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Manifestation of an adaptive neuro-fuzzy model on landslide susceptibility mapping: Klang valley, Malaysia

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ABSTRACT

The purpose of the present paper is to manifest the results of the neuro-fuzzy model using remote sensing data and GIS for landslide susceptibility analysis in a part of the Klang Valley areas i Malaysia. Landslide locations in the study area were identified by interpreting aerial photographs and satellite images, supported by extensive field surveys. SPOT 5 satellite imagery was used to map vegetation index. Maps of topography, lineaments, NDVI and land cover were constructed from the spatial datasets. Seven landslide conditioning factors such as altitude, slope angle, plan curvature, distance from drainage, soil type, distance from faults and NDVI were extracted from the spatial database. These factors were analyzed using a neuro-fuzzy model (adaptive neuro-fuzzy inference system, ANFIS) to construct the landslide susceptibility maps. During the model development works, total 5 landslide susceptibility models were obtained by using ANFIS results. For verification, the results of the analyses were then compared with the field-verified landslide locations. Additionally, the ROC curves for all landslide susceptibility models were drawn and the area under curve values was calculated. Landslide locations were used to validate results of the landslide susceptibility map and the verification results showed 98% accuracy for the model 5 employing all parameters produced in the present study as the landslide conditioning factors. The validation results showed sufficient agreement between the obtained susceptibility map and the existing data on landslide areas. Qualitatively, the model yields reasonable results which can be used for preliminary landuse planning purposes. As a conclusion, the ANFIS is a very useful tool for regional landslide susceptibility assessments.

1. Introduction

Landslides are one of the recurrent natural hazard problems throughout most of Malaysia. According to local newspaper reports (The Star, 2008), in the years 2006–2008 but also in 2009, heavy rainfalls triggered numerous landslides and mud flows along many parts in Peninsular Malaysia. These landslides cost millions of dollars of property loss and even loss of lives. The landslides that occurred along the New Klang Valley Express highways (NKVE) region in the year 2003 have alerted the highway authorities and other governmental organizations towards the seriousness of landslide management and prevention. Landslides in Malaysia are mainly triggered by tropical rainfalls causing failure of the rock surface along fracture, joint and cleavage planes. The lithological units of the country are quite stable but continuous uncontrolled urbanization lead to deforestation and erosion of the covering soil layers, thus causing serious threats to the slopes.

Recently, the Klang Valley area of Selangor state has faced numerous landslide and mudflow events and much damage occurred in these areas. However, only little effort has been made to assess or predict these events which resulted in serious damages. Through scientific analyses of these landslides, one can assess and predict landslide-susceptible areas and even the events as such, and thus reduce landslide damages through proper preparation and/or mitigation. Therefore, understanding the landslides and preventing them is one of the serious challenges in Malaysia. To achieve this aim, in this study, landslide susceptibility analyses have been performed based on the definition of Varnes and IAEG (1984), and verified in the study area using the adaptive neuro-fuzzy inference system (ANFIS) because the ANFIS model has not been used for landslide susceptibility mapping purposes previously although it is a suitable and powerful inference system. The study includes three main stages such as landslide inventory, analyses and verification studies.

In recent years, depending on developments of microcomputers and special softwares, an important increase in regional landslide susceptibility assessments has been provided. There have been many studies carried out on landslide susceptibility evaluation using GIS; for example, Guzzetti, Carrarra, Cardinali, and Reichenbach

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(1999) summarized many landslide hazard evaluation studies based on geomorphological relationships between landslide types, pattern; and the morphological, lithological and structural settings. Recently, there have been studies on landslide susceptibility evaluation using GIS, and many of these studies have applied probabilistic models (i.e. Akgün & Bulut, 2007; Clerici, Perego, Tellini, & Vescovi, 2006; Dahal et al., 2008; Lee & Lee, 2006; Lee & Pradhan, 2006, 2007; Pradhan, Singh, & Buchroithner, 2006; Pradhan & Youssef, 2010), logistic regression analysis (i.e. Akgün, Dag, & Bulut, 2008; Can, Nefeslioglu, Gokceoglu, Sonmez, & Duman, 2005; Gorum, Gonencgil, Gokceoglu, & Nefeslioglu, 2008; Lamelas, Marinoni, Hoppe, & Riva, 2008; Lee, 2005; Lee & Sambath, 2006; Lee, 2007a; Nefeslioglu, Gokceoglu, & Sonmez, 2008; Pradhan, 2010a; Pradhan et al., 2008; Tunusluoglu, Gokceoglu, Nefeslioglu, & Sonmez, 2008; Wang & Sassa, 2005), geotechnical model (i.e. Carro, De Amicis, Luzi, & Marzorati, 2003; Gokceoglu & Aksoy, 1996; Gokceoglu, Sonmez, & Ercanoglu, 2000; Shou & Wang, 2003; Youssef, Pradhan, Gaber, & Buchroithner, 2009; Zhou, Esaki, Mitani, Xie, & Mori, 2003), fuzzy logic and artificial neural network models (i.e. Catani, Casagli, Ermini, Righini, & Menduni, 2005; Choi, Oh, Won, & Lee, 2009; Ercanoglu and Gokceoglu, 2002; Ermini, Catani, & Casagli, 2005; Kanungo et al., 2006; Lee et al., 2003; Lee et al., 2003; Lee et al., 2004; Lee, 2007b; Lui et al., 2006; Lee, Ryu, & Kim, 2007; Melchiorre et al., 2008; Nefeslioglu et al., 2008; Pradhan and Lee, 2010a; Pradhan et al., 2009, 2010; Pradhan, 2010b, 2010c; Pradhan & Pirasteh, 2010; Pradhan and Lee 2010a, 2010c).

Previously, little work has been done on landslide susceptibility in Malaysia. Pradhan and Lee (2007) have performed landslide susceptibility and risk analysis for the Penang Island using a frequency ratio and logistic regression model. Recently, Pradhan and Lee (2010b) have compared three landslide susceptibility maps generated by frequency ratio, multi-variate logistic regression and neural network model for Penang Island. In the last few years, landslide susceptibility evaluation using GIS and soft computing techniques such as fuzzy logic, and artificial neural network models have been applied by researchers in different countries (i.e. Arora, Gupta, & Gupta, 2004; Caniani, Pascale, Sdao, & Sole, 2008; Ercanoglu & Gokceoglu, 2004; Lee et al., 2003, 2004). Recently, Pradhan and Lee (2009) have used ANN model with different training sites for landslide hazard and risk analysis at the Penang Island in Malaysia.

The main difference between the present study and the approaches described in the aforementioned publications is that a neuro-fuzzy model was developed and applied for landslide susceptibility analysis.

2. Geographical and geological settings of the study area

In this research, a landslide-prone area in the Klang Valley in Selangor, was selected for landslide susceptibility analysis using ANFIS based neuro-fuzzy model. The study area is located approximately between 2° 40'E and 3° 50'E and 101° 30'N and 102° 0'N (Fig. 1). The landuse types of the study area are mainly of peat-swamp forest, plantation forest, inland forest, scrub, grassland and ex-mining area.

Tectonically the study area forms a part of the Sunda Shield. Its folded mountain system regionally strikes north to north–west,

Fig. 1. Location map of the study area.