# LANDSLIDE SUSCEPTIBILITY MAPPING USING LOGISTIC REGRESSION METHOD AND GIS TOOL IN CAMERON HIGHLANDS

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## ABSTRACT

This paper presents landslide susceptibility analysis around the Cameron Highlands area, Malaysia using a geographic information system (GIS) and remote sensing techniques. Topographical, geological data and satellite images were collected, processed, and constructed into a spatial database using GIS and image processing. Five landslide occurrence factors were selected as: topographic slope, topographic aspect, rainfall, geology map and land use from satellite images. Previous records of landslides in the study area were mapped based on inventory reports and satellite image processing. Landslide susceptibility map was then generated based on logistic regression equation in a raster GIS environment and classified in five susceptibility classes. The classes are divided into the study area has very low landslide susceptibility, low susceptibility, moderate susceptibility, high susceptibility and very high susceptibility. About 99.978% of the study area has very low landslide susceptibility, 0.003% has low susceptibility, 0.002% has moderate susceptibility, 0.001 % has high susceptibility and 0.015% has very high susceptibility.

## ABSTRAK

Kertas kerja ini membentangkan analisis tanah runtuh kecenderungan sekitar kawasan Cameron Highlands, Malaysia menggunakan sistem maklumat geografi (GIS) dan teknik penderiaan jauh. Topografi, data geologi dan imej satelit yang dikumpul, diproses, dan dibina ke dalam pangkalan data spatial menggunakan GIS dan pemprosesan imej. Lima faktor kejadian tanah runtuh telah dipilih seperti: topografi cerun, topografi aspek, hujan, peta geologi dan penggunaan tanah daripada imej satelit. Rekod terdahulu tanah runtuh di kawasan kajian telah dipetakan berdasarkan laporan inventori dan pemprosesan imej satelit. Peta kecenderungan Tanah Runtuh kemudiannya dihasilkan berdasarkan persamaan regresi logistik dalam persekitaran GIS raster dan dikelaskan dalam lima kelas kecenderungan. Kelas-kelas dibahagikan kepada kawasan kajian mempunyai kecenderungan tanah runtuh yang sangat rendah, kecenderungan rendah, kecenderungan sederhana, kecenderungan yang tinggi dan kecenderungan yang sanga tinggi. Mengenai 99,978% daripada kawasan kajian mempunyai kecenderungan tanah runtuh sangat rendah, 0.003% mempunyai kecenderungan rendah, 0.002% mempunyai kecenderungan yang sederhana, 0.001% mempunyai kecenderungan yang tinggi dan 0.015% mempunyai kecenderungan yang sangat tinggi.

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| | |
|---|---|
| LSM | Landslide Susceptibility Modeling |
| GDEM | Global Digital Elevation Model |
| GIS | Geographical Information System |
| LR | Logistic Regression |
| VLS | Very Low Susceptibility |
| LS | Low Susceptibility |
| MS | Moderate Susceptibility |
| HS | High Susceptibility |
| VHS | Very High Susceptibility |
| GPS | Global Positioning System |
| 3D | 3-Dimensions |
| METI | Ministry of Economy, Trade, and Industry |
| NASA | National Aeronautics and Space Administration |

# CHAPTER 1

# 1 INTRODUCTION

## 1.1 General

Malaysia lately was surprised by some natural disaster, especially involving soil structure. Most recent cases, on 6th Nov 2014 which three people have been killed, while five others were injured at the scene of the flash flood and landslide in Cameron Highlands, occurs about 6.30pm.

Landslides are common natural hazards in Malaysia triggered by heavy rainfall and anthropogenic effects. The country has suffered from landslide events for many decades which were responsible for loss of human life and the damage to the natural resources and developmental projects. In recent years, a more prominent attention of landslide damage has prompted a huge imperative in the advancement on the unstable land in numerous parts of the country. These parts still need more attempts from geoscientists and civil engineers through a scientific analysis in assessing and predicting landslide prone areas to decrease landslide damage with a proper preparation of slope management.

Landslides are described as the mass movements of slopeforming materials comprising rocks, soils, artificial fill, or a combination of these (Umar, Pradhan, Ahmad, Jebur, & Tehrany, 2014). Causal factors such as slope and erosion accumulate in an area and the onset of a rapid trigger event releases the landslide. These trigger events include rainfall, weathering, surface fractures, and earthquakes. The landslide evolves swiftly and can have devastating impacts on the well-being of humans and communities, especially in regions where urban residential areas coincide with mountainous terrains. The economic costs include relocating communities, repairing physical structures, and restoringwater quality in streams and rivers (Akbari, Yahaya, Azamirad, & Fanodi, 2014).

The are among the worst landslide occurred in the modern history of Malaysia. One of the most tragic cases is 48 killed when one of the three blocks of 12-storey Highland Towers condominium in Taman Hillview, Hulu Klang, Selangor, collapsed due to landslide, thus collapses the building on December 11, 1993. There are several cases of landslide that involving highway in Malaysia. Genting Sempah (Kuala Lumpur–Karak Highway) landslide. A landslide at Km 34 feeder road to Genting Highlands, Pahang on 30th June 1995, where 20 people were killed and 22 sustained injuries. Besides that, landslide tragedy shocked the country when killed 5 lives other than bury the 14 bungalows at Taman Bukit Mewah, Bukit Antarabangsa, Ampang, Selangor on December 6, 2008.

In response to the rising problems and the realization of the impacts of landslide hazards in the country, this study been proposed for this Final Year Project and hopefully will be able to solve the above problems. An increasing proportion of building and road development takes place on poor ground, which presents the geotechnical engineer with the challenge of providing satisfactory foundation performance at low cost. According to Audi Munir (2009), ground behavior can be modified by ground treatment so that the ground properties are improved and heterogeneity is reduced. Ground improvement has developed largely as an experienced based technology.

## 1.2 Objectives

The objectives of this research are:

1) To quantify spatial hazard using logistic regression method.
2) To identify the hazard map for Cameron Highlands, Pahang.

3) To enhance the application of geo-spatial information systems and earth observation technology technique in landslides modeling.

## 1.3 Scope of Study

As land for development becomes limited, the need for improved ways for mapping and monitoring of potential landslide areas has become more important. Thus, zoning is used to demarcate and map areas for development control. Scope area of this study have been focusing at Cameron Highlands, Pahang where the impacts of landslides is higher cause Cameron Highlands have through a lot of mountainous topographical.

This research employs GIS tools and logistic regression analysis for LSM. To achieve the objective of the study, a geodatabase including all investigated factors was generated. The affected area by landslides was mapped by preliminary investigation using Aster GDEM.

Basically, this study will collect all relevant data of the study area which obtained from the local organization for landslide mapping on soil curvature, aspect of the soil, slope of soil, land use, rainfall distribution and lithology. This study attempts to extend the application of logistic regression because the method requires fewer theoretical assumptions than discriminant analysis.

## 1.4 Background of Study

Historically the design of structures on unstable and soft compressible soils has created problems for civil engineers. Construction without some sort of soil treatment is usually impractical due to unpredictable long-term settlement and distribution of soil along side the development area.

Preventing natural disaster such as landslide is one of the best practices in watershed management activities. Susceptibility map provides a document that describes the likelihood or possibility of new landslides occurring in an area, and therefore helping to reduce future potential damages in future. Depending on the landform, several factors can cause or accelerate the landslide.

Regarding to this type of problems, susceptibility map are one of the practical method. GIS is an effective tool for managing and manipulating the spatial data with an appropriate model for mapping landslide susceptibility so that the soil may be made to serve better for engineering purposes.

LSM and analysis is done through varieties of methods and techniques. It includes land morphology, soil, slope, aspect and climate conditions, A detailed outline of the various methods and their advantages and disadvantages are systematically compared in literature.

Different techniques or tools may be adopted with various approaches for determining potentially unstable areas or landslide susceptibility assessment. These techniques can be divided into four groups: expert evaluation, statistical methods, nondeterministic model and mechanical approach. Expert evaluation is the most widely used approach for landslide hazard evaluation.

## 1.5 Problem Statement

As stated before, there are varoius different techniques or tools approaches for determining potentially unstable areas or landslide susceptibility assessment. Technically, the objective doing all this types of methods are to reduce the chances of landslide occurs.

Lately, Malaysia had been encountering landslides. The event of the landslides is a direct result of both natural and human elements. This can be seen as a dual process that blend both the elements together. Natural and human factors can not be held obligated for the reason for a landslides as a solitary unit as both components are decently joined. The occurrence of such disaster in the locale has not been caused on just by the common components and not exclusively be created by the human factors.

The common element which cause landslide in Malaysia is a result of the rise of pore water weight by saturation of slope material from either extraordinary or delayed. By this, it debilitates the capacity of the soil to hold the ground because of the permeability of the soil to lose its original profile (nutrients).

The slope of the saturated with water to form debris flows or mudflows. Concentrated mixture of rock and mud may decimate the trees, houses, andcars and obstructing the extension. Mud mixed with stream can result in destroying flooding along the route.

Landslides cause damage to transportation routes, utilities, and buildings and create travel delays and other side effects. For example, block roads, damage and destroy homes, locally disrupt water mains, sewers, and power lines, and damage oil- and gas-production facilities.

**Figure 1.1: The damage Due to Landslide**

## 1.6 Significant of Study

The study is significant in a number of ways. Firstly, the study has generated information on landslide occurrences which will be used for comparative purposes. The study also fills in critical gap since landslide studies have been concentrated in Cameron Highlands, Pahang.

Secondly, the study has generated information which may be used in the decision-making process to mitigate landslide occurrences. Various government departments, local authority and also others could make use of the information, thereby being in a position to check and control the landslides. They could use the information in the preparation of landslide disaster management plans which could reduce or avoid losses from landslides by ensuring prompt assistance to the victims, and achieve rapid and effective recovery. The information may help in the development of an early warning system. They also could use the information to determine best sites for human settlements.

Thirdly, the study could assist the local people in the affected areas to understand better how stable or unstable their physical environments are. They may be well informed of danger-prone areas and risks posed by landslides. This study will provide information on how human activities have contributed to instability of the slopes.

Fourthly, in order to build a safe of structure or slope design, engineer should consider the properties and characteristic of soil at site. Therefore this project is carried out to study the soil properties of slope. This data of soil properties are important to update the exist data. Some data was obtain about past ten years ago and now, maybe the properties of soil are change due to external factor such as weather and flood disaster.

# CHAPTER 2

# 2 LITERATURE REVIEW

## 2.1 Introduction

Landslide in a strict sense, are movement of a mass rock, debris or soil along a downward slope due to gravitational forces. The inherent properties of the earth material, encompassing various geo-technical factors, make a particular area susceptible to landslide. A variety of movements are associated with landslides such as flowing, sliding, toppling or falling. Many landslides exhibit a combination of two or more types of movements resulting in a complex type (Wu, Chen, Cheng, Yin, & Török, 2014).

The statistical analysis of landslide susceptibility is focused around the speculation of the environmental conditions that caused landslide occurrence in the past will lead to slope failures in the future. Beside that, the expanding of construction that involving slope also increases due to the same cause. When slope fails, it is usually not possible to pinpoint a single cause that acted alone and resulted in instability. For example, water influences the stability of slopes in many ways that it is impossible to isolate one (1) effect of water and identify it as a cause failure.

Due to the development of GIS, the statistical approach to the assessment of landslide susceptibility has extremely grown in popularity over the last decades. Such a strategy relies on the assumption that new slope-failures are more likely to occur under the same conditions as those that led to past and present instability (Felicísimo, Cuartero, Remondo, & Quirós, 2013), (Van Den Eeckhaut, Reichenbach, Guzzetti, Rossi, & Poesen, 2009; Vergari, Della Seta, Del Monte, Fredi, & Lupia Palmieri, 2011)

.Hence, the statistical techniques allow an investigator to assess the probability of future landsliding by defining quantitative relationships between the spatial distribution of a set of environmental variables and the occurrence of slope failures.

According to the previous researches, Human activities (Das, 2011);(Vergari et al., 2011) (Umar et al., 2014), land morphology (Gorsevski, Jankowski, Gessler, & Diego, 2006), soil, slope, aspect and climate conditions, proximity to some watershed features such as rivers and fault are the most important parameters. Natural slope that have been stable for many years may suddenly fail because of changes in topography, seismicity, groundwater flows, loss of strength, stress changes, and weathering.

Therefore LR should be one of the methods, LR; (Archer, Lemeshow, & Hosmer, 2007) in order to prrdict the landslides occuring in the area. LR is a very popular statistical technique that has been used worlwide to obtain accurate prediction of landslides occurance. .

## 2.2 Geographical Information System (GIS)

GIS is one of numerous technologies advancements that have changed the way geographer's research and able to give to society. In the previous two decades, these data innovations have been given the huge effect and impact on research techniques indicates to topography, and in the general ways in which researchers and scholars impart and collaborate (Foote, 1997).

GIS is a system designed to capture, store, manipulated, manage and present all type of geographically data. A GIS is a spatial information base, a concept that has no such prohibitive limits. In a general sense, the term portrays any data system that incorporates stores, edits, analyzes, shares, and displays geographic data. GIS applications are instruments that permit clients to make intelligent inquiries (client made quests), analyze spatial data, edit information in maps, and present the consequences of all these operations.

Geographical Information System is an organized collection of computer hardware, software, geographic data, and personnel designed to efficiently capture, store, update, manipulate, analyze, and display all type of geologically referenced data (Feizizadeh, Shadman Roodposhti, Jankowski, & Blaschke, 2014).

GIS is an expansive term that can allude to various diverse innovations, processes, and methods. It is connected to numerous operations and has numerous applications related to engineering, planning, management, and transport/logistics. For that reason, GIS and location intelligence applications can be the establishment for some area empowered administrations that depend on analysis and visualization.

In this research, GIS and ILWIS will be used to analyze and identify the data related to landslides which include the land use of study area, rainfall distribution, topography map, and observed landslides to create a model of landslide hazard area.

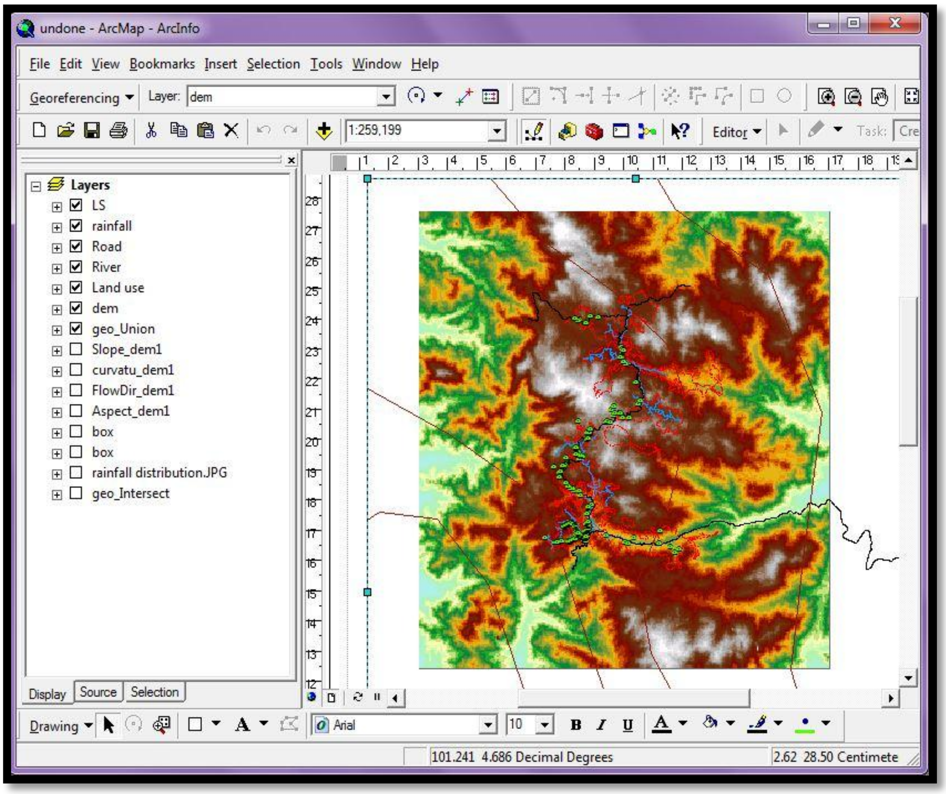


**Figure 2.1: The Example of GIS Application**

## 2.3 Landslide Influencing Parameters

The only way a major role in determining the dependent variable in logistic regression is the more independent variables are included, the more complete the model will be. However, selecting those independent variables with a major role is a difficult task. There are neither inclusive criteria nor guidelines. The general consensus is that any independent variable must be operational (has a certain degree of affinity with the dependent variable), complete (is fairly represented all over the study area), non-uniform (varies spatially), measurable (can be expressed by any of the different types of measuring scales) and non-repetitive (its effect should not account for double consequences in the final result).

In the study area, the main triggering factor for land sliding is the high amount of precipitation. However, the regression analysis does not include precipitation because rain is relatively uniform throughout the study area. The same can be said of seismicity. The contrast in the density of vegetation within the mountains where landslides occur is also hardly visible. Hence, seven landslide-influencing parameters were selected: lithology, bed rock-slope relationship, lineaments, elevation, slope gradient, aspect and proximity to roads.

Following are the factors that affect the landslide occurrences:

1) Lithology
2) Bed Rock-slope Relationship
3) Lineaments
4) Slope Gradient
5) Aspect and Proximity to Roads
6) Seismicity
7) The Density of Vegetation
8) Precipitation of Rain
9) Drainage
10) Climate

### 2.3.1 Lithology

Landslides involve fracturing of the lithosphere on several spatial scales. The lower bound is set by the dynamic fragmentation of rock particles down to sub-millimeter scale during the motion of large bedrock landslides, a process that resembles cataclasis cause by tectonic fault rupture. Thin layer of frictionite formed at large base of large landslide, show evidence if incipient mineral melting similar to hyalomylonite along faults. Frictionite is characterized by physically integrated angular particles of calcium with no evidence of chemical weathering (Weidinger & Korup, 2009).

Lithology is one of the important factors to generate a landslide susceptibility map and it play a major role in determining the site's failure (Pradhan & Youssef, 2010). Every lithological unit has different landslide susceptibility values thus it is important to have the data for susceptibility studies (Caran, Jr, & Thompson, 1982). Thus the landslide susceptibility map that is produced by inaccurate evaluation of weathering unit and degree are unacceptable. In mechanical weathering usually involve an abrasion process which is the movement of rock particles along the bases of the slope causes fragment to knock into each other where the chemical weathering to act on.

### 2.3.2 Bedrock-slope

Bedrock land sliding is a dominant geomorphic process in a number of high-relief landscapes, yet is neglected in landscape evolution models. Frequent small slides produce irregular hill slopes, on which steep toes and head scarps persist until being cleared by infrequent large slides. These steep segments are observed on hill slopes in high-relief landscapes and have been interpreted as evidence for increases in tectonic or climatic process rates. In certain cases, they may instead reflect normal hill slope evolution by land sliding.

### 2.3.3 Slope

The slope stability analysis of the parameter is the slope angle (Akbari et al., 2014) and it is directly related to the landslide which will be used to prepare the landslide susceptibility maps. The slope is exposed surface forming a certain angle to the plane of the horizon. Usually the failure of the slope will associated with a steep slope, but this is not true because there are many cases of slope failure that occurred on gentle slopes.

### 2.3.4 Lineaments

Lineament is a pattern in a factual representation (model) of either the earth's surface or a subsurface datum (whether stratigraphically, structurally, or geophysically defined) and the figure must be linear, continuous, reasonably well expressed (having discernible end points, width, and azimuth), and be related to features of the solid earth. Figures are not lineaments by this definition if they represent either cultural features (such as pipeline corridors, roads, or canals),superficial geomorphic features (such as eolian dunes or shoals of current-transported sediments),or transient climaticorhydrographic features (clouds or cloud shadows, waves,snowdrifts, or, as in one example, a tornadopathway through a forest) unless these features are in fact controlled by geologic trends. Some linear stream channels, lines of vegetation, soi land relief breaks,and other surface alignments do coincide with patterns in the geologic substrate; thesefeatures can, therefore,be recognized as lineaments maps (Caran et al., 1982).

In previous studies show there is related between the lineament and landslide distribution thus it is vital at the early stage of planning to avoid hazard potential from landslide. The lineament is identified as a plane of weakness and a line of landscape which reveal the invisible structure of the rock basement. In fact, the good relation between structured map such as fault trends will allow linemeant to be identified as the structural indication of the particular areas

### 2.3.5 Proximity to Roads

Roadcut is the example of antrophological instability in the mountain area and during the field survey, most of the landslides had occurred along the road corridor (Lee & Pradhan, 2006). A road that had built on the side of the slope will cause a decrease in the load on both topography and on the heel of the slope.

### 2.3.6 Precipitation of Rain

The average annual precipitation in Malaysia is about 2000 – 3000mm varying from place to place. The wettest months are from November to January with the onset of the north-east monsoon which brings heavy rainfall to the east-coast

### 2.3.7 Regolith

The regolith forms by the breakdown of solid bed-rock, through the processes of chemical, biology, and mechanical weathering and complete the transition between bed-rock and soil is included in definition. The regolith contains many different minerals and also many concentration of element that are hazardous to humans. Different physical condition, such as changes in water content, temperature, slope, and pressure control how the regolith behaves.

### 2.3.8 Drainage

The high of annual rainfall cause the most of river system carry a great volume of water relative to their length or catchment areas. The rivers generally flow smoothly directly into the river or catchment area.

### 2.3.9 Climate

Cameron Highlands located at Pahang which is located at East of Malaysia experienced type of climate with high day temperatures and rainfall throughout the year. Day temperatures vary between 28 – 32 degrees Celsius. The flat lowland is hottest while the highlands are much cooler because of modifying effect of altitude. Night time temperature tend to be lower especially towards the later part and average about 20 – 23 degrees Celsius at dawn in the lowlands while 13 degrees Celsius or lower in the highlands.

## 2.4 Weathering and the Formation of Soil

Mass weathering is defined as the downslope movement of products of weathering, erosion, and mass wasting. Weathering is a process of chemical and mechanical alteration marked by the interaction lithosphere, atmosphere, hydrosphere, and biosphere. The resistance to weathering varies with climate, composition, texture and how much a rock is exposed to element.

Weathering processes occurs at the lithosphere/atmosphere interface. This is a zone that extends down into the ground to the depth that air and water can penetrate. In this zone, the rocks make up a porous network, which the air and water migrating through cracks, fractures, and pore space. The effect of weathering often can be seen in outcrops on the side of roads where the road cuts through the zone of alteration into underlying bedrock.

The road cuts and underlying weathered outcroppings of rock shows some similar properties. This upper zone near the surface is made of soil or regolith in which the texture of fresh rock is not apparent. The middle zone shows the rock altered but retaining some of its organized appearance and the lower zone consist of fresh unaltered bedrock.

### 2.4.1 Process of Weathering

There are three main types of weathering. Chemical weathering is the decomposition of rock through alteration of individual mineral grains and it is a common process in the soil profile. Mechanical weathering is the disintegration of rock, generally by abrasion. Mechanical weathering is common in the talus slopes at