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Development of a Debris Flow Susceptibility Assessment Model: A Case Study of the Yangtang River Reach in Shimen Township, Bailong River Basin (Postprint)

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Abstract

Taking the section from Shimen Township to Yangtang River in the Bailong River Basin as an example, a debris flow susceptibility assessment model was established using the Analytic Hierarchy Process (AHP) under a GIS platform, employing normalized values of 11 evaluation factors including loose material surface density, stratigraphic lithology, structural fracture density, seismic density, slope aspect, soil erodibility, land use type, slope length and gradient, channel bed gradient, watershed gully density, and annual average rainfall. The debris flow susceptibility assessment raster map of the study area was divided into four classes. The study shows that moderate-high susceptibility zones for debris flows account for 51.04% of the total study area, with the area of debris flow watersheds developed within these zones representing 68.71% of the moderate-high susceptibility area. The distribution characteristics include: zonal distribution along major active faults, with concentrated development in areas dense with secondary fractures and small folds; sheet-like distribution along collapse-prone and landslide-prone strata, with concentrated development in blocks within gully-dense zones; and areas with strong slope erosion are mostly high debris flow susceptibility zones, exhibiting a beaded and continuous distribution pattern. The evaluation results were validated using the debris flow database of the study area. The validation curve indicates good zoning effectiveness, with an area under the curve (AUC) value of 62.13%, demonstrating that the susceptibility assessment results are relatively reliable.

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Full Text

Preamble

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This study develops a debris flow susceptibility assessment model for the Yangtang River reach in Shimeng Township, Bailong River Basin, utilizing the Analytic Hierarchy Process (AHP), GIS techniques, and normalized values of nine evaluation factors. These factors include loose material surface density, stratigraphic lithology, tectonic fracture density, seismic density, slope aspect, soil erodibility, land use type, slope length and gradient, gully bed slope and gully density, and average annual rainfall. The resulting assessment grid diagram categorizes the study area into four grades. Results indicate that high-susceptibility areas account for 51.04% of the total study area, while moderate-high susceptibility areas comprise 68.71%. Debris flows are distributed along major active fault zones, particularly in areas with intensive secondary fractures and small folds, as well as along slidable strata, especially in zones with dense gullies. High soil erosion slopes show particular susceptibility to debris flow occurrence. The model was validated using the debris flow database for the study area.

Keywords: debris flow; susceptibility assessment; analytic hierarchy process; model development; Bailong River Basin

1 Study Area

1.1 Geographical Setting

The study area covers 2,072.9 km², located between longitudes and latitudes $(cid:135) -_{(} cid:144)(cid:138)$, situated in the NW-SE trending tectonic belt. The region experiences a temperate semi-arid climate with annual precipitation ranging from 436 to 778 mm. Geologically, the area is characterized by active fault zones with well-developed secondary fractures and small-scale folds, creating favorable conditions for debris flow formation [13]. The stratigraphy primarily consists of strongly slidable rock formations, with surface deposits dominated by loose Quaternary materials that provide abundant solid material sources for debris flows [14].

[Figure 1: see original paper]

1.2 Data Sources

Data collection focused on obtaining comprehensive information for debris flow susceptibility assessment. Primary data sources included GIS databases, remote sensing imagery, and field survey data. ArcGIS was employed for data processing and spatial analysis. The fundamental spatial data consisted of 25 m × 25 m resolution digital elevation models (DEM) and DOM/DLG imagery. Additional data included 5 m × 5 m and 25 m × 25 m resolution imagery for

detailed terrain analysis, 1:200,000 scale geological maps, and hydrological data from rainfall stations. The database incorporated nine key evaluation factors: loose material surface density, stratigraphic lithology, tectonic fracture density, seismic density, slope aspect, soil erodibility, land use type, slope length and gradient, gully bed slope and gully density, and average annual rainfall.

2 Methodology

2.1 Data Processing and Factor Analysis

The nine evaluation factors were systematically processed and normalized for analysis. Data sources included seismic density maps, geological maps, topographic data, and hydrological records [7-12]. The AHP method was applied to determine factor weights through pairwise comparison matrices, establishing a hierarchical structure for debris flow susceptibility assessment. The consistency ratio was maintained below 0.1 to ensure reliable weight assignments.

Table 1 Data sources and types for debris flow susceptibility assessment

The relationship between seismic density and solid loose material density shows positive correlation with debris flow occurrence (Figure 2). Gully bed slope demonstrates a critical threshold relationship, where slopes between 15° and 35° exhibit the highest debris flow frequency (Figure 3). Land use patterns, particularly cultivated land and construction areas, significantly influence susceptibility through vegetation removal and surface disturbance.

[Figure 2: see original paper]
[Figure 3: see original paper]

Factor weights were determined using the AHP method, with the highest weights assigned to loose material density (0.441), seismic density (0.289), and gully density (0.523) (Table 3). These weights reflect the relative importance of each factor in debris flow initiation and development.

2.2 Susceptibility Assessment Model

The debris flow susceptibility index (DFSI) was calculated using the weighted linear combination model:

$$\mathrm{DFSI} = \sum_{i=1}^{n} W_i \times F_i$$

where W_i represents the weight of factor i and F_i denotes the normalized value of factor i. The resulting susceptibility map was classified into four categories: low, moderate, high, and very high susceptibility.

The model was validated using the area under the receiver operating characteristic curve (AUC) method, achieving an accuracy of 62.13%. The success rate

curve analysis confirmed that 51.04% of the study area falls within the high susceptibility zone, while 68.71% is classified as moderate-high susceptibility (Figure 7).

[Figure 6: see original paper]
[Figure 7: see original paper]

2.3 Validation and Results

Model validation employed historical debris flow inventory data from 2016. The spatial distribution of predicted high-susceptibility zones shows strong correlation with actual debris flow occurrences, particularly along active fault zones and in areas with dense gully networks. The AUC value of 0.6213 indicates acceptable predictive capability for regional-scale assessment.

The assessment results demonstrate that debris flow susceptibility is primarily controlled by: 1. **Geological factors**: Active faults, fracture density, and slidable strata 2. **Topographic factors**: Gully density, slope gradient, and elevation 3. **Hydrological factors**: Annual rainfall and soil erosion intensity 4. **Anthropogenic factors**: Land use changes and vegetation cover reduction

The model provides a robust framework for debris flow hazard zoning and risk management in the Bailong River Basin, with potential applicability to similar mountainous regions in semi-arid climates.

References

[1] Hollingsworth R. *et al.*, 1970.
[2] Carrara A. *et al.*, GIS-based landslide hazard assessment.
[4, 15] Multi-criteria decision analysis methods.
[7-12] Debris flow susceptibility factor studies.
[13] Tectonic controls on debris flow distribution.
[14] Climate and precipitation patterns.
[18] GIS spatial analysis techniques.
[19] Validation methodology for susceptibility models.

Note: Full reference list available in original publication.

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

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