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Technical Note

Statistical and probabilistic analyses of impact pressure and discharge of debris flow from 139 events during 1961 and 2000 at Jiangjia Ravine, China

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ABSTRACT

Debris flows often cause catastrophic damage to communities in the downstream area, by direct impact and deposition. Theoretical predictions of impact pressure and volume of discharge, however, still remain very challenging, mainly due to inadequate understanding of the complex problems and limited field data at the local scale. In this study, the maximum impact pressure (P_{max}) and total discharge (Q_{total}) of 139 debris flow events that occurred during 1961 and 2000 in the "debris museum" of China (i.e., the Jiangjia Ravine) are reported and interpreted with statistical tests and probabilistic analyses. Four common probabilistic models (Normal, Lognormal, Weibull and Gamma distributions) are used to simulate the distributions of P_{max} and Q_{total}. The level of fitting of each model is assessed by performing two quantity-based statistic goodness-of-fit tests (Chi-square and Kolmogorov–Smirnov tests). The field data show that during the period from 1961 to 2000, the maximum values of P_{max} and Q_{total} are 744 kPa and 1,751,537 m^3, respectively. It is suggested by the goodness-of-fit tests that the Weibull distribution is the only model (among the four probabilistic models) that is able to capture the distributions of P_{max} and Q_{total} of both surge and continuous flows. Using the verified Weibull distributions and Gaussian copula approach, univariate and bivariate exceedance probability charts considering P_{max} and Q_{total} are developed. Regression models between P_{max} and Q_{total} are also established.

1. Introduction

Catastrophic hazards due to debris flow are frequently encountered in mountainous areas all over the world. Debris flow imposes destructive threats to infrastructures (transportation systems, buildings and lifelines) and inhabitants in the downstream areas, by direct impact and sediment deposition (Ngadisih et al., 2014). China is a country in which debris flows are frequently encountered. According to Kang et al. (2004), approximately 45% of the area of China (10^6 km^2) has suffered from debris flows. For example, the recent destructive hazard that occurred in Southern China (Zhouqu, in Gansu Province) in 2010 claimed 1467 lives and buried two villages. Despite the hazardous consequences of debris flows, many infrastructures still need to be constructed in mountainous areas, due to scarcity of usable land.

In order to protect the infrastructures and people from debris flows, one common solution is to construct either rigid or flexible barriers above the downstream area. Rational design of any barrier system largely depends on reasonable estimations of the maximum impact pressure (P_{max}) and total discharge (Q_{total}) induced by a debris flow. In addition to their importance in engineering design, P_{max} and Q_{total} are also two key elements to gauge the risk of the debris flow. Currently, it is still challenging to predict P_{max} and Q_{total} (Iverson, 1997; Eidsvig et al., 2014; Gartner et al., 2014), due to limited understanding of the complex behaviour of debris flows (Chang et al., 2011; Hu et al., 2011). In addition, there is a lack of field data of P_{max} and Q_{total} at the local scale (Liang et al., 2012).

As a result, the key scope of this study is to present and analyse the statistics of P_{max} and Q_{total} from 139 debris flow events that occurred in the Jiangjia Ravine, China. Statistical analyses on the field data are carried out by simulating the distributions of P_{max} and Q_{total} using four common probabilistic models (Normal, Lognormal, Weibull and Gamma distributions). The level of fitting of each model is assessed by performing two statistical goodness-of-fit tests (Chi-square and Kolmogorov–Smirnov tests). Probabilistic models which are not rejected by the goodness-of-fit tests are then used to develop exceedance probability charts, for the estimation of P_{max} and Q_{total}. Not only does this study aim at developing site-specific semi-empirical equations and design charts for local authorities, but it is also intended to shed light on the natural variability of debris flow from a statistical perspective.

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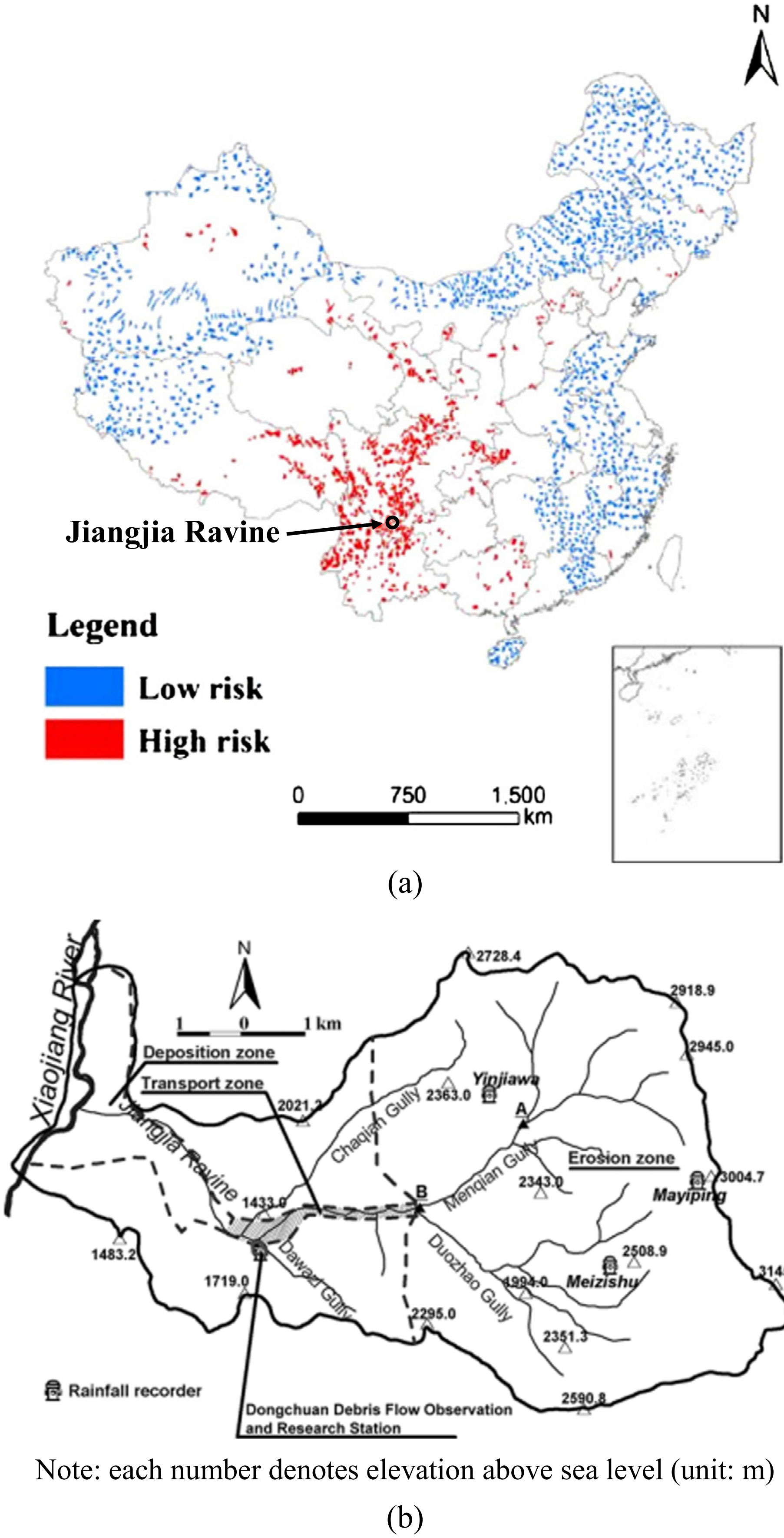

Fig. 1. (a) Spatial distribution of debris flow hazards in China (modified from Liang et al., 2012); (b) Plan view of Jiangjia Ravine (Cui et al., 2005).