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Acceptability of debris-flow disasters and influential factors in a hazard prone area of northwestern China

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ABSTRACT

Risk acceptability is an inevitable problem in human societies. In this case study of a debris-flow prone area in Zhouqu County of Gansu Province in northwestern China, on-site questionnaire surveys were administered and statistical analysis was conducted to evaluate public acceptance of debris-flow disasters and to identify the critical factors influencing their acceptability. The results indicate that local people's principal concern with regard to debris-flow-disaster consequences was disease occurrence, and their secondary concern was environmental destruction. Housing-related destruction represented the most common property-loss concern. The acceptability value of the distance between people's living or working place and debris-flow-disaster location (Distance) was 3.25 (moderate grade); the frequency of debris-flow occurrence in each community or village (Frequency) received an acceptability value of 1.43 (low grade); the warning time before debris-flow occurrence (Warning time) received an acceptability value of 3.18 (moderate grade); and people's willingness to pay for debris-flow-disaster insurance per year (Insurance premium) was reflected by an acceptability value of 3.33 (moderate grade). The significant factors affecting Distance acceptability were age, sex, and income; the significant factors affecting Frequency acceptability were sex, occupation, and income; the significant factors affecting Warning-time acceptability were educational level and income; and the significant factor influencing Insurance-premium acceptability was educational level. Income played the most influential role in respondents' assessments of debris-flow-disaster acceptability. This study may provide insight into the reasons behind the courses of action people choose when faced with debris-flow disasters.

1. Introduction

Natural disasters are inevitable and human civilizations have adapted to their threats and consequences [1]. Safe environments in which people can coexist with a certain level of disaster risk must be established for sustainable development of human communities [2,3]. In the context of this study, "a certain level of disaster risk," refers to the concept of the acceptable disaster risk. In 1969, the acceptable risk concept was proposed by Starr [4] in response to the question, "What kind of safety is the real safety?" Subsequently, Lowrance [5] clarified when a person is in a state of acceptable risk, he is considered to be in a safe state. *Acceptable Risk*, published in 1981, has been considered the starting point of risk acceptability studies [6]. *Acceptable Risk* clarified that a risk is acceptable only when potential benefits may compensate for the risk. That is, an acceptable risk involves balance between the benefit and risk. This concept of acceptable risk is commonly acknowledged by governmental decision-makers. However, the concept fails to emphasize the role of risk communication among various populations. Therefore, a comprehensive and multidisciplinary understanding of acceptable risk has required further definition. In 2009, the acceptable risk definition issued by the United Nations International Strategy for Disaster Reduction (UNISDR) [7] provided such elaboration. According to the UNISDR definition, acceptable risk is the potential loss that a society or a community can accept according to its social, economic, political, and environmental conditions.

Public attention to acceptable risk with regard to natural disasters is increasing. The public are not only the beneficiaries of the disaster-risk mitigation, but also the terminal executors of disaster-risk management [8]. However, few studies have evaluated public awareness of natural-disaster-related acceptable risk. Maynard [9] argued that the public must agree that a risk is acceptable for it to be described as acceptable risk. The Geotechnical Engineering Office of the Civil Engineering and Development Department in Hong Kong [10] conducted a questionnaire survey on acceptable risk of landslides and rock falls, and concluded that an annual casualty incidence less than 10^{-4} is considered acceptable by the public. Using interviews and surveys based on

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indexes of disaster frequency, disaster loss, and public willingness, Yin et al. [11] studied the acceptability of drought disasters in Sichuan and Chongqing, China. Jia et al. [12] designed a debris-flow acceptable risk questionnaire to quantitatively measure public opinion on the acceptability of debris-flow disasters. Additionally, based on the results of a questionnaire survey administered in Zhangjiakou City, Du et al. [13] analysed the acceptability of environmental pollution disasters and discussed the demographic and regional factors affecting the acceptability. One contemporary study of acceptable risk involved the identification and estimation of landslide and debris-flow disasters in school campuses in southwestern China [14]. In another study, Charrière et al. [15] investigated the effects of an informational exhibition on the natural-hazard-related risk awareness of the inhabitants of the Ubaye Valley in southern France. These findings highlight the critical role of risk communication with and among the public. In sum, studies of natural-disaster-related acceptable risk have rarely appraised public attitudes, and public awareness with regard to risk communication is also understudied. Therefore, further study on this topic is urgently required. As Sutanta et al. [16] remarked, methods and measures for reducing disaster risk may be proposed based on the concept of acceptable risk.

Research for the present study was conducted in Zhouqu County of Gansu Province in northwestern China. On-site questionnaire surveys were administered and face-to-face interviews were conducted to evaluate the public's standard of debris-flow-disaster acceptable risk shortly after a large-scale debris-flow. Using statistical analysis, indicators implying the acceptability of debris-flow disasters were identified, and the significant factors influencing the acceptability indicators were further analysed. The results of this study may serve as theoretical references for risk analyses and offer practical implications for debris-flow-disaster adaption and insurance as well as for disaster management.

2. Survey area

Zhouqu is located in the south of Gansu Province within 33°13'–34°01'N and 103°51'–104°45'E, and comprises a total area of 3010 km^2. In 2016, Zhouqu's population was 133,500 persons, and its GDP was CNY 1.47 billion (USD 0.22 billion). Zhouqu is an underdeveloped area and one of the poorest counties in China. Geographically, Zhouqu lies south of Qinling Mountain, and features a diverse landscape of hills and mountains. The terrain comprises highlands in the northwest and lowlands in the southeast. Elevation within Zhouqu ranges between 1173 m and 4504 m above sea level. The average yearly temperature is 13.8 °C, and the average annual precipitation is 360.5 mm [17]. Mountain-related hazards are common. Heavy deforestation has led to frequent debris flows and landslides. Since 1949 (the founding year of the People's Republic of China), six large debris flows have occurred [18] (Table 1).

On August 8, 2010, a massive debris flow occurred in the Sanyanyu and Luojiayu basins and rushed into the downtown of Zhouqu. This debris flow was the most devastating disaster in mainland China since the founding of the People's Republic of China in 1949. To evaluate people's psychological reactions and attitudes towards the disaster and scholarship on disaster acceptability, an on-site questionnaire survey was conducted during July 18–22, 2012. Within Zhouqu, the villages of Sanyan, Luojiayu, Yueyuan, Xijie, Wachang, and the downtown area suffered serious destruction from the debris flow were therefore selected as characteristic survey sites (Fig. 1).

3. Methods

3.1. Questionnaire survey

The objectives of the questionnaire survey were to assess (1) the public's degree of concern about debris-flow disasters; (2) the public's concern about the aftermath of debris-flow disasters; and (3) the degree of acceptance of debris-flow disasters among the public. Accordingly, the opening questions of the survey inquired about respondents' basic information (influencing factors), followed by a transitional question about degree of concern about debris-flow disasters, leading to questions on concerns about debris-flow disaster consequences, and finally inquiries related to the indictors implying the acceptability of debris-flow disasters (Table 2).

Table 1
Recorded debris flows and related destruction in Zhouqu since 1949.

Debris flow	Destruction
June 1961	1 dead and 27 injured. Destroyed more than 160 houses and 89 acres of farmland. Damaged 2 roads and 8 temporary bridges; traffic was interrupted for 45 days.
July 1978	2 dead and 56 injured. Destroyed more than 98 houses and 107 acres of farmland. Damaged a bridge and blocked the Lianglang highway. Post offices and their communication facilities were seriously damaged.
May 1989	51 injured. Destroyed more than 360 houses and 157 acres of farmland. Damaged 10 bridges and roads in urban and suburban areas. Water supply was cut off for 46 days; power and communication facilities were interrupted for 15 days.
April–June 1992	87 injured. Destroyed 344 houses and 217 acres of farmland. Water, electricity, transportation, and communication facilities were interrupted for 47 days; Diversion works for the Sanyanyu basin were seriously damaged.
July 1993	Destroyed 40 houses and 51 acres of farmland. Damaged diversion works built in May 1989, roads, and the water supply. Cement plant, brick factory, and other enterprises were seriously affected.
August 2010	1492 dead, 273 missing, and 2387 injured. Destroyed 63,615 houses and 233 of acres of farmland. Water, electricity, transportation, and communication facilities were completely cut off; 6025 households in 2 communities and 15 administrative villages were seriously affected.

3.2. Data processing

Survey questions were answered by selecting one of five choices, represented as A, B, C, D, and E for each question. Basic data about each respondent (used as the influencing factors) was required to be complete for the questionnaire to be considered valid. The questions on public concern about debris-flow-disaster consequences were answered by multiple choices, as described. Similarly, the questions on public concern about debris-flow disaster and the four indicators implying the acceptability of debris-flow disasters could only be responded to through selection of one of the provided answers corresponding to A, B, C, D, or E.

A Likert scale was used to facilitate quantitative analysis of acceptability based on the four indictors. The choices of A, B, C, D, and E were scored as 5, 4, 3, 2, and 1, respectively, which signify very high, high, moderate, low, and very low acceptability. Thus, the average acceptability of debris-flow disasters for each indicator may be calculated using Eq. (1).

$$\overline{A} = \frac{n_A \times 5 + n_B \times 4 + n_C \times 3 + n_D \times 2 + n_E \times 1}{n} \quad (1)$$

where $\overline{A}$ is the average value of debris-flow-disaster acceptability for each indicator $(1-5)$; n_A, n_B, n_C, n_D, and n_E are the number of respondents that chose A, B, C, D, and E for the indicator, respectively; and n is the total sample number.

We divided the average values of debris-flow-disaster acceptability