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Research Article

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Studies on the risk evaluation of landslide geological disaster in Wulong County

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ABSTRACT

The risk evaluation of Regional landslide geological disaster is based on collection, analysis and processing the landslide geological disasters and the relationship between influencing factors , using GIS platform and technology, build appropriate mathematical evaluation model, calculate the degree of risk of each evaluation unit, and then divided into corresponding level of risk, and analysis of regional geological disasters risk zoning.[]This article assumed that the study area is a certain hierarchy and uncertain system. The hierarchical analysis model is adopted to establish the impact factor of evaluation index system, on the weight of each influence factor of landslide risk quantitative analysis, Also, through the overlay analysis function of GIS for landslide risk evaluation and zoning for qualitative analysis.

Key words: wulong, landslide geological disaster, risk evaluation

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INTRODUCTION

Purpose of the risk evaluation of landslide geological disaster is based on thorough investigation and study ,through the analysis and research to determine the density, strength and landslide occurrence probability and may cause injury zone of the location, range, and the damage degree rank, provide the foundation for the further evaluation of disaster losses and preparing for disaster risk assessment[1-2]. The risk evaluation of landslide geological disaster is the main meaning for the government and the geological disaster management department in terms of preventing disaster and disaster mitigation provides reference for decision-making, so as to promote the sustainable development of local economy and social stability. The occurrence of landslide geological disasters mainly controlled by two aspects reasons: internal cause and external cause. Internal cause mainly refers to the landform, geologic structure, influencing factors of stratum lithology, such as external cause refers to the earthquake, the influence of the rainfall and human engineering activities. Because of the influence factors are fuzzy and uncertainty, and the complexity of the interaction between all the factors may also exist, therefore, brings certain difficulty to the risk evaluation of landslide research. Selecting the appropriate mathematical model is the key to the risk evaluation of regional geological disaster and regionalization, Has a large number of scholars use different mathematical model in the study of the risk evaluation of regional geological disaster and regionalization, Such as analytic hierarchy process (ahp), the amount of information law, unit cluster analysis, discriminant analysis method, fuzzy comprehensive evaluation method and the neural network model, etc. In this study, because of the special location of the study area, the scope is larger, and the research belongs to the typical karst landform, lead to geological disasters risk zoning more influencing factors. Therefore, this article assumed that the study area is a certain hierarchy and uncertain system. The hierarchical analysis model is adopted to establish the impact factor of evaluation index system, on the weight of each influence factor of landslide risk quantitative analysis, Also, through the overlay analysis function of GIS for landslide risk evaluation and zoning for qualitative analysis.

EXPERIMENTAL SECTION

This research adopts AHP (Analytic Hierarchy Process) to establish the model of the risk evaluation of landslide. This method is proposed by satie, a professor at university of Pittsburgh, used to solve hierarchical weighted decision analysis. Based on the nature of the complex problems, influence factors and its inner link analysis, establish to difficult to quantitatively express the complex system decision-making model and method. This method is suitable for complex decision problem to make decisions but lack of quantitative information. The risk evaluation of Landslide is a complex decision problem, participate in the evaluation of the impact factor is difficult to quantitative expression, so the analytic hierarchy process (ahp) was applied to the risk evaluation of Landslide can overcome the problem of objective existence, achieved good results[3].

Basic steps of Analytic Hierarchy Process

(1)To ask questions and to clear up problems include the relationship between the factors and factors;

(2) Set up the structure of the recursive order hierarchy model;

Problem in the first place hierarchical, a hierarchical structure model is constructed. In this model, the research problem is broken into three levels, on a level of elements as a criterion to the next level related elements dominate role, these levels are generally divided into the following three categories: 1) at the top: the purpose of making a decision or to solve the problem, also known as the target layer; 2) the middle tier: also known as the criterion layer and contains a number of involved to achieve the goal of the intermediate links, including those of needed to consider, the son; 3) bottom: including the measures for the realization of the target selection, decision scheme, etc., and index layer or solution.

(3) To construct judgment matrix

To construct judgment matrix is a key link in the process of AHP analytic hierarchy model. the elements of judgement matrix value reflects the relative importance of various factors, These judgments are expressed by the introduction of appropriate scale numerical representation. Judgment matrix is said a layer of all factors relative to the comparison of the relative importance of up a layer factors.

Suppose $U=\{C_1, C_2, \cdots, C_n\}$, to compare the influence of some factors U size. To provide more reliable data, we can take the factor compare two established paired comparison matrix method[4].Where each takes two factors C_i and C_j, the ratio of the size effect on U is expressed by a_{ij}, all the comparison results with matrix $A=(a_{ij})_{n\times n}$ said, call A judgment matrix between U and C (table1).

Table 1 The influence factors of judgement matrix

A	C_1	C_2	……	C_n
C_1	a_{11}	a_{12}	……	a_{1n}
C_2	a_{21}	a_{22}	……	a_{2n}
……	……	……	……	……
C_n	a_{31}	a_{32}	……	a_{nn}

Easy to see, if the ratio of the C_i and C_j 's influence on U is a_{ij} ,then the ratio of the C_j and C_i 's influence on U is $1/a_{ij}$. On how to determine the value of a_{ij}, reference Numbers 1 to 9 and its inverse scale, Table 2 lists the T.Satty 1-9 scale means.

Table2 The elements of judgement matrix in assignment standard

a_{ij}	define	a_{ij}	define
1	C_i and C_j are equally important	2	Between equally important and slightly more important
3	C_i slightly more important than C_j	4	Between slightly and obviously important
5	C_i obviously important than C_j	6	Between clearly and obviously important
7	C_i clearly important than C_j	8	Between apparent and absolute important
9	C_i absolutely important than C_j		

Classification too much increased the difficulty of judgement, beyond people's judgment, generally do n (n - 1) / 2 times two judgment is necessary.

(4)Judgment matrix consistency check
To construct judgment matrix, because of the complexity of the objective things and the partial understanding of the problem, may be the cause of consistency matrix deviation is too large, it will lead to various factors index weight distribution is not reasonable, therefore, need a consistency check of judgment matrix [5]. Consistency check process: for every judgment matrix calculating maximum eigenvalues and corresponding eigenvectors, and then calculate the consistency index, consistency index and consistency ratio, only when the random consistency ratio (CR < 0.10), the consistency of judgement matrix have satisfied.

The risk evaluation hierarchy model of Landslide geological disaster
Through the establishment of the risk evaluation hierarchy model of landslide geological disaster**,** analyse the weights of landslide geological disaster impact factors. The main influencing factors of landslide were internal factors and external factors in the study area. Internal factors include: the topography, geological structure, stratum lithology; External factors include: rainfall, rivers, vegetation coverage, human activity.

Additionally according to landslide formation mechanism and repeatability characteristics of landslide, the study area should be considered landslide remote sensing survey of geological hazard, namely to study the effect of landslide disaster in the area density and scale. Based on this, to determine the study of the main factors to influence factor of landslide disaster in the area, the hierarchy structure model is established. According to the structure model, In wulong county, the evaluation hierarchy model of Landslide geological disaster factor U = {internal factors U1 , external factors U2, historical conditions U3}. Among them:

Internal factors U1 = {topography factor C1, geological structure factorC2, formation lithology factor C3};

External factors U2 = {annual rainfall C4, into rivers from C5, vegetation coverage C6, human activities C7};

Historical condition U3 = { landslide density C8, landslide scale C9};

To construct judgment matrix
Through the comparison of all these factors, to establish the landslide influence evaluation index of judgment matrix and the relative importance of each index in the study area.As table 3, table 4,table 5, table 6.

Table3 The judgment matrix of risk factors and relative importance scale

U	Internal factors U1	External factors U2	Historical condition U3
Internal factors U1	1	1	1/2
External factors U2	1/2	1	1/2
Historical condition U3	2	2	1

Table4 The judgment matrix of internal factors and relative importance scale

U1	topography C1	geological structure C2	formation lithology C3
topography C1	1	1/3	2
geological structure C2	3	1	5
formation lithology C3	1/2	1/5	1

Table5 The judgment matrix of external factors and relative importance scale

U2	annual rainfall C4	into rivers from C5	vegetation coverage C6	human activities C7
annual rainfall C4	1	2	4	1/5
into rivers from C5	1/2	1	2	1/7
Vegetation coverage C6	1/4	1/2	1	1/8
human activities C7	5	7	8	1

Table6 The judgment matrix of historical conditions and relative importance scale

U3	landslide density C8	landslide scale C9
landslide density C8	1	1/2
landslide scale C9	2	1

The consistency check of judgment matrix

(1)To determine the relative weight coefficient

According to the judgment matrix, proceed hierarchy single sorts and hierarchy total sorts, and then to determine the evaluation factors and evaluation index weights. Hierarchy single sorts is aimed at this layer factors in importance, The weight value of Hierarchical single sorts can be obtained by solving the eigenvalue, that is:

$$AW = \lambda_{\max} W_i \qquad (1)$$

In the above formula: A is the judgment matrix, $\lambda_{\max}$ is the maximum characteristic root of A, W is feature vector of A, W_i is corresponding weight value of the single sort element levels.

For example, show consistency check of judgment matrix of internal factors influencing matrix U1. Calculation process is as follows:

$$\overline{C} = (\overline{c}_{ij}),\ \ \overline{c}_{ij} = \frac{c_{ij}}{\sum_{i=1}^{n} c_{ij}},\ \ i, j = 1,2,\cdots n \qquad (2)$$

$$C_1 = \begin{bmatrix} 1 & 1/3 & 2 \\ 3 & 1 & 5 \\ 1/2 & 1/5 & 1 \end{bmatrix};\quad \overline{C}_1 = \begin{bmatrix} 0.2222 & 0.2174 & 0.2500 \\ 0.6667 & 0.6522 & 0.6250 \\ 0.1111 & 0.1304 & 0.1250 \end{bmatrix};$$

According to the line together:

$$\overline{W} = [\overline{w}_1, \overline{w}_2, \cdots, \overline{w}_n]^T, \overline{W}_i = \sum_{j=1}^{n} \overline{c}_{ij}; \qquad (3)$$

$$\overline{W}_1 = \begin{bmatrix} 0.6896 \\ 1.9439 \\ 0.3665 \end{bmatrix};$$

$$W = [w_1, w_2, \cdots, w_n]^T,\quad w_i = \frac{w_i}{\sum_{i=1}^{n} w_i} \qquad (4)$$

Through the above calculation, the weight vector of the single sort for judgment matrix of internal factors U1:

$W_1 = \begin{bmatrix} 0.2299 \\ 0.6480 \\ 0.1221 \end{bmatrix}$.In the same way, the weight vector of the single sort for judgment matrix of external factors U2: $W_2 = \begin{bmatrix} 0.1854 \\ 0.1000 \\ 0.0591 \\ 0.6555 \end{bmatrix}$, the weight vector of the single sort for judgment matrix of historical condition U3: $W_3 = \begin{bmatrix} 0.3333 \\ 0.6666 \end{bmatrix}$, the weight vector of the single sort for judgment matrix of U: $W_T = \begin{bmatrix} 0.2619 \\ 0.2143 \\ 0.5238 \end{bmatrix}$.

(2) Consistency check

Get W_i from the above to calculation, as a basis for the lower elements to the upper one, need to check the consistency of judgement matrix.

$$\lambda_{\max} = \frac{1}{\mathrm{n}} \sum_{\mathrm{i}=1}^{\mathrm{n}} \left[\frac{\sum_{\mathrm{j}=1}^{\mathrm{n}} \mathrm{a}_{\mathrm{i}j} w_j}{w_j} \right] \tag{5}$$

According to the formula (5) , to calculate the feature vector of intrinsic factor U1's judgment matrix .

$$\lambda_{\max} = \frac{1}{3}\left(\frac{1\times0.2299 + 1/3\times0.6480 + 2\times0.1221}{0.2299} + \frac{3\times0.2299 + 1\times0.6480 + 5\times0.1221}{0.6480} + \frac{1/2\times0.2299 + 1/5\times0.6480 + 1\times0.1221}{0.1221} \right)$$ =3.00369

Through the above method to construct judgment matrix, which can reduce the interference of other factors, more objectively reflect the difference between a pair of factor influence. Judgment matrix provided by the decision makers a consistency check are necessary, to decide whether to accept it. The steps of consistency check are as follows:

1) Calculate the consistency index CI .

$$CI = \frac{\lambda_{\max} - \mathrm{n}}{\mathrm{n} - 1} \tag{6}$$

According to the formula (6) is obtained: $CI = \frac{\lambda_{\max} - \mathrm{n}}{\mathrm{n} - 1} = \frac{3.0037 - 3}{3 - 1} = 0.00185$.

2) To find the corresponding average random consistency index RI , as shown in table 7.

Table7 Corresponding RI values of N order matrices

n	1	2	3	4	5	6	7	8	9
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45

3) Calculate the consistency ratio CR .

$$CR = \frac{CI}{\mathrm{RI}} = \frac{0.00185}{0.58} = 0.0032$$

$CR = 0.0032 < 0.10$, Think internal factors the consistency of judgment matrix U1 is acceptable, otherwise the judgment matrix should be amended.

In the same way, we can obtain external factors judgment matrix U2 and historical situation factors judgment matrix U3. The calculation results and conclusions are shown in table 8.

Table8 Consistency check results and conclusions

Matrix	the consistency index CI	the consistency ratio CR	conclusions
U1	0.00185	0.0032	satisfaction
U2	0.078	0.0087	satisfaction
U3		Secondary matrix are always satisfactory	consistency
U	0.0267	0.046	satisfaction

To sum up, according to the actual situation, using the hierarchical analysis method, to determine the effect of geologic disaster danger evaluation factors in the study area weight coefficient, the structure of the consistency of judgment matrix is satisfied, the relative importance attached to score between various factors is feasible.

(3) Calculate the consistency ratio of the weight of each evaluation factor coefficient for total ordering. Hierarchy total sequencing calculation formula:

$$A = \sum_{j=1}^{n} U_j W_{ij} \tag{7}$$

In the above formula: W_{ij} is single sorting weight of each evaluation factor (secondary factors) level, U_j is single sorting weight of each evaluation factor (primary factors) level, A is total order weight of each evaluation index.

Using the formula (7), can be calculated for each to influence the outcome of total sorts of index weights. The results are shown in table 9.

Table9 Each evaluation factor weight total sorts

U	U1	U2	U3	Total order sorting
weight coefficient	0.2619	0．2143	0.5238	$\sum_{j=1}^{n} U_j W_{ij}$
topography C1	0.2299			0.0602
geological structure C2	0.6480			0.1697
formation lithology C3	0.1221			0.0320
annual rainfall C4		0.1854		0.0397
into rivers from C5		0.1000		0.0241
Vegetation coverage C6		0.0591		0.0127
human activities C7		0.6555		0.1405
landslide density C8			0.3333	0.1746
landslide scale C9			0.6666	0.3491

According to the total sorts, the size of the existing geological disaster, the density distribution of geological disasters, the influence factors of human activities is the most serious. These factors for the occurrence of landslide geological disasters play an important role.

RESULTS AND DISCUSSION

The risk evaluation of Regional landslide geological disaster and regionalization

This article used the Regular or irregular grid unit to divide the study area. Specific evaluation using analytic hierarchy process (ahp) combined with GIS technology to calculate each assessment unit of geological disaster risk index, and risk zoning map in the study area is obtained.

Risk index calculation model expressions:

$$Q_{\mathrm{j}} = \sum_{i=1}^{n} w_i v_i \tag{8}$$

In the above formula: Q_{j} is the risk index of j unit, w_i is the weight of i geological hazard factors, v_i is the Degree of geological disaster risk factor score of i.

The influence factors of affecting the geological disaster evaluation factors, and must be endowed with quantitative values. For each unit of all geological hazard factor score of expert experience method is used to quantified expression, level 4 points method [6]. According to the actual situation in the study area combined with the expert experience, the influence factor of landslide hazard assignment are listed in table 10.

Table10 Expert rating assignment of impact factor landslide

The impact factor of landslide	value	value implication
topography	1	Small effect
geological structure	2	General effect
formation lithology	2	General effect
annual rainfall	3	Medium effect
into rivers from	3	Medium effect
Vegetation coverage	1	Small effect
human activities	4	Strong effect
landslide density	4	Strong effect
landslide scale	3	Medium effect

Through formula (9) , using GIS software MAPGIS, will calculate the weight value of factors and the influencing factors of value by the map algebra operation, grid can be obtained the final score value of evaluation unit. According to the final score value of grid evaluation units will risk zoning in the study area into five levels: very high danger zone, high danger zone, medium danger zone, low danger area, no danger zone.

Using MAPGIS software in the spatial analysis module (DTM), to extract the geological disaster risk index of each unit after eliminating discrete data, get the landslide risk of geological disasters in the study area comprehensive plane contour map. In combination with the practical situation of the study area, according to the regional risk zoning standards, on the basis of the landslide geological disaster risk comprehensive contour map, the geological disaster risk is divided into five grades. The results are shown in table 11. According to the landslide hazard contour map, we can get the landslides in the study area geology disaster risk zoning map, as shown in figure 1.

Table11 Landslide geological disaster risk hierarchy table in the study area

Grade	The value interval of contour
very high danger zone	＞3.58
high danger zone	2.93-3.58
medium danger zone	2.23-2.93
low danger area	1.53-2.23
no danger zone	＜1.53

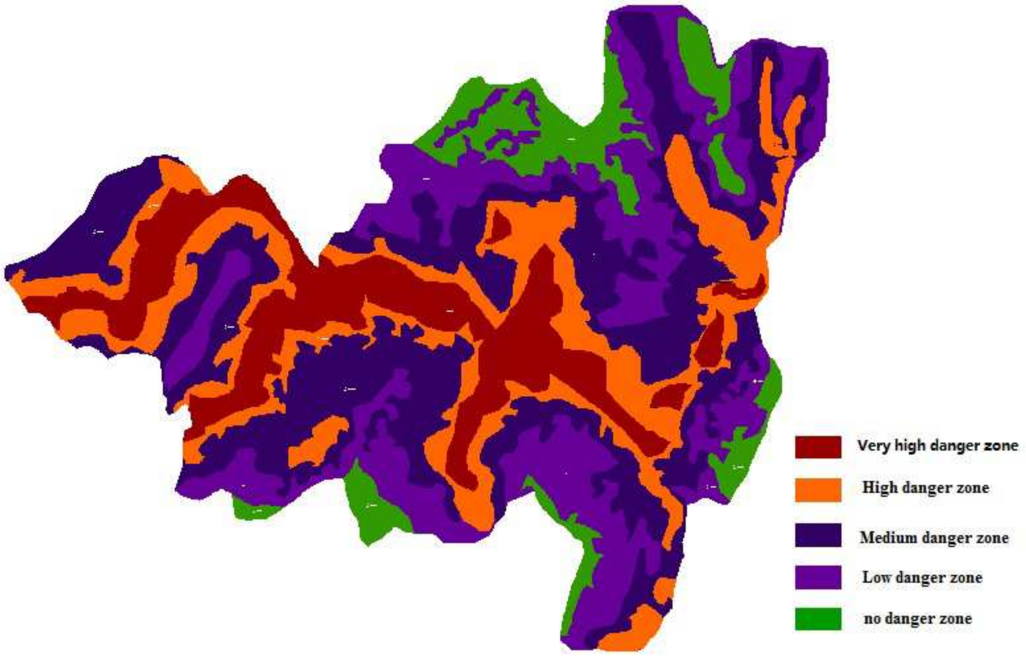

Fig.1 The zoning map of landslide risk in Wulong county

DISCUSSION

The zoning map of landslide risk and the remote sensing image interpretation of landslide geological location are consistent. According to the research results to get the following conclusion:

(1) High landslide geological disaster danger zone in wulong county more concentrated in elevation 600 meters, obvious zonal distribution, mainly concentrated in wujiang river coast low valley area of middle mountain and its main tributaries especially wujiang river, Shi Liang river，Daxi river area is the most serious.

(2) Different sizes of landslide geological disaster distribution range is very wide, strong dispersion, high risk level. Very high danger zone accounts for about 9.1% of the county area, high danger area accounted for 20.4% of the county area, medium risk area accounted for 24.4% of the county area, low danger area accounts for 33.1% of the county area, extremely low danger area accounts for only 13.0% of the county area.

(3) Front open slopes or into a zonal distribution of low and middle mountain slope zone, and high cut slopes or high fill to build the railway, highway and the structure of the slope slide is extremely high danger zone and high danger zone. The area is the place that human activity is frequent, in case of landslides, the loss will be very serious.

(4) Wulong county in the development of landslide and its geological environment is closely related to formation lithology in the county for the Jurassic, Permian and Triassic shale, mudstone, limestone and sandstone, and are easy to slip strata with high sensitivity, and wulong county high steep mountains, valleys and cutting, the geological conditions and landform in rivers incised, under the influence of factors such as rainstorm and human activity, easy to landslides.

In short, the overall landslide of wulong county landslide area is wide, strong dispersion, high risk rating, high strip of high-risk groups of danger and distribution characteristics.

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