

Risk analysis of debris flow based on grey correlation method

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Abstract. In this paper, the research status and evaluation methods of debris flow risk at home and abroad are analyzed. Finally used the grey correlation analysis method, according to the climate and geographical conditions of Jilin province has chosen six factor model (watershed cut density, loose source quantity per catchment area, vegetation coverage, main ditch slope, slope gradient, length of supply section), and determine each factor weight. Based on this, the risk level of six debris flow gullies in Longjing city was determined.

1. Research status at home and abroad on risk

In the late 19th century, when the Russian road engineer, Stenervski, designed the Georgian military highway through the main Caucasus mountains, the origin and risk of debris flow were initially involved^[1]. However, it was not until the 1930s and 1940s that the quantitative research on debris flow hazard was started, which led to the unprecedented development of the study on debris flow hazard. In the 1970s, the most representative of debris flow hazard evaluation was the study and classification of debris flow hazard by Japanese scholars such as Adachi Katsuji. However, at that time, the hazard only refers to the frequency of debris flow occurrence, and the evaluation of debris flow hazard is very limited^[2].

In China, the study of debris flow risk assessment can be traced back to the risk classification of debris flow gully in Mr. Wang Lixian's classification of wild creek. In the 1980s, Chinese scholar Tan Bingyan began to study the debris flow hazard, mainly aiming at the judgment of debris flow gully and the degree of debris flow hazard^[3]. At the beginning of the study on debris flow risk in China, the traditional geographical analysis method is adopted, and the superposition and correlation analysis is conducted by extracting related disaster inducing factors. In 1988 Liu Xilin in the studies of debris flow risk decision^[4] will combine qualitative analysis with quantitative analysis effectively, the multi-factor comprehensive evaluation model is put forward for the first time, and in the later research deepening and perfecting^[5-6], make it more and more conforms to the characteristics of the Chinese mountain landslides, greatly promote the debris flow risk research in China. Since the 1990s, with the maturity of various mathematical theories, debris flow hazard assessment in China has also begun to mature, and various research methods have been increasingly improved, and computer technology has been gradually applied in research work. The risk assessment method has also developed from the traditional qualitative description and incomplete statistical analysis to the semi-quantitative evaluation or quantitative evaluation, the evaluation content has been increasingly perfect and reasonable, and the scientific evaluation has been increasingly strengthened^[7]. It is the first time in China to carry out risk assessment of landslide debris flow on a large scale in the study of risk zoning of landslide debris flow in Ertan hydropower station area of Yaolang River, Three Gorges hydropower station on Yangtze River and the upper reaches of the Yangtze River^[8-10], indicating that the risk assessment of debris flow in China has entered the actual application stage. Subsequently, debris flow



hazard assessment became a hot spot of debris flow disaster research, such as the risk assessment of debris flow in yunnan province^[11-12] and the risk assessment of landslide debris flow in the upper reaches of the Yellow River^[13].

2. Grey relational analysis

The current assessment method of debris flow risk is shown in figure 1. Grey relational method is a method which can reduce subjective judgment of human factors and rank influence factors after dimensionless.

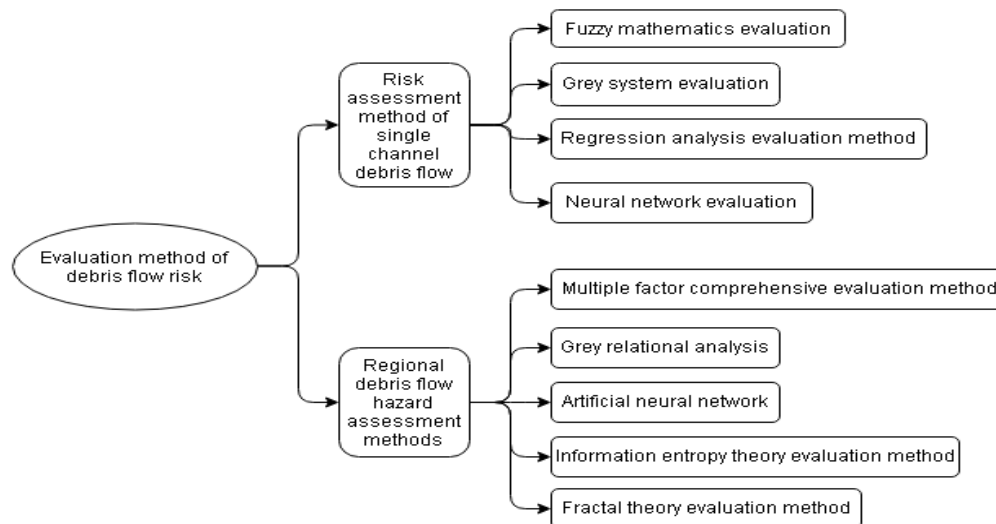


Figure 1

Liu Xilin^[14] adopts double series of grey correlation method to select 7 factors put forward the new formula of single gully debris flow risk evaluation, he introduce the latest single ditch debris risk evaluation technology and its improvement, a new method of evaluation factor conversion function assignment, and put forward the theory formula of debris flow risk assessment for the first time and its numerical solution, at the same time also points out the difficulties faced by debris flow risk theory research. Wei Binbin^[15] considered such as rainfall and under the action of the earthquake by using grey correlation analysis in beichuan county 72 debris flow gully debris flow scale, the basin area, main gully length and watershed relative relief, valley cutting, unstable ditch bed density ratio, average annual rainfall and earthquake intensity 8 impact factor weights, based on the earthquake debris flow risk assessment model and further carry on the risk assessment. Huang wei^[16] et al. analyzed the risk factors of glacier debris flow in nyingchi, considered 10 factors, and selected 6 typical debris flow gullies in the study area. They used the grey relational degree method to screen out 7 major influencing factors, including the daily maximum temperature, basin area, the maximum outburst amount of a debris flow, the length of the main channel, the maximum elevation difference of the basin, and the area of glacier snow, and determined the weight value.

3. Climatic and environmental characteristics of Jilin province

Jilin province is located in eastern China monsoon climate zone, is a moderate temperate zone. The climate is characterized by short, dry, windy, rainy and frequent spring droughts. Hot and humid summer, precipitation concentration, floods; Autumn is cool with less precipitation; Winter is cold and long, dry, with little precipitation. The entire province average annual temperature of 2 ~ 6 °C, southeast is higher, lower in the northwest. The maximum freezing depth is generally 1.7-2.0m^[17-19]. Precipitation in the province has averaged 400 ~ 1000mm in recent years, gradually decreasing from east to northwest. Precipitation in the southeast was 800 ~ 1000mm on average, of which the southern slope of Changbai mountain was as high as 1000 ~ 1400mm, precipitation in the central and

eastern part was 600 ~ 800mm, and precipitation in the western plain was relatively low, mostly 400 ~ 600mm. Precipitation is concentrated in the province from June to September, accounting for 70% to 80% of the year. Snow falls from November to March, less than 5% of annual precipitation.

4. Build a model

4.1. Select factor

In order to verify the correctness and rationality of the method studied, this paper selected six debris flow gully data in a high-occurrence area of debris flow in Jilin province for the study of debris flow risk assessment. Among them, main groove slope (X_1), loose material source quantity (X_2) per catchment area, hillside slope (X_3), watershed cutting density (X_4), vegetation coverage (X_5) and supply section length are the evaluation factors (X_6). The specific values are shown in table 1^[20].

Table 1

Debris flow risk factors						
Name of debris flow	The main channel length(X_1)	Loose source quantity per catchment area(X_2)	Slope gradient(X_3)	Watershed cut density(X_4)	Vegetation coverage(X_5)	Length of supply section(X_6)
DF0025	0.82	0.75	0.12	9.9	0.70	0.58
DF0026	0.78	0.79	0.09	11.1	0.71	0.61
DF0027	0.63	0.81	0.56	8.78	0.66	0.59
DF0028	0.75	0.87	0.45	6.23	0.74	0.57
DF0029	0.82	0.79	0.35	7.95	0.70	0.64
DF0030	0.81	0.86	0.21	10.25	0.78	0.56

When the grey correlation method is adopted to establish the evaluation model, due to the incomparability of the influencing factors, the weight of each factor is quantitatively analyzed and the weight of each factor is quantitatively normalized. According to the transformation function proposed by Liu Xilin [14], all of them are converted into values between 0 and 1.

4.2. Model establishment

According to relevant theories of grey correlation method^[16,21], the evaluation function is established according to the following steps:

4.2.1. *Composition of correlation series*, namely $X = \{X^1, X^2, X^3, X^4, X^5, X^6\} = \{\text{main groove slope, loose material source amount per catchment area, slope of slope, watershed cutting density, vegetation coverage, supply section length, are evaluation factors}\}$.

4.2.2. Data averaging and dimensionless processing

$$X'_i(k) \equiv \frac{1}{n} \sum_{k=0}^n X_i(k) \quad (1)$$

In the formula, $k = 1, 2, \dots, m$, m are the number of influencing factors; $i = 0, 1, \dots, n$, n are the number of debris flow channels.

4.2.3. Absolute difference sequence

$$\Delta_{ij}(k) = |X'_i(k) - X'_j(k)| \quad (2)$$

In the formula, $k = 1, 2, \dots, m$; $i, j = 0, 1, \dots, n$

4.2.4. Correlation coefficient

$$\xi_{ij}(k) = \frac{\Delta_{\min} + \rho \Delta_{\max}}{|X'_i(k) - X'_j(k)| + \rho \Delta_{\max}} \quad (3)$$

In the formula, ρ is the resolution coefficient, and its value range is $[0, 1]$. Generally, it takes 0.5.

4.2.5. Correlation

$$r_{ij} = \frac{1}{n} \sum_{k=1}^m \xi_{ij}(k) \quad (4)$$

The correlation coefficients obtained were respectively substituted into equation 4) to find the correlation degree of comparison sequence X_j to reference sequence X_i .

4.2.6. The factor weights

$$\omega_i = \frac{\bar{r}_{(i)}}{\sum_{i=1}^6 \bar{r}_{(i)}} \quad (5)$$

4.2.7. The evaluation function is based on the weight of each factor. Establishment of evaluation

$$\text{function } H = \sum_{i=1}^6 \omega_i X_i \quad (6)$$

4.2.8. The paragraph text follows on from the subsubsection heading but should not be in italic.

4.3. Application of the model

According to the basic data in table 1, all factors were transformed with the conversion function, and the correlation degree between 6 factors was obtained. The correlation degree matrix was formed:

$$R = \begin{bmatrix} 1.0000000 & 0.7264251 & 0.6765854 & 0.6910061 & 0.7180547 & 0.6928811 \\ 0.8651223 & 1.0000000 & 0.7510680 & 0.7476194 & 0.8567680 & 0.8963407 \\ 0.5988605 & 0.6368840 & 1.0000000 & 0.8104538 & 0.8197315 & 0.8872598 \\ 0.5925627 & 0.8034835 & 0.6074778 & 1.0000000 & 0.7130413 & 0.7374134 \\ 0.6899245 & 0.6816513 & 0.6671581 & 0.6651671 & 1.0000000 & 0.6907058 \\ 0.6017247 & 0.9235814 & 0.6485204 & 0.7784446 & 0.7340162 & 1.0000000 \end{bmatrix}$$

Calculate the average value of each line according to the relational degree matrix R

$$\bar{r}_{(1)} = 0.7411316$$

$$\bar{r}_{(2)} = 0.7146324$$

$$\bar{r}_{(3)} = 0.7539452$$

$$\bar{r}_{(4)} = 0.7349540$$

$$\bar{r}_{(5)} = 0.7734256$$

$$\bar{r}_{(6)} = 0.7530045$$

Substitute the average value into equation 5 to calculate the weight of each factor (table 2).

Table 2 Weight of each factor

Weight of each factor						
factor	X_1	X_2	X_3	X_4	X_5	X_6
weight	0.17183334	0.1783638	0.1683754	0.1800576	0.1741236	0.1518305

By substituting the weight of each factor into equation 6), the evaluation function of debris flow risk in the earthquake area is obtained:

$$H = 0.17183334X_1 + 0.1783638X_2 + 0.1683754X_3 + 0.1800576X_4 + 0.1741236X_5 + 0.1518305X_6 \quad (7)$$

The risk value of debris flow gully in Longjing city is calculated from equation 7). Based on the statistics, the classification standard of debris flow risk in the earthquake area is determined according to the field survey and basic data (table 3).

Table 3 Classification standard of debris flow risk in earthquake area

Classification standard of debris flow risk in earthquake area				
Very low risk	Low risk	Moderate risk	Highly dangerous	High risk
$0 \leq H < 0.45$	$0.45 \leq H < 0.6$	$0.6 \leq H < 0.75$	$0.75 \leq H < 0.9$	$0.9 \leq H < 1.0$

The risk assessment of debris flow gully is given in table 4 according to the classification standard of debris flow risk in the earthquake area.

Table 4 Risk assessment of six debris flow gully

Serial number	DF0025	DF0026	DF0027	DF0028	DF0029	DF0030
Risk value	0.41	0.37	0.69	0.56	0.51	0.63
risk	Very low	Very low	Moderate	Low	Low	Moderate

5. Results analysis

According to the weight of each factor in table 3, the dominant order of each factor is: $X_4 > X_2 > X_5 > X_1 > X_3 > X_6$. That is, watershed cut density > loose source quantity per catchment area > vegetation coverage > main ditch slope > slope gradient > length of supply section.

6. Conclusion

(1) the influencing factors of debris flow in the earthquake area mainly include: watershed cut density, loose source quantity per catchment area, vegetation coverage, main ditch slope, slope gradient, length of supply section.

(2) the grey correlation method is used to calculate the correlation degree and weight of each factor, to reduce the subjective judgment of human factors on the influence factors of debris flow activity in earthquake stricken areas, and to provide theoretical and data support for our study on debris flow risk assessment in earthquake stricken areas.

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