Relationship between Geological Hazards Distribution and Slope Factors in Qin-Ba Mountain Area

Lixing Zhao 1, *

1College of Geological Engineering and Geomatics, Chang’an University, Xi'an 710061, Shaanxi, China

*Corresponding author e-mail: zhaolixing1995@chd.edu.cn

Abstract. The distribution of geological hazards is closely related to the slope factors. This paper adopts the methods of field geological survey and GIS software to investigate the geological hazards in the study area, and uses statistical methods to analyze the relationship between landslides development and slope factors, including elevation, slope shape and topographic relief amplitude. The results are as follows. (1) Landslides are mainly distributed in low altitude areas, and the disaster density is highest in the range of 500 to 700 meters elevations. (2) Compared with other slope shape types, the number and density of landslides on linear slope are the highest. (3) Within the topographic relief amplitude range of 0 to 10 meters, the landslide density is the highest.

Keywords: Qin–Ba Mountain Area, Geological disaster, Geological survey, Slope factor

1. Introduction

Geological disasters are disastrous events formed by various geological processes during the development of the Earth. Geological disasters include landslides, avalanches, and mudflows.[1] Among them, landslide refers to the geological phenomenon that soil or rock mass sliding down integrally or dispersedly along a weak zone under the action of gravity.[2] Avalanche is a geological phenomenon that rock mass on the steep slope suddenly breaks away from the rock mass, rolls and accumulates at the foot of the slope under the action of gravity.[1] Compared with landslides and avalanches, the mudflows have high water content, strong fluidity and large impact area.[3]

China is a country with frequent geological disasters. Compared with central and eastern China, geological disasters in the west are more frequent.[4] Shaanxi is one of the geological disaster-prone areas. According to incomplete statistics, there have been 8193 geological disasters in Shaanxi Province in the past 20 years, of which landslides accounted for 60%, most of which occurred in the Qin-Ba (QB) Mountain area in southern Shaanxi.[5]

The QB Mountain Area in southern Shaanxi has large terrain and complex geological structure.[6] Therefore, QB Mountain Area is a high-risk area for geological disasters in the country. After 2000, there were six large-scale geological disasters in Shaanxi Province, five of which were located in the
QB Mountain area in southern Shaanxi, causing a large amount of property damage and many casualties. This shows that prevention and reduction of disasters is very important.\textsuperscript{[7]}

Methods of disaster prevention and reduction mainly include identification and investigation of geological disasters. Geological disaster investigation has been highly valued by researchers.\textsuperscript{[8],[9]} In recent years, scientists have used more indicators (such as meteorology, geomorphology and geological factors) to assess the risk and vulnerability of geological disasters.\textsuperscript{[10]} In order to reduce the threat of geological disasters to the safety and property of people, and to accurately detect potential geological disaster areas, the identification of geological disaster is of vital importance. Generally, field surveys are used in conjunction with optical satellite imagery for disaster identification.\textsuperscript{[11],[12]}

In this paper, we use the methods of field geological investigation and aerial photography to make statistics and analysis of the correlation between the distribution of geological hazards and slope factors, which provides a reference for disaster reduction and prevention in this area.

2. Overview of Study Area

2.1. Location

The study area is located in the QB Mountain Area, with a range of $107^\circ45'00'' ~ 108^\circ00'00''$E, $32^\circ30'00'' ~ 32^\circ40'00''$N, belonging to Zhenba County, Shaanxi Province. The county is 210km away from Xi'an.G210 road passes through Zhenba County and leads to Xi'an. All villages in the study area have road connections and traffic is convenient.

2.2. Landform

The study area is located in the northwestern part of the South Bashan, with developed rivers, serious erosion, deep gullies and terrain elevation between 560-1980m. The study area is mainly mountainous. Landforms in study area are divided into three categories according to absolute elevation and relative elevation: low mountain, middle mountain and river terrace. Among them, middle mountain landform is dominant, accounting for about 74% in study area.

3. Distribution Law of Geological Hazards

3.1. Types of Geological Hazards in the Study Area

Landslides, avalanches, and mudflows and unstable slopes in the survey area were investigated by using the methods of remote sensing interpretation and field investigation. There are 103 geological disasters in the study area, including 93 landslides (36 old landslides, 57 new landslides and unstable slopes), accounting for 90.29%, 6 landslides, accounting for 5.83%, and 4 debris flows, accounting for 3.88%. The survey results are shown in table 1.

| Types       | Number | Percentage (%) |
|-------------|--------|----------------|
| landslide   | 93     | 90.29          |
| avalanche   | 6      | 5.83           |
| mudflow     | 4      | 3.88           |
| total       | 103    | 100            |

As seen from table 1, the geological disasters in the study area are mainly landslides, accounting for 90.29% of the total. Therefore, this paper studies relationship between landslides distribution and slope factors, including elevation, slope shape and topographic relief amplitude.

3.2. The Relationship between Hazards Distribution and Elevation

Surface elevation usually reflects topography and geomorphology. In this paper, the absolute height of disasters are divided into four ranges: 500-900m, 900-1300m,1300-1700, and above 1700. The
relationship between landslides and elevation range in the study area is shown in table 2 and figure 1. It can be seen that 1300-1700 elevation range has the largest area, while the 500-700 elevation interval has the highest landslides disaster density and no landslide occurred at elevations greater than 1700 meters. The main reason is that frequent human engineering activities in the low-altitude area cause the slope instability and deformation.

Table 2. Statistical table of the relationship between hazards distribution and elevation

| Elevation Range | Area (km²) | Number of disasters | Percentage of disasters (%) | Density of disasters (a/km²) |
|-----------------|------------|---------------------|-----------------------------|-----------------------------|
| 500-900         | 56.12      | 33                  | 35.48                       | 0.59                        |
| 900-1300        | 166.76     | 43                  | 46.24                       | 0.26                        |
| 1300-1700       | 169.21     | 17                  | 18.28                       | 0.10                        |
| >1700           | 41.78      | 0                   | 0.00                        | 0.00                        |

Figure 1. The relationship between hazards distribution and elevation

3.3. The Relationship between Hazards Distribution and Slope Shape

Profile curvature extracted from DEM is a measure of change rate of ground elevation along direction of the maximum slope, which can indirectly represent the slope morphology. According to profile curvature, slope morphology is divided into three types: concave slope (profile curvature >0.5), convex slope (profile curvature <-0.5), linear slope (-0.5<profile curvature <0.5). Relationship between disasters and slope shape types is statistically analyzed, results are shown in table 3 and figure 2. It can be seen that linear slope has the highest disaster density, while convex slope has the lowest.

Table 3. Statistical table of the relationship between hazards distribution and slope shapes

| Slope shape types | Area (km²) | Number of disasters | Percentage of disasters (%) | Density of disasters (a/km²) |
|-------------------|------------|---------------------|-----------------------------|-----------------------------|
| Concave slope     | 73         | 16                  | 17.20                       | 0.22                        |
| Linear slope      | 249.3      | 60                  | 64.52                       | 0.24                        |
| Convex slope      | 117.7      | 17                  | 18.28                       | 0.14                        |
3.4. The Relationship between Hazards Distribution and Topographic Relief Amplitude

Topographic relief amplitude (TRA) reflects the fluctuation of the surface and is usually expressed as the difference between the highest and lowest elevations in a given area. In this paper, a rectangle with an area of 3600 m$^2$ was used to calculate the topographic relief amplitude. The TRA is divided into 6 grades: 0-10m, 10-20m, 20-30m, 30-40, 40-50 and >50m. Statistical analysis of the relationship between landslides and TRA is shown in Table 4 and Figure 3. It can be seen that the disaster density in the region with a fluctuation of 0-10m is the largest, followed by the region with a fluctuation of 10-20m. The number of disasters in the area with a fluctuation of 10-30 accounted for 70.97% of the total. The disaster density in the area with fluctuation above 50 meters is relatively low, mainly because the area with fluctuation >50m is less affected by human engineering activities.

Table 4. Statistical table of the relationship between hazards distribution and TRA

| Relief amplitude | Area (km$^2$) | Number of disasters | Percentage of disasters (%) | Density of disasters (a/km$^2$) |
|------------------|---------------|---------------------|----------------------------|-------------------------------|
| 0-10             | 36.71         | 12                  | 12.90                      | 0.33                          |
| 10-20            | 113.87        | 33                  | 35.48                      | 0.29                          |
| 20-30            | 157.14        | 33                  | 35.48                      | 0.21                          |
| 30-40            | 88.56         | 11                  | 11.83                      | 0.12                          |
| 40-50            | 28.19         | 3                   | 3.23                       | 0.11                          |
| >50              | 10.03         | 1                   | 1.08                       | 0.10                          |

4. Conclusion

A total of 103 geological disasters were investigated in the study area, including 93 landslides, 6 avalanches and 4 mudflows.
Landslide development in the study area is closely related to slope factors, including slope elevation, slope shape and topographic relief amplitude. Landslides are mainly distributed in the linear slope with elevation range of 500 to 700 meters and topographic relief amplitude of 0 to 10 meters.

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