Geomorphology 112 (2009) 190–204

Contents lists available at ScienceDirect

Geomorphology

journal homepage: www.elsevier.com/locate/geomorph

Determining landslide susceptibility in Central Taiwan from rainfall and six site factors using the analytical hierarchy process method

Chun-Hung Wu, Su-Chin Chen *

Department of Soil and Water Conservation, National Chung Hsing University, No. 250, Guoguang Rd., South District, Taichung City 402, Taiwan, ROC

ARTICLE INFO

Article history:
Received 5 April 2008
Received in revised form 25 May 2009
Accepted 1 June 2009
Available online 12 June 2009

Keywords:
Landslide susceptibility assessment model
Landslide-susceptibility threshold value
Analytical hierarchy process
Rainfall events
Taiwan

ABSTRACT

This work provides a landslide susceptibility assessment model for rainfall-induced landslides in Central Taiwan based on the analytical hierarchy process method. The model considers rainfall and six site factors, including slope, geology, vegetation, soil moisture, road development and historical landslides. The rainfall factor consists of 10-day antecedent rainfall and total rainfall during a rainfall event. Landslide susceptibility values are calculated for both before and after the beginning of a rainfall event. The 175 landslide cases with detailed field surveys are used to determine a landslide-susceptibility threshold value of 9.0. When a landslide susceptibility assessment value exceeds the threshold value, slope failure is likely to occur. Three zones with different landslide susceptibility levels (below, slightly above, and far above the threshold) are identified. The 9149 landslides caused by Typhoon Toraji in Central Taiwan are utilized to validate the study's result. Approximately, 0.2%, 0.4% and 15.3% of the typhoon-caused landslides are located in the three landslide susceptibility zones, respectively. Three villages with 6.6%, 0.4% and 4.9% of the landslides respectively are used to validate the accuracy of the landslide susceptibility map and analyze the main causes of landslides. The landslide susceptibility assessment model can be used to evaluate susceptibility relative to accumulated rainfall, and is useful as an early warning and landslide monitoring tool.

Crown Copyright © 2009 Published by Elsevier B.V. All rights reserved.

1. Introduction

In Taiwan, rainfall events during the rainy season (May to September) frequently induce landslides. Prediction of such landslides is an important means of mitigating these geological disasters. Landslides are controlled by a complex set of natural- and human-related site factors; however, and forecasting different types of landslides requires different methods, techniques, and tools. Numerous methodologies have been developed to assess and map landslide susceptibility (Bishop, 1955; Sidle, 1992; Dietrich and Montgomery, 1994; Carrara et al., 1999; Guzzetti et al., 2000; Marta et al., 2005; Jiang et al., 2006). Such methodologies generally employ hydrological and statistical models. Hydrological models assess slope stability on the basis of topographical, hydrological, and soil texture parameters, and calculate the equilibrium safety factor along a critical slip surface using the ordinary method of slices (Fellenius, 1927) or its variations (Bishop, 1955; Janbu et al., 1956; Morgenstem and Price, 1965; Spencer, 1967). Sidle (1992) also utilized limit-equilibrium techniques to assess slope stability with vegetation-root cohesion. Dietrich et al. (1995) applied the theory of colluvial soil thickness, which addresses soil profile development from bedrock, to determine slope stability. Jiang et al. (2006) used the contact element method to simulate landslide displacement. These assessments depend on whether the safety factor exceeds 1.0. Statistical models, in contrast, assess slope stability by means of multivariate analysis of selected and weighted site factors such as geology, topography, climate, land use and vegetation. Several methods have been proposed to establish statistical models for different study areas. Chung and Fabbri (2004, 2008) developed the two-stage approach, which involves creation of a hazard map with likelihood ratio functions and estimation of the occurrence probability of future landslides. Komac (2006) derived a landslide susceptibility model using the analytical hierarchy process and multivariate statistics. Numerous studies have also used logistic regression to evaluate the probability of landslide occurrence (Guzzetti et al., 1999; Dai and Lee, 2002; Ayalew and Yamagishi, 2005).

Rainfall is the primary factor triggering landslides in Taiwan, and can also be used as a key factor in predicting where and when landslides will occur. Several studies have used rainfall characteristics, such as duration, intensity, maximum and antecedent rainfall during a particular period, to identify the threshold value for landslide initiation. Caine (1980) investigated 73 shallow landslides and used local rainfall records to determine an upper rainfall threshold of $I = 14.82D^{-0.39}$, where I is rainfall intensity (mm h^{-1}) and D is rainfall duration (h). Some studies (Caine and Mool, 1982; Brand et al., 1984; Cannon and Ellen, 1985; Larson and Simon, 1993; Jakob and Weatherly, 2003) applied the rainfall intensity–duration equation to estimate the threshold. With regard to specific rainfall characteristics, Wieczorek and Sarmiento (1983) used total rainfall duration before a specific rainfall intensity occurs; Govi et al. (1985) applied total rainfall during a specific period after rainfall starts; and Crozier (1986) utilized the ratio of total rainfall to antecedent rainfall.

* Corresponding author. Tel.: +886 4 22851558; fax: +886 4 22853967.
E-mail address: scchen@nchu.edu.tw (S.-C. Chen).

0169-555X/$ – see front matter. Crown Copyright © 2009 Published by Elsevier B.V. All rights reserved.
doi:10.1016/j.geomorph.2009.06.002

Guzzetti et al. (2004) identified the local rainfall threshold on the basis of local rainfall and landslide records; they concluded that landslide activity in Northern Italy initiates 8–10 h after the beginning of a storm and that the most significant activity occurs in response to rainfall intensities of 8–10 mm h^{-1}. However, only a limited number of studies have investigated the relationship between rainfall and landslide susceptibility by using a statistical model to determine the threshold value for landslide initiation.

This study explores landslide susceptibility in Central Taiwan through use of rainfall distribution and the inventory of landslides caused by Typhoon Toraji in 2001 to develop a landslide susceptibility assessment model (LSAM) employing the analytical hierarchy process (AHP) method. It discusses the threshold value for landslide initiation caused by rainfall events, and analyzes when and where landslides are likely to occur.

2. Regional setting

The study area in Central Taiwan encompasses an area of 6232 km^2 and consists of Nantou County and the townships of Herping, Wanrung and Alisan (Fig. 1). This region has a subtropical climate. The dry season from November to March has an average rainfall of 801.7 mm (23.4% of annual rainfall), and a wet season from April to October has an average rainfall of 2624.6 mm (76.6%). Most rainfall events occur during the wet season and are often associated with typhoons.

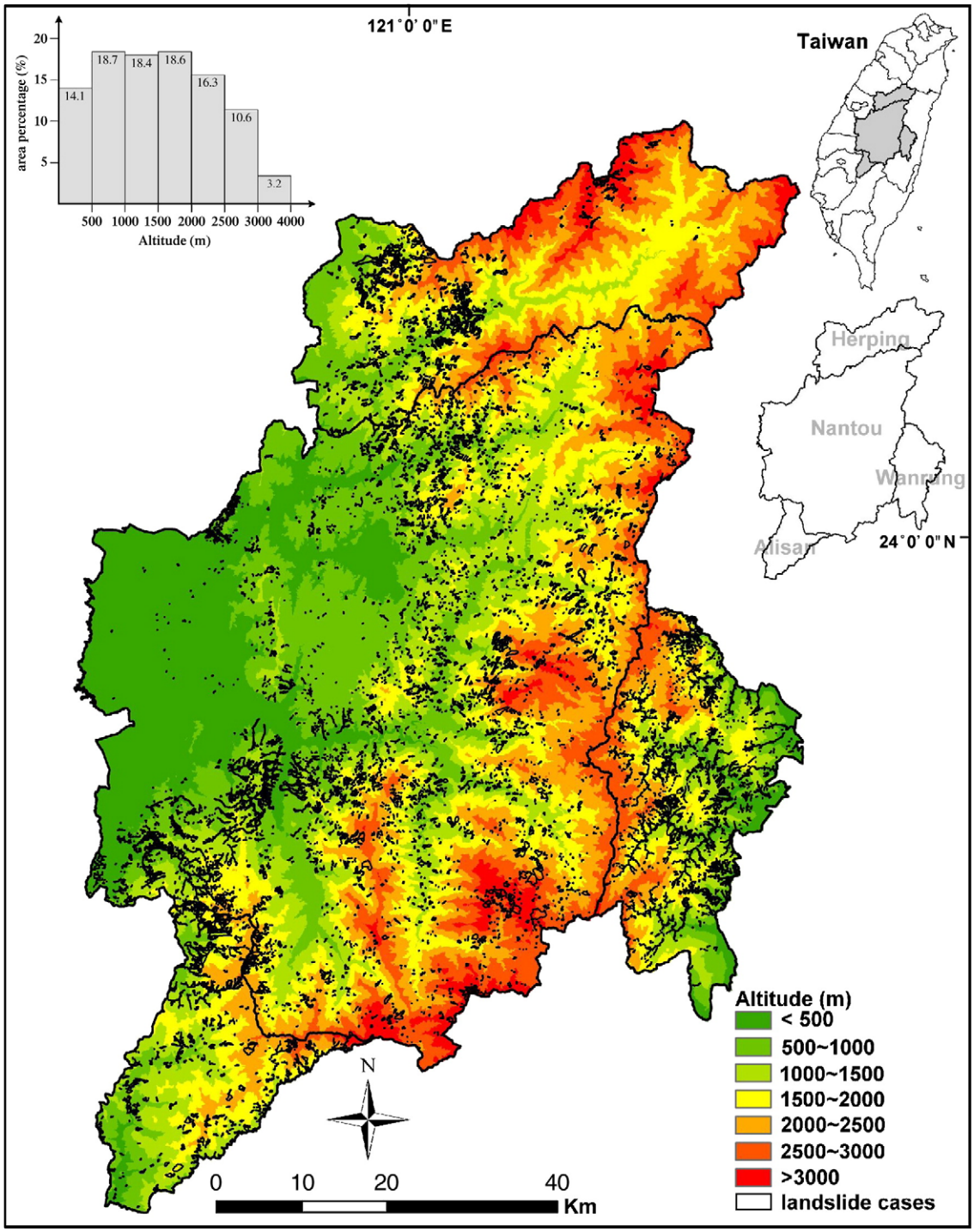

Fig. 1. Altitude of the study area in Central Taiwan and inventory of landslides caused by Typhoon Toraji.

Download English Version:

https://daneshyari.com/en/article/4686233

Download Persian Version:

https://daneshyari.com/article/4686233

Daneshyari.com