Susceptibility Evaluation of Debris Flow Based on Experience Weight Method Combined with “3S” Technology: A Case Study from Dongchuan in Yunnan Province, China

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Abstract. Dongchuan, located in Yunnan Province, China, is well known as “debris flow museum” in the world because of its special geological background and intensive mining activities. There are more than 100 ravines of debris flow in the area of 1859 km², which have caused disastrous damages. Regional gullies for debris flow susceptibility evaluation can play an important role in reducing damage of debris flows in Dongchuan. In this paper, we selected Dongchuan as a case study to research the susceptibility evaluation of debris flow based on experience weight method combined with “3s” technology. The result shows that most of debris flow gullies in Dongchuan face high risk, while few face moderate risk or very high risk.

1. Introduction
The debris flow susceptibility refers to occurring possibility of debris flow for gullies in the condition of rainfall. Particular geology and landform conditions are necessary for debris flows happening, which are the basis of debris flow susceptibility evaluation.

The debris flow susceptibility evaluation includes single gully evaluation and regional gullies evaluation. The method of single gully evaluation is that, firstly geology and landform background were obtained by field investigation, then each background factor was quantified based on experts’ knowledge, and finally the possibility of debris flow susceptibility was got by overlay analysis of each background factor. Regarding regional gullies evaluation, one the one hand we can give meshing mark according to the data of regional important gullies investigation, which needs a lot of field work; on the other hand, we can comprehensively assess regional debris flow susceptibility based on factors of landform and water analysis. [1] chose seven factors (the maximum volume of once flow, occurrence frequency of debris flow, watershed area, main channel length, watershed relative height difference, gully incision density and the length ratio of sediment supplement) and created a debris flow hazard
assessment model based on support vector machine (SVM) in Yunnan Province as learning samples. Authors [2] chose six factors (rock type, structural fault, slope gradient, relative relief, annual average rainfall and normalized vegetation) and studied debris flows susceptibility in the Benzilan—Changbo segment of the upper Jinsha River based on GIS technology and analytical hierarchy process (AHP).

However, the evaluation methods for regional debris flows adopted few evaluation indicators at present. Even more, the distribution of debris flow gullies in existence which has direct influence on assessment result is necessary for the evaluation. In this study, evaluation methodology for single debris flow gully based on experience weight method was introduced in regional debris flows susceptibility evaluation. A typical example was selected from Dongchuan District, Yunnan Province, China. Dongchuan can be said to be natural museum for debris flow in the world, located at from 102°45′E to 103°19′E and from 25°57′N to 26°33′N with the area of 1859 km². More than 100 debris flow gullies distribute along Xiaojiang River which is the largest drainage basin in Dongchuan.

2. Brief introduction of geological condition and debris flows in Dongchuan

Dongchuan is located in north of Kunming, the provincial capital of Yunnan. The landform is high-middle valley deeply cut by river with mountain land area accounting for 97.3%. Relative height difference is 3649.1m from the lowest 695m to the highest 4344.1m (figure 1). Subtropical monsoon climate is the main climate in Dongchuan. However, vertical climate is prominent with the feature of distinct dry-rainy season and intensive rainfall because of terrain. Mean annual precipitation is 1000.5mm, while month maximum rainfall is 208.3mm and day maximum rainfall is 153.3mm. Precipitation of rainy season from May to September accounts for 88% of annual precipitation.

![Figure 1. Three-dimensional terrain map of Dongchuan](image-url)

The stratum and lithology in Dongchuan develops well, from Presinian rocks to Quaternary deposits. The main lithology is slate, phyllite, sandstone, limestone, mudstone and shale. Rock masses are stratiform and cataclastic mainly, and weak structural planes exist. Tectonic movement is intensive and earthquake occur frequently. Human activities have been very strong in Dongchuan because of the abundant copper resource. Dongchuan is the third largest copper mining area in China with more than 2000 years mining history, especially in recent 300 years. Vegetation in Dongchuan was destroyed badly for mining and smelting. Because of special geological background and strong human activities, Dongchuan is well known as “debris flow museum” in the world. There are more than 100 ravines of
debris flow in the area, and several of them are very famous, such as Debris flows in Jiangjia Ravine, Daqiao Ravine, Dabaini Ravine, Xiaobaini Ravine and Heishan Ravine. As one of the most disastrous mine debris flows in China, Heishan Ravine debris flow occurred in the morning of May 27th in 1984, which caused 121 deaths, 34 injuries, 13 million Yuan direct loss and 14 days production halts of Yinmin Mine [3]. Therefore, research on regional debris flows susceptibility evaluation in Dongchuan is very important to reduce the hazard loss.

3. To generate drainage basin

Digital elevation model (DEM) is the main data to be used for drainage basin analysis at present. DEM data can reflect the local topographic feature with certain distinguish-ability. Therefore, natural water system in some geographic spaces can be extracted automatically by means of algorithm on the basis of the local topographic feature. ASTERGDEM data with 30m distinguish-ability was used in this study, and the technique process is shown in figure 2. The distribution of extracted regional water system in Dongchuan is shown in figure 3.

4. Debris flows disaster-forming background investigation

Disaster-forming conditions of debris flows include landform, geological environment, and vegetation cover and so on. Disaster-forming factors such as gradient, the longitudinal slope of gullies, curvature of gullies, formation lithology and vegetational cover were used in this study. Gradient was obtained based on digital elevation model (DEM) (figure 4a). The longitudinal slope of gullies was the ratio of altitude difference between upstream and downstream (figure 4b). Curvature of gullies was the ratio between the actual length and straight-line distance from upstream to downstream (figure 4c). Data acquisition of formation lithology was from 1:50000 geological map (figure 4d). Vegetational cover was based on the NDVI (Normalized Difference Vegetation Index) standard by Landsat ETM (figure 4e).

5. The susceptibility assessment of debris flows based on experience weight method

The susceptibility assessment of debris flow based on experience weight method has been used widely in single debris flow [4].
The experience weight was mainly based on the experience accumulation of experts studying specific region. In this study, we used the value of evaluation factors and risk for single mine debris flow from “Code for Geological Environment Survey and Assessment in Mining Areas” by China Geological Survey (table 1).

**Table 1. The value of evaluation factors and risk for single mine debris flow**

| Factors                        | Weight (Wi) | Very high (0.9) | High (0.7) | Moderate (0.5) | Low (0.3) |
|-------------------------------|-------------|-----------------|------------|----------------|-----------|
| 24h maximum rainfall (mm)     | 0.18        | >100.0          | 50.0~100.0 | 25.0~50.0      | <20.0     |
| Vegetation coverage (%)       | 0.05        | <30.0           | 30.0~50.0  | 50.0~70.0      | >70.0     |
| Catchment area (km²)          | 0.15        | >10.0           | 5.0~10.0   | 1.0~5.0        | <1.0      |
| Longitudinal slope (%)        | 0.11        | >40.0           | 28.0~40.0  | 15.0~28.0      | <15.0     |
| Curvature of gullies          | 0.05        | >1.4            | 1.3~1.4    | 1.2~1.3        | <1.1      |
| Total source (10³m³)          | 1.5         | >200            | 50~200     | 10~50          | <10       |
| Lithology of mineral waste residue | 0.12     | Mudstone, siltstone and phyllite | quartz schist, slate | Hard metamorphic rocks, granite and limestone | Hard metamorphic rocks, granite and limestone |
| Stability of mineral waste residue | 0.1       | Instability, no debris retaining project | relatively stable, few debris retaining projects | relatively stable, many debris retaining projects | stable, good debris retaining projects |
| Blocking degree of gullies (%) | 0.09        | 70.0            | 50.0~70.0  | 20.0~50.0      | <20.0     |
| Rank score                    | >80         | 60~80           | 50~60      | <50            |           |
Figure 4. a-e) Distribution of disaster-forming background of debris flows in Dongchuan
a-gradient;
b-the longitudinal slope of gullies;
c-curvature of gullies;
d-lithology;
e-vegetation cover
Maximum rainfall in 24h in Dongchuan is 153 mm. Total volume of source was calculated according to average thickness of 1 meter. Stability of mineral waste residue and blocking degree of gullies were required to be examined gully by gully, and they were assigned as high risk and very high risk respectively in this study. The rest indexes of risk degree were given according to the value in table 1. Finally, evaluation indicators added together according to its weight, and the total score of susceptibility for each drainage basin was got. High score stands for high susceptibility, while low score stands for low susceptibility.

The result shows that, most of debris flow gullies in Dongchuan face high risk (146 gullies, score from 60 to 80), while few face moderate risk (13 gullies, score from 50 to 60) or very high risk (1 gully, score more than 80) (figure 5). It is obvious that the susceptibility of debris flows in north of Dongchuan are more and higher than other parts from the view of relative amount and degree. Field investigation also showed the same result (figure 6, 7).

![Figure 5. Susceptibility tendency chart of debris flows in Dongchuan](image1)

![Figure 6. Feature of the valley in C18 location (The direction of the camera is 250°)](image2)
6. Conclusion
1) Because of special geological background and intensive mining activities, debris flows develop well in Dongchuan. It is a typical example to research regional debris flows susceptibility evaluation.

2) In this study, evaluation methodology for single debris flow gully based on experience weight method was introduced in regional debris flows susceptibility evaluation. The value of evaluation factors and risk for single mine debris flow from “Code for Geological Environment Survey and Assessment in Mining Areas” by China Geological Survey was used. The result shows that most of debris flow gullies in Dongchuan face high risk, while few face moderate risk or very high risk.

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