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Statistical approach to earthquake-induced landslide susceptibility

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ABSTRACT

Susceptibility analysis for predicting earthquake-induced landslides has most frequently been done using deterministic methods; multivariate statistical methods have not previously been applied. In this study, however, we introduce a statistical methodology that uses the intensity of earthquake shaking as a landslide triggering factor. This methodology is applied in a study of shallow earthquake-induced landslides in central western Taiwan. The results show that we can accurately interpret landslide distribution in the study area and predict the occurrence of landslides in neighboring regions. This susceptibility model is capable of predicting shallow landslides induced during an earthquake scenario with similar range of ground shaking, without requiring the use of geotechnical, groundwater or failure depth data.

1. Introduction

The study of earthquake-induced landslide susceptibility on a regional scale commonly requires the employment of an analytical slope-stability method and the infinite-slope model (Wilson and Keefer, 1985; Jibson and Keefer, 1993; Harp and Wilson, 1995; Jibson et al., 1998, 2000; Liao, 2004). This method requires calculation to determine the limit-equilibrium of the slope stability given the strength parameters, failure depth, and groundwater conditions for every calculation point in the study area. This requirement causes immense problems in terms of data acquisition and control of spatial variability of the variables (Hutchinson, 1995; Guzzetti et al., 1999).

In traditional landslide susceptibility analysis (LSA), it is most common to use a statistical approach where landslide inventories and causative factors are utilized to build a susceptibility model for the prediction of future landslides. Many different methods and techniques for assessing landslide hazards have been proposed and tested. These have already been systematically compared and their advantages and limitations outlined (Carrara, 1983; Varnes, 1984; Carrara et al., 1995; Hutchinson, 1995; Chung and Fabbri, 1999; Guzzetti et al., 1999; Chung, 2006; van Western et al., 2006; Keefer and Larsen, 2007). Most of these approaches require multi-temporal landslide inventories so that the susceptibility model can predict landslide occurrence over a given time period (Guzzetti et al., 1999).

In the study of earthquake-induced landslides, the landslide inventory is naturally event-based; it is not possible to use a multi-temporal landslide inventory. Therefore, the temporal significance of a susceptibility model should incorporate the use of a triggering factor, like that used in the deterministic method. In this study, we demonstrate our new method using an example. We first look at data from the Kuohsing area in central western Taiwan, where many landslides were triggered by the 1999 Chi-Chi earthquake (Liao and Lee, 2000). The results are then validated by looking at an example from the neighboring Tungshih area.

2. Regional setting

The island of Taiwan has an area of 36,000 km^2. The highest peak is Yushan, which is 3952 m above sea level, and there are numerous other peaks over 3000 m. Taiwan is tectonically active being on the collision zone between the Asiatic continent and the Luzon Arc (Chai, 1972; Bowin et al., 1978; Teng, 1990). Active crustal deformation (Bonilla, 1975, 1977; Yu et al., 1997), frequent earthquakes (Hsu, 1971; Tsai et al., 1977; Wu, 1978), numerous typhoons and a high erosion rate (Dadson et al., 2003) presently characterize the rapid earth altering processes and changing landforms of the region.

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