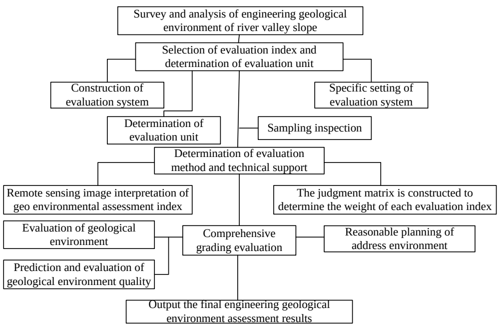

Figure 1 Framework of geological environment evaluation for river valley slope projects

2.2 Construction of projects' geological environment evaluation system

Based on the above-mentioned geological environment evaluation framework of river valley slope projects, the Delphi method is used to preliminarily determine the geological environment evaluation index, the cluster analysis is used to screen the evaluation index, and finally the projects' geological environment evaluation system is constructed. The specific process is as follows:

Delphi method was put forward in 1946 by US Rand Corporation and Douglas Corporation, also known as expert prescribed procedure investigation method. This method can be used to predict and evaluate, and is widely used in various fields. The essence of this method is a kind of feedback anonymous correspondence method, consulting experts and scholars in related fields in written form, and then sorting out, summarizing and summarizing everyone's views on the problem. In this way, several rounds of consultation are conducted to make everyone's opinions gradually converge, and the collective opinions of experts sorted out are taken as the evaluation index [5].

Referring to Likert's five subscale method, the preliminary comprehensive environmental indexes are listed into a scale to consult the experts' attitude and views on the rationality of the indexes. Five fuzzy evaluation languages, namely "Greater impact", "Great impact", "General impact", "Little impact" and "less impact", are used as the scoring criteria.

Clustering analysis is a method to classify the interested objects according to the characteristics, so that the individuals in each category have homogeneity as much as possible, and the heterogeneity between different categories is higher as much as possible. In this study, according to the experts' scoring of various influencing factors, cluster analysis is carried out to screen out the factors with lower influence. In this study, the cluster analysis [6] is carried out through the evaluation matrix composed of expert scoring.

The principle is to assume that $A_1, A_2, A_3, \ldots, A_n$ denotes n classes, the distance between i and j in the matrix is denoted by d_{ij}, and the distance D_{pq} between A_p and A_p is the minimum value of d_{ij}. The distance between each two samples is calculated by d_{ij}, and the symmetric matrix of sample distance is obtained, which is denoted as $D_{(0)}\left(D_{pq} = d_{pq}\right)$. The minimum value of symmetric matrix of sample distance is set as D_{pq}, and A_p and A_q are combined as A_c, and the distance between A_c and other classes is obtained by the following formula:

$$D_{ck} = \min d_{ij}\left(i \in A_p, j \in A_k\right) = \min\left\{\min d_{ij}\left(i \in A_p, j \in A_k\right), \min d_{ij}\left(i \in A_q, j \in A_k\right)\right\} \tag{1}$$

The rows p, q and columns p, q in $D_{(0)}$ are replaced with D_{ck} to obtain a new distance symmetric matrix $D_{(1)}$; then according to the above calculation method, it is calculated repeatedly until these classes are classified into one class [7].

Taking the preliminary division of indexes as an example, through the theoretical analysis method of literature review and collection of relevant data, the preliminary selected indexes include geological conditions, geomorphic conditions, engineering conditions, hydrological conditions, human conditions, economic conditions, infrastructure conditions and surface landscape, and experts are selected to score.

IBM SPSS Statistics 22 is used to analyze and process the results of expert scoring. In IBM SPSS Statistics 22, the system clustering method is used, and the closeness between different types is expressed by the class spacing. After complex clustering calculation, the pedigree diagram is obtained. In the pedigree diagram, we can clearly find that in the range of "0-25", the "Human conditions" and "Economic conditions" are obviously different from the other six influencing factors. If the scale "15" is taken as the boundary, the influencing factors can be divided into two categories, namely "The factors that have a greater impact on the geological environment parameters of river valley slope projects" and "The factors that have a smaller impact on the geological environment parameters of river valley slop projects". After two rounds of consultation with experts, it has screened out the two factors of "Human conditions" and "Economic conditions", and got the first level of the index system [8]. Using the above methods, through repeated consultation, cluster analysis and screening, the geological environment evaluation system of river valley slope projects is finally determined, as shown in Table 1.

Table 1 Projects' geological environment evaluation system of river valley slope

Evaluation category	First level indexes	Secondary indexes
Geological conditions	Natural building materials	Material distribution map
	Fault structure index	Tectonic density index
Geomorphic conditions	Geomorphic type index	Distribution of geomorphic types
	Visual analysis index	Visual analysis
	Soil and water loss index	relief amplitude
Engineering conditions	Engineering geotechnical index	Rock hardness
		Soil index
	Geological hazard index	Types of disasters
		Disaster density
Hydrologic condition	River width index	Automatic extraction of river sheet
	Groundwater enrichment index	Distribution of water bearing rocks
Infrastructure conditions	Infrastructure indexes	Highway density network
		Railway density network
Surface landscape conditions	Land use index	Types of land use
	Vegetation coverage index	Normalized vegetation index

2.3 Weight calculation of projects' geological environment evaluation index

Based on the above-mentioned evaluation system of geological environment of river valley slope projects, AHP is used to calculate the weight of evaluation index, so as to prepare for the subsequent evaluation of geological environment of river valley slope projects.

Referring to the analysis results of Delphi method and cluster analysis method, the influence of the lower elements on the upper elements is judged, and the elements in this layer are compared. In order to quantify the judgment, it is necessary to accurately describe the importance of the two elements to the upper elements. The 1 ~ 9 scale method is used as the standard to establish the order comparison judgment matrix of the evaluation index [9]. 1 ~ 9 scale method and comparison judgment matrix are shown in Table 2.

Table 2 Table of 1 ~ 9 scale method and comparison of judgment matrix

(1) 1 ~ 9 scale method

Scale value	Meaning of value	Scale value	Meaning of value
$A_{ij}=1$	Element i and element j have the same importance to the upper	$A_{ij}=9$	Element i and element j are very important to the upper elements

	elements		
$A_{ij}=3$	Element i and element j are slightly important to the upper elements	$A_{ij}=1/A_{ij}$	The importance of element i to element j is the reciprocal of element to element
$A_{ij}=5$	Element i and element j are importance to upper elements	$A_{ij}=2n$, $n=1,2,3,4$	The importance of element i to element j is between $A_{ij}=2n-1$ and $A_{ij}=2n+1$
$A_{ij}=7$	Element i and element j are much more important to the upper elements		

(2) Comparison of judgment matrix

A	A_1	A_2	A_3	$\cdots$	A_n
A_1	A_{11}	A_{12}	A_{13}	$\cdots$	A_{1n}
A_2	A_{21}	A_{22}	A_{23}	$\cdots$	A_{2n}
A_3	A_{31}	A_{32}	A_{33}	$\cdots$	A_{3n}
$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$
A_n	A_{n1}	A_{n2}	A_{n3}	$\cdots$	A_{nn}

Each behavior is as example to compare. Firstly, the relationship between A_1 and A_2, A_3 … A_n is compared, then the relationship between A_2 and $A_3 \cdots A_n$ is compared, and so on, until the last line of the matrix is obtained. The diagonal of the matrix is A_{nn}, that is, the elements are compared with themselves, so A_{nn} is all 1. It just needs to complete the part above the diagonal, and the value below the diagonal is the reciprocal of the corresponding relationship above the diagonal. According to the number of upper elements, the corresponding number comparison judgment matrix is constructed to calculate the weight of the lower elements belonging to each upper element.

After completing the construction of the index comparison judgment matrix, it is necessary to calculate the weight of each index by calculating the characteristic vector of the index comparison judgment matrix A. At the same time, in order to verify the rationality of the judgment matrix and prevent the logical disorder of "A is more important than B, B is more important than C, but C is more important than A", consistency test is needed. In AHP, the consistency of thinking judgment is very important. In the judgment matrix, $A_{ij}=1/A_{ij}$ > 0, $A_{ii}=1$, is a positive reciprocal matrix. When $A_{ij}A_{jk}=A_{ik}$, it is a consistency matrix. If A_{ij} of the judgment matrix accords with the above relation, then it has complete consistency.

The weight of the first level evaluation index of geological environment in river valley slope projects is determined as shown in Table 3.

Table 3 Weight table of the first level evaluation index for geological environment of river valley slope projects

Index	Geological conditions	Geomorphic conditions	Engineering conditions	Hydrologic condition	Infrastructure conditions	Surface landscape conditions	W
Geological conditions	1.000	3.000	1.000	3.000	1.000	3.000	0.253
Geomorphic conditions	0.333	1.000	0.333	3.000	0.333	1.000	0.101
Engineering conditions	1.000	3.000	1.000	3.000	0.500	0.333	0.156
hydrologic condition	0.333	0.333	0.333	1.000	0.333	0.333	0.056
Infrastructure conditions	1.000	3.000	2.000	3.000	1.000	3.000	0.284
Surface landscape conditions	0.333	1.000	3.000	3.000	0.333	1.000	0.146

2.4 Remote sensing image data processing of projects' geological environment

According to the evaluation system of projects' geological environment, the corresponding remote sensing image data is obtained, and the corresponding software is used to preprocess it, so as to facilitate the subsequent acquisition of remote sensing data of projects' geological environment [10].

ERDAS USAImage8.6 remote sensing image processing software of ERDAS Company is using to preprocess and compile remote sensing geological image map of river valley slope projects. Its working method is to use remote sensing technology to carry out image synthesis and geometric correction by computer. Through image processing technologies such as data conversion, superposition and mosaic graphics, the amount of remote sensing information is enhanced, the interpretation accuracy is improved, and each marker layer is established. Then there is the field verification work, that is, to record the individual points with poor exposure conditions, low interpretation level and high degree of interpretation, but in doubt, to carry out field inspection and confirmatory investigation [11]. Finally, the raster image, vector layer and annotation layer are established by using the thematic mapping editor of the software to form an intuitive and realistic image. The specific pretreatment process is as follows:

(1) Radiometric correction

There are two main reasons for radiation distortion: radiation distortion caused by atmosphere and radiation distortion caused by sensor. Atmospheric factors affecting satellite image data include atmospheric radiation and atmospheric spectral transmittance. Atmospheric emissivity is the scattering of incident radiation by the atmosphere, which makes part of the scattered light enter the sensor and changes the radiation intensity of ground objects. The method of atmospheric radiation correction is to subtract the atmospheric radiation value from the value of each pixel. No correction is needed. When the atmosphere is uniform, the atmospheric radiation value is constant. The TM image data of three different time phases selected in this study have been preliminarily processed by the data providing department, so the atmospheric radiation correction has not been carried out on the images used in this study.

The radiation distortion caused by the instrument is mainly due to the fact that in the satellite sensor, there are often multiple detectors working at the same time in a band to receive signals from different regions. When there is no radiation into the detector, there should be no signal, but actually there is a weak signal, so that the linear relationship generates an intercept on the signal axis, and the intercept of each detector is different. The difference in the performance of the detector leads to the non-uniformity of the received image and the generation of fringes. The radiation distortion produced by the instrument itself has been corrected by the data processing center before the product reaches the user [12].

(2) Geometric correction

Remote sensing images need geometric correction to process layer, data and spatial analysis. People often use Ortho photo topographic maps. Therefore, the distortion of various remote sensing images is needed to correct based on topographic maps. The geometric correction steps are as follows:

Step 1: select control points: control points with the same name on remote sensing image and topographic map are selected to establish the projection relationship between image and map. In the calibration, the ground control points are used to project the control points from the geographical space to the image space through the coordinate transformation function. The accuracy of geometric correction directly depends on the accuracy, distribution and number of ground control points.

There are 10 geometric correction ground control points in this study, which are evenly distributed in the image, and are obvious and accurate positioning and recognition marks on the image, which not only ensures the accuracy of spatial registration, but also has a certain amount of guarantee. After the ground control points are selected, different correction operators and interpolation methods are selected for calculation. At the same time, the error analysis of ground control points is carried out to make its accuracy meet the requirements. Finally, the corrected image is compared with the topographic map to investigate the correction effect;

Step 2: establish the global mapping function: the correction mathematical model is determined according to the geometric distortion of the image and the number of ground control points, to establish the spatial transformation relationship between the image and the map, such as polynomial method, affine transformation method, etc.;

Step 3: resampling interpolation: in order to make the corrected output image pixels correspond to the input uncorrected image, the input image data is rearranged according to the determined correction formula. In resampling, because the coordinates of the corresponding position calculated are not integer values, the new pixel values must be obtained by interpolating the surrounding pixel values.

(3) Image enhancement and transformation processing

Equal density segmentation processing of pseudo color: black-and-white remote sensing images represent the morphological attributes and distribution characteristics of ground objects with different shades of black and white hues. On the photosensitive material, the depth of black and white tone is different in density. For the corresponding digital image, the density value of the image is converted into the brightness value of the corresponding pixel. Therefore, the change of remote sensing image's brightness value is divided into several levels according to a certain order of magnitude, and each level is represented by a color to generate a color image, which is called equal density segmentation image of pseudo color. Because the black-and-white color change in the image is converted into color display, the display quality of the image is improved, so it is more convenient for interpretation and information extraction.

The equal density segmentation process of pseudo color is as follows

1) The image is input into the computer and stored in the memory;

2) The brightness value of each pixel in the image is counted to generate the display histogram. The distribution range of brightness value is determined, and the minimum and maximum values are recorded as $I_{\min}$ and $I_{\max}$ respectively;

3) the level number of segmentation N is determined to calculate the segmentation interval ΔI, namely $\Delta I = \frac{I_{\max} - I_{\min}}{N}$;

4) The brightness value of each pixel in the input image is converted. If the pixel brightness value is $S(i, j)$, it is judged and converted according to the following formula:

If $I_{\min} < S(i, j) \le I_{\min} + \Delta I$, then $S(i, j) = 0$;

If $I_{\min} + \Delta I < S(i,j) \le I_{\min} + 2\Delta I$, then $S(i,j) = 1$;

If $I_{\min} + (N-1)\Delta I < S(i,j) \le I_{\min} + N\Delta I$, then $S(i,j) = N$.

All pixels of the image are converted, and the original brightness value is replaced by the converted new value;

5) The new pixel value is colored. For example, the pixel with the value of 0 is assigned to dark gray, that is: 0 → dark gray, 1 → blue, 2 → light blue, etc. The color pixel "dot matrix" of the pixel is output in turn, to form the equal density segmentation map OF pseudo color.

Due to the limitation of space, other preprocessing processes will not be described in detail.

2.5 Remote sensing data acquisition of projects' geological environment

There are two kinds of methods for remote sensing information extraction of projects' geological environment: one is visual interpretation, AND the other is computer information extraction. In the process of interpretation, the combination of the two is better [13].

The geological environment interpretation mark of image is the image feature that can directly reflect and distinguish geological information in remote sensing image, including shape, size, shadow, hue, color, texture, pattern, location, and layout. Some of the marks can be used to directly identify the nature, type and status of geological bodies or phenomena in the image; or through the identified geological bodies or phenomena, the reasoning analysis of their mutual relations can be carried out to further clarify other objects that are not easy to interpret directly in the remote sensing image.

Shape: refers to the special shape of the target in the image. What can be seen in the remote sensing image is the top or plane shape of the target. The shape of geological structure in the image is the clearest, which is also the main basis of our remote sensing interpretation of geological body.

Size: refers to the size of the shape, area or volume of the terrain on the image.

Shadow: refers to the shadow of geological body on the image due to blocking direct sunlight. The shadow part is mainly the shadow of the higher mountains blocking the river system and valley.

Hue: the depth of black and white in an image. Hue is represented by gray scale recovery, and the same object will have great difference in different band images.

Color: refers to the color and color scale on the color image. The color of the true color image is consistent with the natural color. According to the need, some features can be highlighted, which is more convenient to identify specific targets.

Texture: also known as image structure, it refers to the thickness of the smooth or rough texture matched with the hue, that is, the texture of the target surface on the image.

Pattern: the pattern formed by the regular combination and arrangement of target objects. It can reflect the characteristics of various artificial and natural features, such as ridge of farmland, crown of fruit trees, etc., and various water system types, vegetation types and cultivated land types also have their own unique pattern structure.

Location: refers to the environmental part where the ground objects are located. All kinds of ground objects have specific environmental parts, so it is an important sign to judge the attributes of ground objects.

Layout: it is the spatial configuration between multiple objects. There is a certain interdependence between the ground features and the ground features.

Through the analysis of the close relationship or interdependence between the objects, the existence, attribute and scale of another object can be confirmed from the known objects. This is a method of logical reasoning to judge the object, which has important significance in remote sensing interpretation.

The application steps of visual interpretation in this study are as follows:

Step 1: the first is to understand the auxiliary information of the image: be familiar with the image acquisition platform, remote sensor, imaging method, imaging date, season, area, image scale, spatial resolution, color synthesis scheme, etc., and to understand the degree of interpretation. The data used in this study are remote sensing impact data of 1990 and 2004 TM bands.

Step 2: analysis of known professional data: the most basic method of visual interpretation is from "Known" to "Unknown". The so-called "Known" refers to the existing relevant data or the ground situation mastered by the interpreter, and the corresponding analysis of these ground situation data and images is carried out to confirm the relationship between them. The actual hydrogeology, soil, topography and geological survey data along Dabao highway are important auxiliary information to help interpretation.

Step 3: establishment of interpretation mark: according to the given image features, namely shape, size, shadow, hue, color, texture, pattern, position and layout, the corresponding relationship between the image and the actual lunar target is established.

Step 4: pre interpretation: correlation analysis method is used to interpret the image according to the interpretation mark, draw the type boundary, mark the feature category, and form the pre interpretation map.

Step 5: ground fact finding: in the indoor pre interpretation of the map there are inevitably errors or difficult to determine the type, it needs field investigation and verification.

Step 6: detailed interpretation: according to the field survey results, the errors in the pre interpretation map are corrected, to determine the unknown types, refine the pre interpretation map, and form the formal original interpretation map.

Step 7: type transfer and mapping: the type boundary on the original map is transferred to the geographic base map. According to the needs, it can color various types, decorate the map and form a formal thematic map.

The main purpose of computer information extraction is to classify and process remote sensing images. In this study, supervised classification method is used to classify and process remote sensing images. Supervised classification is a statistical classification method which only based on the spectral information of all kinds of ground objects in the image, according to the Bayesian criterion (the loss of wrong classification is minimum), and no one intervenes. Taking the maximum value in the multi-dimensional space established by multiple feature bands as the class center, the discriminant function is established based on Bayesian criterion to automatically identify and classify. The main points and steps of the method are as follows: A. establish feature space; B. pre classification number > feature band number + 1; C. search the maximum value of multi-dimensional histogram in feature space; D. automatically merge the maximum value according to pre classification number and determine the variance range; E. classify and get preliminary results.

The schematic diagram of remote sensing image classification processing is shown in Figure 2.

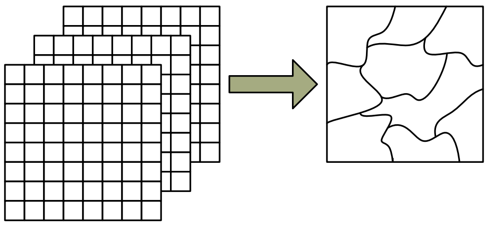

Figure 2 Schematic diagram of remote sensing image classification processing

Through the above process, the extraction of remote sensing information of projects' geological environment is completed, which lays a solid foundation for the final realization of projects' geological environment evaluation.

2.6 Implementation of projects' geological environment evaluation

Based on the above extracted remote sensing information of projects' geological environment, the grey evaluation method is constructed based on AHP to realize the comprehensive geological environment evaluation of river valley slope projects.

Analytic hierarchy process, referred to as AHP, is a decision-making analysis method of hierarchical weight, which divides the factors related to decision-making into target level, criterion level and measure level, and analyzes the problem quantitatively or qualitatively. AHP is suitable for decision-making problems with complicated evaluation factors and difficult quantitative description of evaluation target value. The grey system theory was first put forward by Professor Deng Julong in Sino-US control system academic conference in 1981, Shanghai. The grey system is essentially a system in which part of the information is known and other information is unknown. It is a neutral existence which is different from black and white. It can build a model which can make full use of the least known information for prediction, decision-making, evaluation and other work. Grey evaluation refers to the method that the model contains grey elements or combines grey model with other evaluation models in the evaluation process. This study combines AHP with grey evaluation method, which not only overcomes the shortcomings of grey evaluation method without objective and specific evaluation system, but also solves the scientific weighting method of each evaluation index. The combination of the two methods can evaluate the geological environment of river valley slope projects more effectively [14].

In the grey system theory, the form of whitening weight function is changeable and not fixed, which means to explain the value possibility of grey class with the function form of a segment of trigonal line or S-shaped curve in rectangular coordinate system, and to evaluate the degree of research index belonging to a certain grey class in the research. Whitening weight function is often designed according to researchers' understanding of research problems and existing research conditions. In a single AHP analysis method, the results are often qualitative analysis dominant, subjective influence is difficult to show quantitatively. By introducing the whitening weight function into AHP, the weight given by AHP can be combined with the quantitative analysis of whitening weight function, so that the analysis results are more convincing, and the proportion of each index in the engineering environmental evaluation system in the lower reaches of Tumen River is more scientific [15].

To determine the evaluation grey class in the study is to define the grade number of the evaluation grey class, the grey number of the evaluation grey class and the whitening weight function of the grey number. This requires specific analysis and design according to the specific situation. The commonly used whitening weight function $f_n(x)$ has the following three forms:

(a) The grey number is $\otimes \in [0, d_1, \infty]$, and its whitening weight function is

$$f_1(x) = -\begin{bmatrix} \frac{x}{d_1} & x \in [0, d_1] \\ 1 & x \in [d_1, \infty] \\ 0 & x \in [-\infty, 0] \end{bmatrix} \tag{2}$$

(a) The grey number is $\otimes \in [0, d_1, 2d_1]$, and its whitening weight function is

$$f_2(x) = -\begin{bmatrix} \frac{x}{d_1} & x \in [0, d_1] \\ 2 - \frac{x}{d_1} & x \in [d_1, \infty] \\ 0 & x \notin [0, 2d_1] \end{bmatrix} \tag{3}$$

(a) The grey number is $\otimes \in [0, d_1, d_2]$, and its whitening weight function is

$$f_3(x) = -\begin{bmatrix} 1 & x \in [0, d_1] \\ \frac{d_2 - x}{d_2 - d_1} & x \in [d_1, d_2] \\ 0 & x \notin [0, d_2] \end{bmatrix} \tag{4}$$

According to the projects' geological environment evaluation system and the actual situation, the evaluation criteria are divided into four gray categories: " more suitable, suitable, poor suitability and unsuitable", and given the score 4, 3, 2, 1. e is the number of grey class, and the corresponding values of four grey classes are 1, 2, 3 and 4. The whitening weight function is constructed as follows:

i. If the grey class is "excellent condition", the value of e is 1, grey number is $\otimes_1 \in [4, \infty]$, and whitening weight function is as follows:

$$f_1(d_{ij}) = -\begin{bmatrix} \frac{d_{ij}}{4} & d_{ij} \in [0, 4] \\ 1 & d_{ij} \in [4, \infty] \\ 0 & d_{ij} \notin [0, \infty] \end{bmatrix} \tag{5}$$

II. If the grey class is "good condition", the value of e is 1, the grey number is $\otimes_2 \in [0, 3, 6]$, and the whitening weight function is as follows:

$$f_2\left(d_{ij}\right) = -\begin{bmatrix} \dfrac{d_{ij}}{3} & d_{ij} \in [0,3] \\ \dfrac{6-d_{ij}}{3} & d_{ij} \in [3,6] \\ 0 & d_{ij} \notin [0,6] \end{bmatrix} \tag{6}$$

Due to the limitation of space, the whitening weight functions of "poor condition" and "extremely poor condition" are not shown, and they are recorded as $f_3\left(d_{ij}\right)$ and $f_4\left(d_{ij}\right)$.

The results of geological environment evaluation of river valley slope projects can be obtained by multiplying and superimposing the whiteness weight function, evaluation index value and weight, which can provide more accurate data support for projects' geological environment exploration and governance of river valley slope, and also provide suggestions for upgrading of river valley slope projects.

3. Experiment and result analysis

In order to verify the application performance difference between the proposed method and the existing methods, the experiment is designed by using MATLAB software

3.1 Selection of subjects

In this study, a river valley slope project is selected as the experimental object, and its construction area is the experimental area. The specific location is shown in Figure 3.

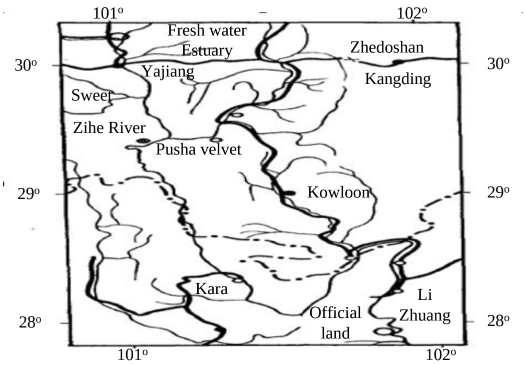

Fig. 3 Location of experimental area

On the valley slopes of both banks of the experimental object, a total of 235 physical and geological phenomena are identified, of which landslide accounts for 19.6%; collapse (including steep bank collapse) accounts for 45.1%; rock heap accounts for 35.3%, as shown in Table 4.

Table 4 Physical and geological phenomena of experimental objects

Shore	Left bank	Right bank	Total
Landslide	23	23	46
Collapse	49	57	106
Rock heap	40	43	83
Cumulative	112	123	235
Frequency	0.22	0.24	0.46

For the geological environment evaluation of valley slope projects, it is of great significance to analyze the length of physical geological phenomena in valley slope per unit length. Here, the distribution along the valley is called the length distribution of physical geological phenomena. It is a comprehensive index to measure the stability of river valley slope. The cumulative length data of physical and geological phenomena in the experimental area are shown in Table 5.

Table 5 Cumulative length of physical and geological phenomena in experimental area

Shore	Left bank	Right bank	Total

Landslide	17.05	15.60	32.65
Collapse	29.40	27.75	57.15
Rock heap	15.15	15.17	30.32
Cumulative	61.60	58.52	120.12

Note: the unit is km

3.2 Determination of secondary evaluation index weight

The determination of secondary evaluation index weight is the key to realize the geological environment evaluation of river valley slope projects, so it needs to be determined before the experiment, so as to ensure the smooth progress of the experiment.

The weight of secondary evaluation index is shown in Table 6.

Table 6 Weight table of secondary evaluation index

First level indexes	Secondary indexes	Weight
Natural building materials	Material distribution map	0.250
Fault structure index	Tectonic density index	0.750
Geomorphic type index	Distribution of geomorphic types	0.429
Visual analysis index	Visual analysis	0.143
Soil and water loss index	relief amplitude	0.429
Engineering geotechnical index	Rock hardness	0.750
	Soil index	0.250
Geological hazard index	Types of disasters	0.250
	Disaster density	0.750
River width index	Automatic extraction of river sheet	0.750
Groundwater enrichment index	Distribution of water bearing rocks	0.250
Infrastructure indexes	Highway density network	0.250
	Railway density network	0.750
Land use index	Types of land use	0.750
Vegetation coverage index	Normalized vegetation index	0.250

3.3 Analysis of experimental results

According to the selected experimental object and the determined secondary evaluation index weight, the geological environment evaluation experiment of river valley slope projects is carried out. In order to objectively show the application performance of the method, the actual evaluation values of geological environment of river valley slope projects under different working conditions are given. On this basis, the existing method and the proposed method are used to evaluate the geological environment, and compared with the actual evaluation value, and the results are compared with the actual evaluation values. The performance of the method is shown by the difference between the two, and the analysis process of specific experimental results is as follows:

The experimental data under two working conditions are obtained through experiments, as shown in Table 7.

Table 7 Experimental data under two

working conditions

(1) Evaluation error data sheet of condition 1

Number of experiments	Existing methods	Proposed method
1	4.56%	2.01%
2	6.23%	2.03%
3	4.01%	1.01%
4	4.23%	1.89%
5	4.15%	0.20%
6	4.10%	0.18%
7	4.58%	2.54%
8	4.12%	1.45%
9	5.56%	1%
10	5.89%	0.98%

(2) Data sheet of evaluation error for condition 2

Number of experiments	Existing methods	Proposed method
1	5.89%	0.21%
2	6.01%	1.56%
3	5.12%	0.48%
4	5%	1.74%
5	5.12%	0.51%
6	4.23%	1.23%
7	6.89%	1.20%
8	7.01%	1.01%
9	6.45%	1.04%
10	5.48%	0.98%

As shown in Table 7, under condition 1, the error range of the existing method to evaluate the geological environment evaluation of river valley slope projects is 4.01% - 6.23%, and that of the error range of the proposed method is 0.18% - 2.54%; under condition 2, the error range of the existing method is 5.00% - 7.01%, and the error range of the proposed method is 0.21% - 1.74%.

Through the comparison of the above experimental results, compared with the existing methods, the error of the proposed method is lower, which fully proves that the application performance of the proposed method is better.

4. Discussion

In this study, remote sensing technology is used to comprehensively evaluate the geological environment of river valley slope projects, and a systematic evaluation system is constructed. The improved grey evaluation method based on analytic hierarchy process is substituted into the evaluation system, and good results are achieved. This method can not only make use of the macro and comprehensive characteristics of remote sensing technology, but also absorb the powerful spatial analysis, data management analysis and visualization functions of GIS. Compared with the method of detailed field investigation and evaluation, it can save cost and is convenient and fast, and also can provide early reference planning for it. The main results are as follows

(1) The projects' geological environment is affected by multiple factors. The combination of Delphi method and cluster analysis method can well construct the first-class indexes from the aspects of geological conditions, geomorphic conditions, engineering conditions, hydrological conditions, infrastructure conditions and landscape conditions, and then further determine the evaluation index factors at all levels. The weight of each index can be determined scientifically by using the analytic hierarchy process, in order to build the evaluation system and method of projects' geological environment based on remote sensing and geographic information system, and finally to realize the projects' geological environment evaluation by using spatial layer operation and gray evaluation technology.

This is a set of complete and operable projects' geological environment evaluation technology system, and has been applied in the experimental object with good effect.

(2) The projects' geological environment evaluation system constructed in this study can be extended from the study area to other similar areas, in which the weight allocation and index quantitative classification standards are not unique, and can be modified independently according to the actual situation or the change of demand, which provides an effective reference for the local engineering environmental evaluation.

This study has successfully constructed the projects' geological environment evaluation system of the lower reaches of Tumen River and achieved good results, but there are still some problems and aspects need to be improved in the research process

(1) The extraction process of each index factor mainly uses man-machine interactive interpretation as the main means. Due to the lack of resolution of satellite images and their own experience and knowledge, it is inevitable that there will be interpretation errors in the extraction process of an evaluation factor, which will reduce the evaluation quality of the system and affect the accuracy of the evaluation results.

(2) Due to the limited data obtained by remote sensing, there is no detailed exploration data to support, the accuracy of thematic map for each index factor is lower than that obtained by detailed field exploration, and the regional division and classification are more macroscopic, which leads to the low quality of data at the input end of the system, but basically meets the needs of research. In addition, limited to the level of professional knowledge, some problems related to other professional engineering construction are not fully considered, but it can provide data reference for remote sensing professional.

(3) In the application process of the improved grey evaluation based on AHP, the quantitative standard and quantitative grading standard of the evaluation index are only preliminary division and evaluation, and there is still a lot of room for improvement in the method. And whether the engineering evaluation system in this paper is suitable for other regions remains to be explored. If it is applied to the engineering evaluation in other regions, the evaluation index factors and the corresponding weight distribution in the system also need to be modified.

(4) In the process of research, the field exploration work is less, and only a rough survey has been carried out on the stratum lithology, natural building materials, geological disasters, infrastructure conditions and other aspects in the study area. Because of the lack of professional geophysical exploration methods for individual index factor extraction, the accuracy of the results may be reduced. In the future, we should strengthen the work quality and methods of field investigation verification, improve the extraction accuracy of evaluation index factors, so as to improve the reference of projects' geological environment evaluation results.

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