UNIVERSITI PUTRA MALAYSIA

LANDSLIDE HAZARD ANALYSIS USING FREQUENCY RATIO MODEL

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By

MEHRNOOSH JADDA

Thesis submitted to the School of Graduates Studies, University Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

August, 2009

I would like to dedicate this thesis with love to

the memory of my father "Mohammad Jadda"

to keep his spirit alive

Abstract of thesis presented to the Senate of University Putra Malaysia in fulfilment of the requirement for the degree of Master of Science.

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Chairman: Dr Helmi Z. M. Shafri, PhD

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In the north part of Iran (Alborz Mountain belt), landslides occur frequently due to climatologic and geologic conditions and high tectonic activities, that results, annually, millions of dollars financial defect excluding casualties and unrecoverable resources. The reliable hazard map would help to mitigate the consequences of landslide occurrences by land-use management and other strategies. This paper evaluates the hazardous area in Marzan Abad (Central Alborz, North part of Iran) using probabilistic–Frequency ratio (PFR) model, Geographic Information System (GIS) and Remote sensing techniques. Hazardous areas have been analyzed and mapped using the landslide occurrence factors by frequency ratio model.

In GIS platform, layers such as geology, geomorphology, soil, slope, aspect, elevation, annual precipitation, land use, distance from faults, lineaments, roads and drainages were displayed, manipulated and analyzed. The validation of hazard map has been estimated with the validation group of actual landslides and rate curves method. The Area Under the Curve (AUC) evaluates how well the method predicts landslides. The results have showen satisfactory agreement between prepared hazard map and existing data on total landslide locations (93.60%) and validation group of landslide locations (91.68%) So, the methodology used in this study was validated.

Final hazard map classified in five hazardous classes (very high, high, moderate, low and non hazardous area). Receiver Operating Characteristic curve method (ROC curve) was used to validate the classification and based on its area under the curve value, final classification was evaluated as excellent classification (AUC=0.94).

This study evaluates geology, soil and distance to road networks as the most effective factors on landslide analysis and deep valleys, old landslide traces, area near the roads and faults as the most hazardous areas for landslide occurrence in Marzan Abad area.

Abstract tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah

ANALISIS BAHAYA TANAH RUNTUH MENGGUNAKAN MODEL NISBAB FREKUENSI

Oleh

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Ogos, 2009

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Di bahagian utara Iran (Alborz Mountain belt), tanah runtuh kerap berlaku disebabkan oleh keadaan iklim dan geologi, aktiviti tektonik tinggi yang memberi hasil tahunan, masalah kewangan yang berjuta dolar tidak termasuk kecelakaan dan sumber tidak berganti. Peta risiko yang dipercayai dapat membantu untuk mengurangkan akibat kejadian tanah runtuh daripada pengurusan guna tanah dan strategi lain. Kertas ini mengkaji kawasan berisiko di Marzan Abad (Pusat Alborz, bahagian utara Iran) menggunakan contoh nisbah kekerapan-kebarangkalian (PFR), GIS dan remote sensing. Kawasan berisiko dianalisa dan dipetakan mengguna faktor kejadian tanah runtuh dari contoh nisbah kekerapan.

Di dalam GIS, lapisan seperti geologi, geomorfologi, tanah, kecerunan, aspek, ketinggian, hujan tahunan, guna tanah, jarak dari gelinciran, raut, jalan raya dan lembang saliran dipapar, dimanipulasi dan dianalisa. Pengesahan peta risiko dianggarkan dengan menggunakan pengesahan daripada kumpulan tanah runtuh sebenar dan kaedah kadar lengkungan. Kawasan di bawah lengkungan (AUC) menilai betapa baik kaedah ini meramal tanah runtuh. Keputusan menunjukkan persetujuan memuaskan antara peta risiko yang dibuat dan data yang sedia ada pada jumlah lokasi tanah runtuh (93.60%) dan pengesahan kumpulan lokasi tanah runtuh (91.68%). Oleh itu, metodologi yang digunakan dalam kajian ini adalah disahkan.

Peta risiko terakhir dikelaskan dalam 5 kelas risiko (sangat tinggi, tinggi, sederhana, rendah dan kawasan bukan risiko). Kaedah lengkungan ROC digunakan untuk mengesah pengkelasan dan berdasarkan pada keputusan AUC, pengkelasan terakhir dinilai sebagai pengkelasan unggul (AUC=0.94). Bagaimanapun analisis faktor digunakan untuk mengkaji kesan faktor in pada risiko tanah runtuh.

Kajian ini menilai geologi, tanah dan jarak ke jaringan jalanraya sebagai faktor yang sangat efektif pada analisa tanah runtuh dan lembah dalam, kesan tanah runtuh lama, kawasan berhampiran dengan jalan dan gelinciran sebagai kawasan yang sangat berisiko untuk kejadian tanah runtuh di kawasan Marzan Abad

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Additional thanks are given to all my friends for their friendship and I wish the best of luck to everyone. Finally, every sincere and special appreciation is extended to all my family, specially grandmother and grandfather, who gave effortlessly their love, support and prayers throughout my academic career.

I certify that a Thesis Examination Committee has met on 27th August 2009, to conduct the final examination of Mehrnoosh Jadda on her thesis entitled "**Landslide hazard analysis using frequency ratio model**" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the master degree).

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This thesis was submitted to the Senate of University Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of **Master of Science**. The members of the Supervisory Committee were as follows:

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DECLARATION

I declare that the thesis is my original work expect for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at University Putra Malaysia of at any other institution.

Mehrnoosh Jadda

Date

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CHAPTER 1

INTRODUCTION

1.1. Introduction

Natural hazards like landslides, avalanches, floods and debris flows can result in a lot of property damage and human losses in mountainous regions. Landslides are among the most hazardous natural disasters and during the years, landslide hazard and risk have been attempted to be assessed and its spatial distribution to be portrayed (Metternicht *et al*., 2005). This geological phenomenon includes a wide range of ground movement and generally defined as a down slope movement of a mass of soil and rock material (Cruden, 1991).

Landslides are very common geological slope failure phenomenon in some countries like Brazil, Peru, Malaysia and Iran. Generally, lots of their areas have been subjected to slope failure under the effect of numerous factors, and triggered by events such as extreme rainfall or earthquake or both.

Landslides result from interdependent spatial-temporal processes, including hydrology (rainfall, evaporation, transpiration and groundwater), vegetation surcharge (weight of vegetation), root strength, soil and bedrock condition, topography, and human activities (Wu and Sidle, 1995). Human activities, such as urban expansion and deforestation, also increase the potential for landslides and result in adverse impacts to the environment

(Burton and Bathurst, 1998). The recent increasing of land-use changes has raised the level of landslide susceptibility, particularly in mountainous regions.

In the US alone, landslides cause an estimated annual average economic cost of $1.5 billion. In Japan, annual losses are $2 billion and in Italy, annual losses are more than $2.6 billion. Worldwide in the 20th century the Asian continent has experienced the most landslide events (220 reported), the Americas reported the most deaths and injuries (25,000+) while Europe had the highest average damage per single event ($23 million) (Gorsevski and Jankowski, 2008). In Iran also, because of its climate and heavy rain falls, landslide has a high level occurrence and makes a lot of losses and economic. Therefore more attention needs to be paid to the people who live within landslide-prone areas. And more available database about them and the measures taken are needed to avoid loss.

Mapping areas susceptible to landslides is essential for land-use management and should become a standard tool to support land management decision-making. Consequently, the need for methodologies which guide managers to choose the best management strategies while minimizing impacts from land-use activities in vulnerable slope areas is increasing (Gorsevski *et al*., 2006). The spatial prediction of landslide hazards is one important field of geo-scientific research in which statistical classification rules have been applied. As noted by Uromeihy and Mahdavifar (2001), the preparation of a landslide hazard zonation map is the first step in assessing the degree of hazard and evaluating its potential.

The aim of the zonation methods is, to identify areas that are susceptible to future landslides, based on the knowledge of past landslide events and terrain parameters, geological attributes and other possibly anthropogenic environmental conditions that are associated with the presence or absence of such phenomena (Brenning, 2005). During the recent decades, the use of landslide susceptibility and hazard maps for land use planning has increased significantly. These maps rank different sections of land surface according to the degree of actual or potential landslide hazard, thus, planners are able to choose favorable sites for urban and rural development. The reliability of these maps depends mostly on the applied methodology as well as the available data used for the hazard risk estimation (Parise, 2001).

In recent years, the use of GIS for landslide hazard modeling has been increasingly used. It is because of the development of commercial systems, such as ArcGIS (ESRI) and the quick access to data obtained through Global Positioning System (GPS) and remote sensing. Moreover, GIS is an excellent and useful tool for the spatial analysis of a multi-dimensional phenomenon such as landslides and for the landslide susceptibility mapping (Carrara *et al*., 1999; Lan *et al*., 2004; Van Westen *et al*., 1999).

1.2. Statement of problem and justification

Recently, South Asia has suffered extensive loss of life and colossal damage to property as a result of geo-hazards such as tsunami, earthquake, floods, cyclones and landslides. In short, it is notable that the Asia itself, as the most hazardous and vulnerable continent, has been suffering more than 50 per cent of events, 90 per cent of casualties and 49 per cent of the losses of natural disasters in the globe, leading to an average rate of 41 thousand tolls and 29 billion dollars loss a year. The maximum economical casualties caused by natural disaster within 1900 to 2005 occurred in Asia and Pacific (www.unescap.org).

Landslides pose a serious threat to natural resources, human lives and property. Landslides have represented 4.89% of the natural disasters that occurred worldwide during the years 1990 to 2005 (Kanungo *et al*., 2006). This trend would be continued in future if unplanned urbanization and development be increased and/or irregular deforestations be continued.

Landslide is one of the main natural hazards in Iran that annually makes great economic and personal defect. Primary estimations show that annual fiscal defects of landslide are about 500 billion Rials (about $600 Million) which does not involve the loss of unrecoverable resources (Nasiri, 2005).

Mountainous feature, high tectonic activity, geological and climatologically variety make the Iranian plateau capable for the occurrence of various kinds of landslides (especially in Alborz and Zagros active mountainous belts). Concerning climate condition, economy, and tourist attractions, the landslide risk along Alborz range specifically in central Alborz has a higher risk than other regions (Shoaei *et al*., 2005).

Although, there are some studies such as Uromeihy and Mahdavifar (2001), Moghadas and Ghafoori (2007) and Tangestani (2009), that tried to evaluate landslide hazard in some study areas of Iran, but there is no enough attention to evaluate the landslide hazardous areas in Iran, especially in central Alborz. Consequently, landslide losses continue to grow at an ever-increasing rate as human development expands into unstable hillside areas. As an example, in Iran's northern province of Mazandaran (January 2007), a landslide has inflicted heavy damages on the water, power, communication installations, utilities and a large number of residential units in the stricken area. This incident started initially with a slow landslip in the area, which has accelerated and turned into a landslide, damaging 20 villages. The costs of damages have been estimated about $5,000,000. Landslides at the Hajiabad- Oshan road (2003), Fasham- Meygon road (2006), Atashgah-e-Karaj (2008) (Figure 1.1) and several landslides and rock falls that occurred on the Chalus–Tehran road (induced by Baladeh–Kojour earthquake on 28th May 2004), also have indicated what can happen when things go wrong.

It is difficult to ignore the huge losses to buildings, roads, rails, power lines, water lines, mineral equipments, oil industry, urban infrastructures, dams, forests, natural resources, farming lands and rural areas caused by landslide. In addition to physical losses, landslides cause environmental damage. When debris flows, generated by landslides entering rivers, lakes or other water bodies negatively affect water quality.

Seeing the need of resolving and minimizing such untoward incidences, the aim of this study is to test of frequency ratio model in the study area to identify areas that are more susceptible to future landslides and preparation of landslide hazard map of the area. Final hazard map will be used to do the best decisions about land use management in the future and avoid more losses.

Frequency ratio model was recently used by some researchers (Lee and Dan ,2005; Lee and Pradhan, 2006; Lee *et al*., 2004 and Yilmaz 2008) in Vietnam, Malaysia, Korea and Turkey. The achieved results are completely satisfiable and comparable with the more complicated statistical models. Despite the success of this model it has never been applied for landslide studies in Iran. In this study, this model is going to be tested and used for the first time in Iran.

This model is based on the observed relationships between each factor and the distribution of landslides. Hazardous areas can be identified based on the knowledge of past landslide events, terrain parameters and other effective factors on landslide to do the best decisions about land use management in the future and avoid more losses. In this study landslide hazard map of the area has been prepared, its validity verified and effect of each factor was evaluated.

Figure 1.1 Landslide in Atashgah-e- Karaj 2008