Application of Grey Theory to Debris Flow Hazard Assessment in Zhouqu Nanyu Gully: A Postprint

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Abstract

To analyze the degree of influence of various factors on debris flow disaster risk, based on a summary and analysis of investigation results regarding the influencing factors of debris flow disasters in Nanyu Gully, Zhouqu, grey theory was utilized to analyze the correlation degree between debris flow disaster risk and influencing factors, and to establish a predictive model. The results indicate that the influence degrees of factors including gully bank slope, degree of channel blockage and erosion-deposition amplitude, average longitudinal gradient and length of the channel, vegetation coverage within the channel, watershed area and population density, volume of loose solid material sources, and disaster point density are relatively comparable; within the same region, the risk degree of debris flow disasters in different gullies is significantly affected by factors such as gully bank slope, degree of channel blockage, erosion-deposition amplitude, average longitudinal gradient of the channel, and channel length; a susceptibility assessment model for debris flow disasters was established based on natural and anthropogenic factors, which can provide a basis for the deployment of debris flow disaster prevention and control efforts within the region.

Full Text

Preamble

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Abstract: This paper focuses on analyzing the vulnerability degree of debris flow hazards, which is affected by various environmental factors. Using grey correlation analysis based on field survey results, the correlation degree between different influencing factors and debris flow disaster susceptibility was studied for different debris flow gullies in Nanyu Gully, Zhouqu County, Gansu Province, including the "August 8"large debris flow disaster instance. The results show that the susceptibility of debris flow disaster is relatively similar for factors such as bank slope, channel blockage, scouring range, slope gradient and channel length, vegetation, drainage area, population density, solid matter source, and geological hazard points density. For different gullies in the same area, the hazard level of debris flow disaster is significantly impacted by bank slope, channel blockage, scouring range, slope gradient, and channel length. The model can predict the vulnerability of debris flow and provide important information for hazard prevention and control.

Keywords: geological engineering; mud-rock flow hazards; grey correlation theory; susceptibility assessment

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2. Methodology

2.1 Data Collection

Field investigation data were collected from different debris flow gullies in Nanyu Gully, Zhouqu County, including the "August 8" large debris flow disaster event. The evaluation system for debris flow hazard occurrence susceptibility was established based on analysis of influencing factors. The investigation included: (1) measurement of bank slope angles and channel geometric parameters; (2) assessment of channel blockage conditions and scouring range; (3) vegetation coverage and drainage area characteristics; and (4) solid matter source distribution and geological hazard points density.

The evaluation 指标体系 (index system) comprises 11 factors: bank slope (S), channel blockage (P), scouring range (G), channel length (L), slope gradient (V), vegetation (A), drainage area (M), population density (B), solid matter source (D), geological hazard points density (E), and channel width (not used in final model). The comprehensive evaluation results for different gullies are presented in .

2.2 Grey Correlation Analysis Method

Based on grey system theory, the correlation degree between influencing factors and debris flow hazard susceptibility was calculated. The grey correlation analysis process involves: first, establishing the reference sequence (hazard susceptibility) and comparison sequences (influencing factors); second, normalizing the data sequences; third, calculating the correlation coefficients and correlation degree; and finally, ranking the factors by their influence.

The grey correlation degree calculation formula is:

$$)(cid:150) < (cid:176)\tilde{}^{-\breve{}} =>\grave{} \acute{} \ddot{}m'(cid:223)\,"(cid:223);(cid:146)–¢G(cid:244)(cid:127)|\ –(cid:201)\,^{\circ}\,¸P[UABCDEOP$$

where _i(k) is the correlation coefficient at point k, Δ_i(k) is the absolute difference between reference and comparison sequences, and is the resolution coefficient (typically 0.5).

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3. Results and Analysis

3.1 Evaluation Index System

The evaluation index system was constructed based on field survey data from 22 debris flow gullies in Nanyu Gully. The system includes quantitative indices for bank slope, channel geometry, and qualitative indices for blockage conditions and vegetation coverage. Each gully was assigned a hazard susceptibility rating based on comprehensive scoring.

3.2 Grey Correlation Analysis Results

The grey correlation analysis results show the correlation degree ranking: _G > _B > _E > _S > _L > _V > _A > _P > _M > _D. This indicates that scouring range, population density, and geological hazard points density have the strongest correlation with debris flow hazard susceptibility, while drainage area and solid matter source show weaker correlation.

The correlation degree values demonstrate that bank slope, channel blockage, and scouring range are the primary controlling factors for debris flow hazard occurrence in Nanyu Gully. The mean values of survey data for different gullies

are presented in , where X (k) represents the hazard susceptibility rating and X_i(k) represents the normalized values of influencing factors.

3.3 Model Validation

To validate the model, the predicted hazard susceptibility was compared with actual historical debris flow events. The validation results show that the grey correlation model achieves 85% accuracy in predicting high-hazard gullies. The model particularly excels in identifying gullies with high susceptibility where scouring range exceeds 50m, bank slope angles are greater than 35°, and channel blockage coefficient exceeds 0.6.

The validation confirms that the evaluation system based on grey correlation theory can effectively assess debris flow hazard susceptibility and provide reliable information for disaster prevention planning in Nanyu Gully.

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Note: Figure translations are in progress. See original paper for figures.