LANDSLIDE SUSCEPTIBILITY MAPPING OF KOTA KINABALU AREA SABAH USING GIS AND REMOTE SENSING

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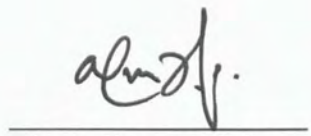

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ABSTRACT

LANDSLIDE HAZARD MAPPING IN KOTA KINABALU AREA USING GIS AND REMOTE SENSING

The aim of this study was to evaluate the landslide susceptibility in Kota Kinabalu area, Sabah, using the Geographic Information System (GIS) and Remote Sensing tools. In this study, the landslide susceptibility was analyzed using the Probabilistic Frequency Ratio (PFR) model. Based on the PFR analysis model, three main causative factors were identified for the landslide occurrences in the study area; the geomorphological factor, the human factor and the geological factor. The geomorphological factor (79.21%) was the most influencial causative factor followed by the human factor (72.42%). The relations between the attribute factors and landslide locations in the study area were determined by their likelihood value based on the spatial analysis. Generally, areas generally featuring steep slope gradient and widely underlain by river (1^{st} order) with human interference in the natural setting of thick forest cover was prone to landslide occurrence.

ABSTRAK

Kajian ini dijalankan untuk mengkaji bencana tanah runtuh di sekitar kawasan Kota Kinabalu dengan menggunakan aplikasi GIS dan remote sensing. Dalam kajian ini, model analisis nisbah kebarangkalian berdasarkan frekuensi telah digunapakai. Berdasarkan model analisis, terdapat tiga faktor utama yang mempengaruhi kejadian tanah runtuh di kawasan kajian; faktor geomorfologi, faktor manusia dan faktor geologi. Faktor geomorfologi (79.21%) merupakan faktor yang paling mempengaruhi kejadian tanah runtuh di kawasan kajian diikuti oleh faktor manusia (72.42%). Hubungan antara faktor penyumbang kejadian tanah runtuh dengan lokasi tanah runtuh telah dikenalpasti berdasarkan nilai kebarangkalian dalam analisis spatial. Secara amnya, kawasan yang mempunyai kecerunan tinggi dan diliputi oleh sungai (order pertama) berserta gangguan aktiviti manusia mempunyai kebarangkalian yang tinggi untuk mengalami bencana tanah runtuh.

TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

LIST OF PHOTOGRAPHS

CHAPTER 1:

INTRODUCTION

1.1 Preface

Landslide is one of the major natural hazards which account for enormous property damage and life causalities. In Malaysia, most of the landslide occurred in hilly areas and closely related to the geology and geomorphology of the area, geotechnical properties of the slope material and in some cases poor or improper management of slope area (Frederick, 2003). In Kota Kinabalu area, a total of 14 landslides occurred and recorded during a day of heavy rainfall in early 2000 (Mineral and Geoscience Department of Malaysia, 2000) in which several road and public properties were damaged. In early 2001, a large scale landslide occurred at the northern part of Kota Kinabalu area where three persons were killed and several houses damaged. Table 1.1 shows some of the major landslide incidents in Kota Kinabalu area.

Social and economic losses due to landslides can be reduced by means of effective planning and management. These approaches include:

a) Restriction of development in landslide prone area.
b) Use of physical measures (drainage, slope geometry, structures and etc) to prevent or control landslide.
c) Development of warning system.

With the advancement of remote sensing and Geographic Information System (GIS), this study can provide a useful reference and information to indentify landslides-prone areas by utilising the technologies for landslide assessment and prediction in the study area.

Table 1.1: Major landslide incidents in Kota Kinabalu area from year 1999-2010

DATE	LOCATION	CASUALTIES	REMARK
Jan, 1999	Kg. Garib, Inanam, Kota Kinabalu, Sabah	One person killed	
Jan, 2001	Sepanggar bay, Menggatal, Sabah	3 persons killed and several houses damage	
Jan, 2005	Sepanggar bay, Menggatal, Sabah	1 person killed	
Jun, 2010	Taman Jindo, Ph 7 Kota Kinabalu, Sabah.	None	15 houses affected (5 houses badly damages)
Jun, 2010	Inanam-Minintod Road Kota Kinabalu, Sabah.	None	Road closed (temporarily)
July, 2010	Taman Fantasi, Kota Kinabalu, Sabah.	None	Several houses affected
July, 2010	Fong Yin Ting Road, Kota Kinabalu, Sabah.	None	Road closed (temporarily)
July, 2010	Chang Yai Villa Apt. Kota Kinabalu, Sabah.	None	3 houses affected
Aug, 2010	Jalan Asrama Kota Kinabalu, Sabah.	None	Road closed (temporarily)

Source: Minerals and Geosciences Department of Malaysia, Sabah (1999-2010).

1.2 Study Area

The study area lies on the western coast of Sabah. It is bounded by latitudes 5°57'N and 6°14'N and longitudes 116°00'E and 116°16'E. Sabah occupies the northern part of Borneo which is bounded by the South China Sea to the west and Sulu Sea to the east (Figure 1.1).

The map sheet was named Kota Kinabalu after the capital city, and the mapped area extends eastwards as far as Kiulu, Tuaran town in the north and Likas in the south which also includes the nearby islands of Gaya and Sepanggar. The total land area is approximately 540 km^2 with two main administrative districts comprising of Kota Kinabalu and Tuaran (Figure 1.2).

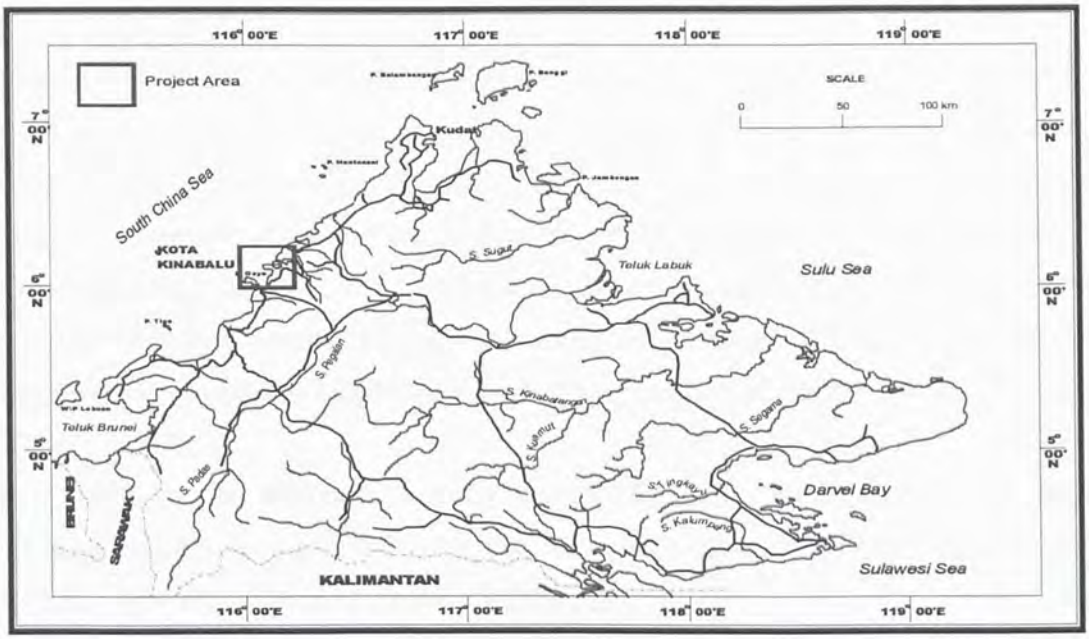


Figure 1.1: Study area

Figure 1.2: The administrative boundary of the study area

1.2.1 Accessibility

A good network of roads around the city of Kota Kinabalu provides excellent access to the area and its surroundings. Tuaran Road and Sulaman Road are among the main roads linking Kota Kinabalu City to other areas such as Tuaran and Tamparuli districts. These two roads are very important for the development of the surrounding areas especially Sepanggar. Most of the roads in the study area are built along the coast and between valleys. Telipok-Natai and Kokol roads are the only roads that cut through the mountains (Figure 1.3) and these roads had been upgraded in early 2009.

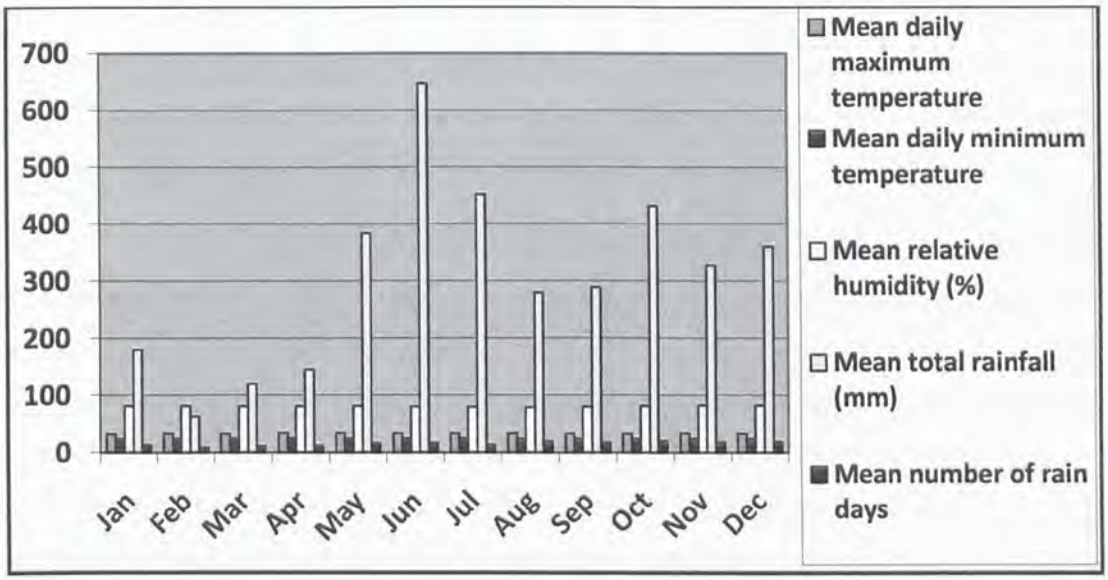
The nearby islands are easily reached by boat from the mainland. Boat services can be arranged with the boat operators around the city jetty. On the islands, there are no roads except for footpaths.

Figure 1.3: The road system in the study area

1.2.2 Climate

Kota Kinabalu experiences a typical equatorial climate, with constant temperature, considerable rain and high humidity. Two prevailing monsoons characterise the climate in this part of Sabah; the Northeast Monsoon and the Southwest Monsoon. The Northeast Monsoon occurs between November and March, while the Southwest Monsoon occurs between May and September. There are also two successive inter-monsoons from April to May and from September to October. Temperature variation throughout the year is small. However, April and May are generally the hottest months, while December and January are often the coolest (Table 1.2). However, rainfall varies markedly throughout the year. February and March are typically the driest months while rainfall peaks in the inter-monsoon period around October. Humidity is relatively high, generally over 80% throughout the year.

Table 1.2: Weather averages for Kota Kinabalu for 2005 and 2006 (Source:Kota Kinabalu International Airport Meteorological Station)



1.2.3 Landuse

Kota Kinabalu Wetland Centre is the only remains of 24 hectares of mangrove forest that once existed extensively along the coastal region of Kota Kinabalu. Previously known as Likas Swamp or Likas Mangrove and later Kota Kinabalu City Bird Sanctuary, the Centre came foremost out of 20 wetlands selected by the Sabah

Wetlands Inventory Committee in 1986. Apart from Kota Kinabalu Wetland Centre, most of the swamps and lowlands are located in the Tuaran area which is in the northern part of the study area.

The landuse in Kota Kinabalu area are classified into 11 categories which are building, forest, the secondary forest, the disturbed forest, the urban and developed area, cultivated land, grassland, mangrove and tidal swamp, lake/pond, clear land and the paddy field. The nearby islands are still covered with dense jungle (Gaya Island and Sepanggar Island) and the Gaya Island is under the National Park administration, where wild animals and primary jungle are protected.

1.2.4 Topography

The topography of the study area can be divided into five categories; the high land, the moderate high land, the moderate low land, the low land and very low land (Figure 1.4). The height of the high land ranges from 725m to 900m; the moderate highland ranges from 500m to 725m, followed by the moderate low land with height ranging from 275m to 500m and the lowland area which is 50m to 275m high. Elevation below 50m is categorised as the very low land area.

Most of the high to moderate high lands (500-900m) are located in the east and southeast of the study area. These areas are free from physical development activities except for a number of slope cuttings for the upgrading of roads. As for the moderate low land (275-500m), most of these areas are covered by the cultivated plant such as rubber trees and fruit trees. The lowlands (50-275m) are best described as the undulating hills and small isolated foothills located at the western part of the study area. Most of these areas were cleared for new housing developments and road networks. In the north, the area is generally very low and is underlain by the coastal plain.

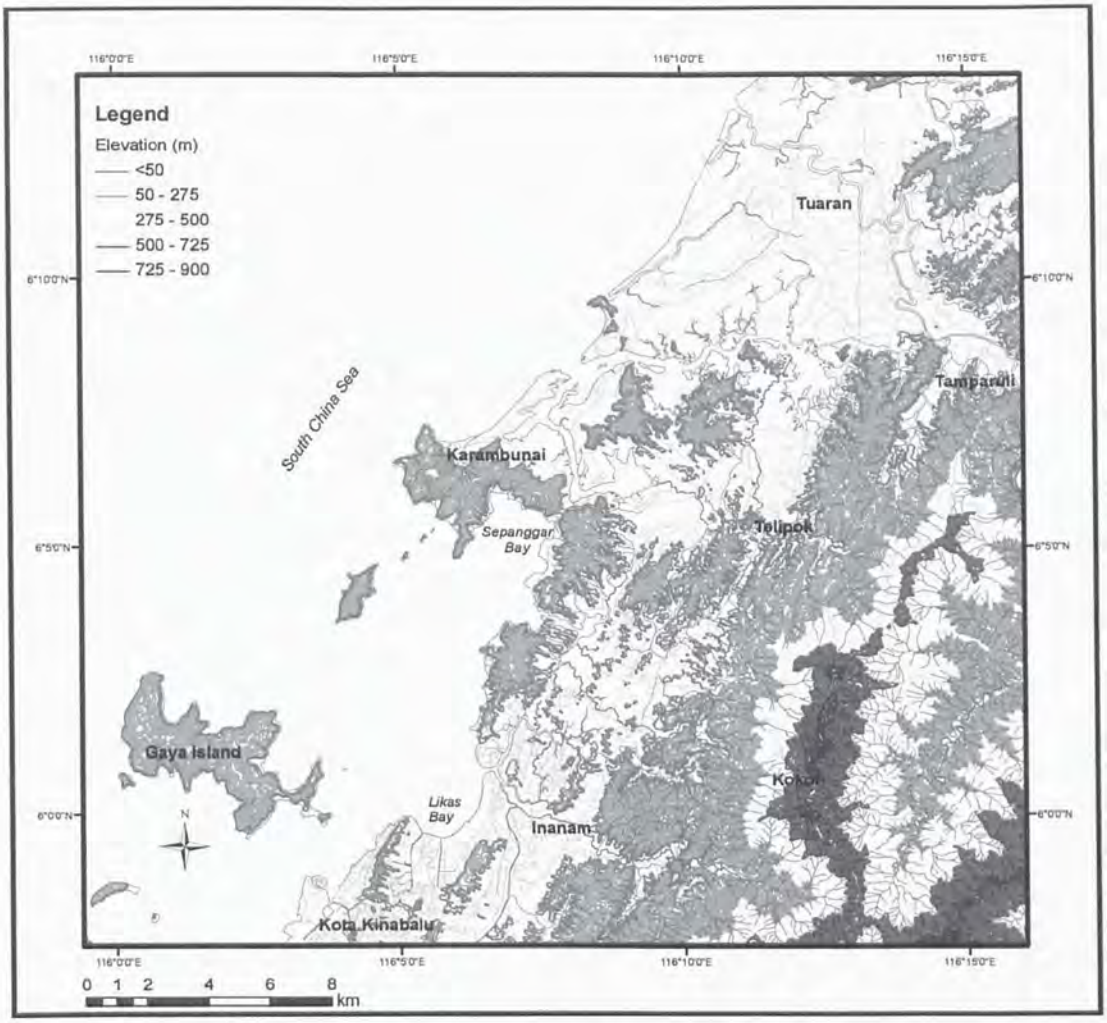


Figure 1.4: Elevation map of Kota Kinabalu area

1.2.5 Drainage

Sungai Tuaran, Sungai Inanam and Sungai Tombongan are among the main rivers in the study area (Figure 1.5). Sungai Tuaran, Sungai Mengkabong and Sungai Tambalang are located in the northern part of the study area while Sungai Likas, Sungai Inanam and Sungai Menggatal are in the southern part of the area. Sungai Tombongan is the only river located in the interior and flows toward the east. There are four different directions of river flows in the study area; Southeast to Northwest direction, South to North direction, Northwest to Southeast direction and Southwest to Northeast direction, before draining into the South China Sea. The main rivers in

the area are mostly wide and meandering indicating the current flows is slow where they allow the sediments to be deposited on the river bed.

The drainage systems in the study area are generally dendritic. However, at places upriver, they formed V-shaped valleys which suggest the area is underlain by hard rock.

Figure 1.5: Drainage system of the study area

1.3 Objective

The general objective of this study is to assess the landslide susceptibility area using the remotely sensed data and GIS techniques together with field observation. The objective can be elaborated as follows:

i. To assess the landslide susceptibility area using the Probabilistic Frequency Ratio (PFR) model (Saro Lee & Pradhan, 2006).
ii. To relate the relationship between the landslide occurrences with the attribute factors.
iii. To determine the most influencial attribute factors to the landslide occurrences in the study area.
iv. To produce a landslide susceptibility index map with the scale of 1:50,000.

1.4 Method of study

This study is divided into three stages; namely preliminary investigation, detailed investigation and interpretation and presentation of the study result.

1.4.1 Preliminary Investigation

Desktop study was part of the preliminary investigation which involved an extensive literature review pertaining to every aspect of the geological information available in the area. A base map with the scale of 1:50,000 were prepared for reference during fieldworks. A short field trip was carried out at this stage to obtain the general idea of the ground features of the study area.

Preliminary study and review of literatures have been carried out both at Geosciences and Mineral Department of Malaysia, Sabah and Malaysian Remote Sensing Agency (MACRES) in Kuala Lumpur. Preliminary study also included the interpretation of aerial photographs and satellite images, which is an important method for assessing geological characteristic and landslide investigation in the study area. Seven series of aerial photographs (year 1969-1972) at the scale of 1:30,000

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