VARIABILITY AND RAINFALL AGAINST SLOPE FAILURE FOR PENANG ISLAND

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VARIABILITY AND RAINFALL AGAINST SLOPE FAILURE FOR PENANG ISLAND

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I hereby declare that all corrections and comments made by the supervisor(s)and examiner have been taken into consideration and rectified accordingly.

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ABSTRAK

Hujan merupakan salah satu faktor yang membawa kepada masalah ketidakstabilan cerun di Malaysia terutamanya Pulau Pinang yang mepunyai topografi beralun dan berbukit. justeru itu, kajian ini dijalankan di dua lokasi yang tertentu di Pulau Pinang iaitu di kawasan air itam dan batu lanchang dengan berbantukan perisian IDRISI Selva. Objektif kajian ini adalah pertama untuk mengenal pasti kepelbagaian iklim perubahan parameter, kedua untuk menganalisis menggunakan model yang sesuai untuk analisis tanah runtuh dan akhir sekali untuk menyediakan peta kerentanan tanah runtuh berdasarkan taburan hujan. Variasi hujan tahunan dan monsoon jangka masa panjang (30 tahun) dan (17 tahun) telah dikaji. Daripada plot siri masa dan analisa trend variasi purata tahunan,Batu Lanchang memberikan trend positif. Untuk variasi purata monsoon, monsoon timur laut dan monsoon barat laut, kedua-dua Air Itam dan Batu Lanchang memberikan trend positif. Analisa indeks kejadian ekstrem menunjukkan bahawa perubahan iklim membuatkan kawasan ini ini menjadi lebih lembab dengan jumlah yang tinggi hujan monsun timur laut dan monsun barat daya. Secara keseluruhan, parameter yang digunakan dalam pemetaan tanah runtuh Air Itam dan Batu Lanchang adalah ketinggian, penggunaan tanah, harta tanah dan keamatan hujan dengan penggunaan system IDRISI Selva untuk mengenal pasti kawasan berisiko yang terdedah kepada tanah runtuh.

ABSTRACT

Rainfall is one of the factors that can cause slope instability problems in Malaysia especially Penang Island is one of the areas which have corrugated and hilly topography. Thus, this study had been done throughout the two locations in Penang Island and they are Air Itam and Batu Lanchang with the helps by one of the IDRISI Selva software. The objectives of this study are first to identify variability of climate change parameter, second to analyse using suitable model for landslide analysis and lastly to provide landslide susceptibility maps based on the rainfall distribution. This Yearly and monsoonal variations of long term rainfall (30 years) and (17 years) data were studied. From time series plot and for mean yearly variations, both Air Itam and Batu Lanchang provides positive trend. For mean monsoonal variations for Northeast monsoon and Southwest monsoon, both Air Itam and Batu Lanchang provide positive trends. The climate extreme indices analysis shows that climate change makes this region become wetter with high amount of rainfall in Northeast monsoon and Southwest monsoon. Overall, parameters used in landslide mapping of Air Itam and Batu Lanchang are elevation, land use, soil properties and rainfall intensity with the application of IDRISI Selva to identify risky areas that prone to landslide.

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LIST OF ABBREVIATIONS

COV	**C**oefficient **o**f **V**ariation
DID	**D**epartment of **I**rrigation and **D**rainage
IPCC	**I**ntergovernmental **P**anel on **C**limate **C**hange
SPSS	**S**tatistical **P**roduct and **S**ervices **S**olution
GIS	**G**eographical **I**nformation **S**ystem

NOMENCLATURES

n	Total number of parameter
j	Number of groups or weightage
w_{ij}	The weightage parameter i in group j
P_{ij}	The rating for parameter i in group
n_j	The number of parameter in group j
$\bar{x}$	Mean concentration of parameter
σ	Standard deviation of parameter

CHAPTER 1

INTRODUCTION

1.1 Introduction

In Malaysia, hilly area in Penang Island can be considered as a potential for development because of the attractive setting they provide. Furthermore, hill site development is the sign of luxurious project which can support the tourism country. However, hill area development is often open to risks to constructions, people and environment. Examples of environmental risk at hill areas are erosion, sliding and fall of slope which creates many issues and problems.

Slope failure is one of the common natural disasters that have been a nightmare for all of us especially for those who work in the real estate because it can cause an enormous loss and government become more aware to it. From the experience, slope failure, landslide, flooding and soil erosion has been an example which can cause injury to person, danger to life, environment and economy (Razman, 2005).

The high rise building on hilly terrain becomes the trademark because of the limited land especially in Penang Island. According to Sew and Tan (2003), construction at the hill site with proper planning, design, good construction and maintenance can reduce the risk. Hilly area experience incidence result of landslide threat caused by slope instability, especially the intensity of rainfall in Malaysia is very high and hence, the slope is easily exposed to erosion and landslide. Hence, measures to stabilize slope in the hilly area is very important.

1.2 Problem Statement

The rain activities is one of the natural occurrences that could effects the strength of soil. Penang Island is recorded in having much landslide cases within the past decade. Some of the slope instabilisation is from the rainfall disaster. Because of the problems, local authorities like Ministry of Housing and Local Government (KPKT) in collaboration with Environmental of Department (DOE), Jabatan Perancangan Bandar dan Desa (JPBD), Irrigation and Drainage Department (JPS), Institute of Public Works Malaysia (IKRAM) and several other departments already discussed criteria to control construction activity implementation in hill areas (Chan, 1998).

Several development areas in Penang Island focused near or on hilly site. Even though many guidelines in Malaysia on hilly terrain development have been endorsed by the government to ensure the safety of development, the tragedy in hill slope developments still happens. The issues such as slope failure and soil erosion can affect people and also environment because of the lack of design and management on geotechnical aspect especially which is part of the geotechnical report. Many projects at hill areas expose to failure because of several factors involve in geotechnical which affect environment.

Lee and Pradhan (2006) found that the present research in Penang include the model on landslide and soil erosion hazard as the management of slope but does not include the environmental risk through proposed development area. Based on the information found in the literature, Low et al. (2008), Mukhlisin et al. (2010), and Low and Ali (2012) used the Geographical Information System (GIS) application to perform area based slope hazard assessment and mapping. Thus, the mapping can be used for predicting the landslide occurrence due to parameters.

1.3 Objectives

The objectives of the study are as follows:

1. To identify variability of climate change parameter in Penang.
2. To analyse using suitable model for landslide analysis in Penang.
3. To provide landslide susceptibility maps based on the rainfall distribution in Penang.

1.4 Scope of Study

Study areas has been selected at Air Itam and Batu Lanchang, Penang Island (Malaysia) which has the available 30 years of rainfall data for Air Itam and 17 years of rainfall data for Batu Lanchang provided by Department of Irrigation and Drainage (DID). This project will be using IDRISI Selva to provide landslide susceptibility maps and landslide modelling for the location.

In IDRISI Selva, Landslide hazard mapping model utilising weighted landslide causative factors able to predict which areas that are prone to landslide. The process includes inserting parameters from Malaysian Meteorological Department and Department of Irrigation and Drainage (DID). The parameter from Malaysian Meteorological Department such as type of soil, Digital Elevation Model (DEM) and land use are all important parameters needs to include in analysis through the locations selected in Penang Island area.

1.5 Organization of Thesis

This thesis is divided into five chapters represented all the data obtained and result in detail.

Chapter 1 explains the outline of the thesis including problem statements, followed by objectives and scope of study.

Chapter 2 discusses previous research studies related to improving the problems by earlier researcher. In addition, the general overview of effects of rainfall against slope failure will include in this chapter.

Chapter 3 explain in detail all the procedures and materials involved in this research that were used to achieve the objectives of the research.

Chapter 4 respectively represents the result obtain from the analysis and discussion for the overall result.

Chapter 5 discuss the conclusion and summary of this study based on the result obtained from Chapter 4. Some recommendation for further studies are included in this chapter.

All the references and appendix are attached at the end of this research.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Nowadays, occurrences of slope failure have increased due to the nature of the topography and the weather condition in Malaysia. Poor slope analysis design may cause slope failure which has been known as one of the most frequent catastrophe that can lead to great loss in properties and life. To overcome this problem, analysis of slope failure must be carried out to determine the slope stability. In Malaysia, most landslides occur on man-made slopes due to lack of maintenance, construction negligence and design errors. For the design of the slopes, correct information on soil properties, groundwater regime, geology of the site, selection and methodology for analysis are important factors that require special attention from the design engineer (Gue and Tan, 2002).

2.2 History of environmental issues in Malaysia

In Malaysia, landslides are among the deadly hazards which occur quite frequently during the rainy seasons. Some of the common types of landslide in Malaysia are earth slides, rock falls and debris flow. Landsides have occurred in several parts of Malaysia such as Paya Terubong, Penang, Highland Towers, Kuala Lumpur, and Pos Dipang, Perak, claiming hundreds of lives. Major landslides that occurred within infrastructures have resulted in great economic loss to the public and business compared to those occurring in residential areas due to disruption to the transportation network and property damage as show in Table 2.1 (PWD, 2007a) and Table 2.2 below List of Slope failure in Penang 2003-2009 (The Sun 1996, Neoh 1998, Ooi 2008 & Zainal Abidin et al. 2009).

Table 2.1: History of landslide events (PWD, 2007a)

Events	Fatalities
Highland Tower On 11th December 1993	Killed 48 People When An Apartment Block Collapsed
Gua Tempurung At PLUS Highway In 1995	Killed A Motorist
Debris Flow In Genting Sempah On June 1995	Destroyed Vehicles And Caused 20 Deaths
Debris Flow Pos Dipang, Perak On 30th August 1996	Caused 44 Fatalities
Landslide In A Housing Area At Simunjan, Sarawak On 28th November 2002	Killed 16 Peoples
Reduced A House To Rubbles In Hillview, Ampang On 20th November 2002	Caused 8 Deaths
Rock Slope Failure At Bukit Lanjan (North Klang Valley Expressway) On 26th November 2003	Expressway Being Closed For 6 Months
Debris Flow At Gua Tempurung (Plus Highway) On 12th October 2004	No Fatalities
Taman Harmonis, Selangor On 5th November 2004	Killed A Person
Kampung Pasir, Ulu Kelang, Selangor On 31st May 2006	Killed 4 Peoples
Section 10, Wangsa Maju, Kuala Lumpur On 9th October 2006	No Deaths But The Occupants Of 3 Blocks Of Apartments Have To Be Moved
Km 8.5, Jalan Persekutuan 606 Sepanggar, Sabah On 26th June 2006	Killed A Person And A Number Of Houses Effected
Near Federal Government Quarters At Precint 9, Putrajaya On 22nd March 2007	No Fatalities Were Recorded But 25 Cars Were Destroyed

Table 2.2: List of Slope Failure in Penang From 2003-2009

No	Date	Location	Impact
1	3/11/2009	Batu Maung, Pulau Pinang.	Life threatening
2	02/11/2009	Penang War Museum, Penang	Road was closed
3	22/10/2008	Pangsapuri Taman Paya Terubung, Penang	Destruction of properties
4	09/09/2008	Pantai Acheh, Penang	Life threatening
5	07/09/2008	Jalan Tun Sardon, Penang	Road was closed
6	10/09/2008	Sri Mutiara PLKN Camp, Penang	Building hanging / unsafe
7	08/09/2008	Tun Sardon road, Penang	Road was closed to public
8	05/09/2007	Penang Hill, Penang	Slope erosion occurred
9	12/11/2005	Jalan Paya Trubong, Pulau Pinang	Boulder fell on road
10	05/10/2003	Km 1.4 Tun Sardon road, Penang	Massive slope failure

2.3 Climate

The climatic factors that influence erosion are rainfall amount, intensity, and frequency. Climate effects erosion potential both directly and indirectly. In the direct relation, rain is the driving force of erosion (Goldman et al, 1986).During periods of frequent rainfall a greater percentage of the rainfall will become runoff. This is due to high soil moisture or saturated condition.

The indirect relation is the yearly pattern of rainfall and temperature determines both the extent and growth of vegetation (Goldman et al, 1986). While frozen soil is highly resistant to erosion, rapid thawing of the soil surface brought on by warm rains can lead to serious erosion. Temperatures also influence the type of precipitation. A highly intense rainfall of relatively short duration can produce far more erosion that a long duration storm of low intensity. Areas with warmer climates have thinner organic cover on the soil. Organic matter protects the soil by shielding it from the impact of falling rain and soaking up rainfall that would otherwise become runoff.

2.4 Malaysian Climate Condition

Malaysia is one of the countries with very high amount of annual rainfall. The total annual rainfall amount is between 2,000 to 4,000mm and rainy days between 150 to 200 days yearly. Climate change is rapidly increased and become very serious global issue. The emission and concentration of carbon dioxide and greenhouse gases is affecting the increase in temperature, and thus leading to global warming. The world community is very concerned with the impacts of climate change and the current series of extreme weathers that could possibly affect the global climate systems. Regionally, Malaysian surface climate is influenced by two monsoon regimes namely the southwest monsoon and the northeast monsoon. The southwest monsoon, characterized by low level southwesterly winds, commences in May and usually lasts between 3-4 months up to August. On the other hand, the northeast monsoon is dominated by northeast winds that cross over the South China Sea. The season usually commences in November and ends in February the following year. Intermittently during these period, strong pulses of wind known as cold surge penetrates to the most southern region of the South China Sea (Chang et al., 2005).

Malaysia is one of the countries in the world which is experiencing a warming trend for the past few decades. According to Intergovernmental Panel on Climate Change (IPCC) in year 2001, the global land precipitation has raising about 2% since the early of the 20th century. They also reported in year 2007, the extremely hot temperature, heat waves and heavy precipitation events will contribute to become more frequent. In the past few years, the frequency of long dry period tended to be higher with significant increase in the mean and variability of the length of the dry spells. All the indices of wet in these areas show a decreasing trend. Increasing temperature with long dry periods would give variable result of weather and climate (Deni et al., 2010).

2.5 Malaysian Meteorological Data

The rainfall stations in Malaysia are managed by The Malaysian Meteorological Department. This agency is responsible in gathering and providing results for the public in Malaysia, meteorological data based on daily scientific observation. The average daily rainfall data can be classified into small, moderate, high and very high intensity class of rainfall which can be describe as follow (Varikoden *et al.*, 2011):

i. Small intensity class

For the above class, it is essential for a country like Malaysia to assess the rate of flash flood and the hot spots of flash flood. Based on the previous research, the small intensity class occur more than 70% of time during Northern Monsoon period in all area of Peninsular Malaysia and the relative contributes to the total seasonal rainfall is small in the east coastal area. During the early northeast monsoon seasons the entire region has frequency of occurrence is negligibly small. This indicates that the region receives rainfall from small intensity category during most of the time. The range of rainfall intensity for small intensity class is (I < 4 mm/h).

ii. Moderate intensity class

In Peninsular Malaysia, Northeast monsoon contributes above 30% in the area of Kuala Lumpur and Cameron Highland. This may be due to the organized cloud cluster during the seasons which indicates among the moderate class. The total seasonal rainfall is also less than 25% in most of the place except Terengganu and Johor. In early northeast monsoon period, the rainfall in this intensity class is from 10% to 13%. The range of rainfall intensity for moderate intensity class is between ($4 < I > 8$ mm/h).

iii. High intensity class

The high intensity class usually occur in the east coast belt, especially in Terengganu and Kuantan during the northeast monsoon. During northeast monsoon Period, the eastern regions get heavy rainfall and this may be attributing to the northeast monsoon cold surges (Tangang et al., 2008). The range of rainfall intensity for high intensity class is between ($8< I > 12$ mm/h).

iv. Very high intensity class

This intensity class is crucial to decide the flood prone area because this class is mainly contributing to the total rainfall. Furthermore, in many cases, there were localized centres of prolonged heavy rainfall that leads to flash floods (Juneng et al., 2007). The chances of flash flood are more during northeast monsoon period in the east coastal belts. The range of rainfall intensity for very high intensity class is ($I > 12$ mm/h).

In general, during the northeast monsoon seasons over the eastern and some parts of the western regions have small intensity rainfall which contributes less rainfall and therefore the high and very high intensity rainfall contributes more to these regions during this seasons. Table 2.3 shows the classification of intensity classes.

Table 2.3: Classification of rainfall intensity

Rainfall Intensity		Remarks
mm/H	mm/Day	
< 4 mm/H	< 96 mm/Day	Small
4 < I < 8 mm/H	96 < I < 192 mm/Day	Moderate
8 < I < 12 mm/H	192 < I < 288 mm/Day	High
>12 mm/H	>288 mm/Day	Very High

2.6 Slope Failure

Slope failures are significant natural hazards in many areas throughout the world. Generally, a slope failure can be defined as a downward movement of a large amount of material. For this reason, slope failures are also referred to a mass movements and each type of mass movement has different effect to slope. This kind of finding was supported by Saimi (2009) who also explained that mass movements can be explained as downward movement of rock or soil under impact by gravity**.** Ishak (2009) found that the slope movements are includes into complex movement category which indicates that the slope movement has more than one type of movement involved. The type of slope movements is also classified based on the type of material of the slope as show in Table 2.4.

Table 2.4: Classification of slope failure (Ishak, 2009)

Type	Form	Definition
Falls	Free Fall	Sudden dislodgement of single or multiple blocks of soil or rock which fall in free descent.
	Topples	Overturning of a rock block about a pivot point located below its centre of gravity.
	Rotational Or Slump	Relatively slow movement of an essential coherent block (or blocks) of soil, rock, or soil-rock mixture along some well-defined ach-shaped failure surface.
	Planar Or Translational	Slow to rapid movement of an essential coherent block (or blocks) of soil or rock along some well-defined planar failure surface.
Slides	Subclasses • Block Glide • Wedges • Lateral Spreading • Debris Slide	• A single block moving along a planar surface. • Block or blocks moving along intersecting planar surface. • A number of intact block moving as separate unit with differing displacement. • Soil-rock mixture moving along a planar rock surface.

Cont'd Table 2.4 Classification of Slope Failure (Ishak, 2009)

Avalanches	Rock or debris	Rapid to very rapid movement of an incoherent mass of rock or soil-rock debris wherein the original structure of the formation is no longer discernible, occurring along an ill-defined surface.
Flows	Debris, sand, silt, mud, soil	Soil or rock-soil debris moving as a viscous fluid or slurry, usually terminating at distances far beyond the failure zone: resulting from excessive pore pressure.
Creep		Slow, imperceptible down slope movement of soil or soil rock mixtures.
Solifuction		Shallow portions of the regolith moving down slope at moderate to slow rates in Artic to sub-Artic climates during period of thaw over a surface usually consisting of frozen ground.
Complex		Involves combinations of the above, usually occurring as a change from one form to another during failure with one form predominant.

2.7 Soil erosion

Soil erosion from unpland areas is primaly the result of soil detachment and transport by rainfall and runoff (Van Liew and Saxton, 1983). Soil erosion is a gradual process that occurs when the actions of water, wind, and other factors eat away and wear down the land, causing the soil to deteriorate or disappear completely. In the case of slope, an altered bare surface of the slope with the formation of sheet, rill and gully erosion features will cause instability of the slope. This situation will gradually cause slope failure or landslide as is commonly known (Roslan and Tew, 2004).

2.8 Landslide

The landslide hazard causes severe loss of life, injury, damage to property, destruction of communication networks and loss of precious soil and land. Landslides are universal phenomena, but more than being ‘natural hazards’, they are induced by human activity.

According to Hussein (2004), landslide can be initiated by rainfall, earthquakes, volcanic activity, changes in groundwater, disturbance and change of a slope by man-made construction activities, or any combination of these factors.

2.9 Rating approach

The rating or ranking system is to evaluate the parameter or attribute according to the particular category. Rating especially on risk using the large value or scale to show the particular in risk condition and the small scale show the parameter is safe. Basically, risk value classified to five types which very high, high, moderate, low and very low risk (Budetta et al., 2007).

2.9.1 Rating for landslide hazard

Review from the (Budetta et al., 2007) which develop the rating for landslide at the coastal slopes and cliffs before mapping based on the parameter which deal with topographical, geological, geomechanical, environment and wave hydraulic characteristics of the studied area. The main steps of work are:

1. Choice of parameter relevant to landslide hazard zonation,
2. The analysis of binary interaction between parameters,
3. The weighting of interaction importance,
4. The rating assignment to different classes of parameter values

2.10 Weightage

The important or critical parameters of the slope area which is given seventy per cent weightage are land use stability, slope geometry and soil properties. Casualties of people, slope geometry and land use stability is also given seventy per cent weightage because it has higher ranking from the previous analysis when equal weightage was given. The factors which determine the risk especially in probability land sliding for a particular slope such as geology, slope gradient and aspect, elevation, type of soil (soil grading characteristics) and soil geotechnical properties (Dai *et al*., 2001)are also important.

Table 2.5: Group of Weightage

j	w_i	P_{ii}
1	0.7	P_{11} = Land Used Suitability P_{21} = Geometry Of Slope P_{31}= Soil Properties P_{41}= Soil Grading Characteristics P_{51}= People Casualties
2	0.2	P_{12}= Factor Of Safety P_{22}= Earth Coverage
3	0.1	P_{13}= Distance P_{23}= Blasting Activity

2.11 Geographic Information System

A geographic information system or geographical information system (GIS) is a system for creating and managing spatial data and associated attributes. Theoretically, it is a computer system that capable of integrating, storing, editing, analysing, and displaying geographically-referenced information (after Chang, Kang Tsung, 2004). GIS also defined as a "smart map" tool that allows user to create interactive queries, analyze the spatial information, and editing data. According to Chang and Kang Tsung, (2004), Geographic information system technology can also be used for scientific investigation, resource management, asset management, development planning, cartography and route planning.

2.11.1 Component of a GIS

Likes any other information technology, GIS requires the following four components to work with geographically referenced data (Chang, Kang Tsung, 2004):

a) Computer System. The computer system includes the computer and the operating system to run GIS. Typically the choices are PCs that uses the Windows operating system (e.g. Windows NT. Windows 2000, Windows XP) or workstations that use the UNIX operating system. Additional equipment may include monitors for display, digitizers and scanners for spatial data input, and printers and plotters for hard-copy data display.

b) GIS software. The GIS software includes the program and the user interface for driving the hardware. Common user interfaces in GIS are menus, graphical icons, and command lines.

c) Brainware. Equally important as the computer hardware and software, the brainware refers to the purpose and objectives, and provides the reason and justification for using GIS.

d) Infrastructure. The infrastructure refers to the necessary physical, organizational, administrative, and cultural environments that support GIS operations. The infrastructure includes requisite skills, data standards, data clearinghouse, and general organizational patterns.

2.11.2 The Future of GIS

GIS is a rapidly growing technological field that incorporates graphical features with a tabular data. All application of GIS will help in analyzing a large datasets, allowing a better understanding of terrestrial processes and human activities to improve economic vitality and environmental studies and quality. In geography, geology, planning, business marketing, and other disciplines, they could have benefited the GIS tools and methods. Together with cartography, remote sensing, global positioning system, photogrammetry, and geography, the GIS have evolved into a discipline with its own research base known as geographic information sciences. Geographic Information System (GIS) has been almost a compulsory tool in landslide hazard and risk assessment (Westen 2004). This is due to its capability in data input, manipulation of large quantity of spatial data, data management, analysis, and query of the inferable meaning of data. GIS also has the capability to make spatial prediction by combining data layers according to purposely embodied rules. Using these functions of GIS, spatial analysis of areas that susceptible to landslide can be performed.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter provides a description of the selected sites used in this study and procedures used to achieve the research objectives. This chapter explained in detail the method and process from the data collection, trend analysis for rainfall using time series plot, comparison of five years of rainfall according to its historical failure, development of model using weighted causative factor and mapping the landslide susceptibility map using Idrisi Selva. Figure 3.1 shows the methodology flow chart of this study.

3.2 Site Description

In this study, locations of study area are the locations of rain gauge stations and the locations are located at northern region of Peninsular Malaysia.

3.2.1 Rain gauge stations

The daily rainfall data from two rain gauge stations were obtained from the Malaysian Drainage and Irrigation Department for the period of 1984 to 2013 for Air Itam and 1997 to 2013 for Batu Lanchang. The unit of measurement is millimetres. The location of the stations is shown in Figure 3.2.

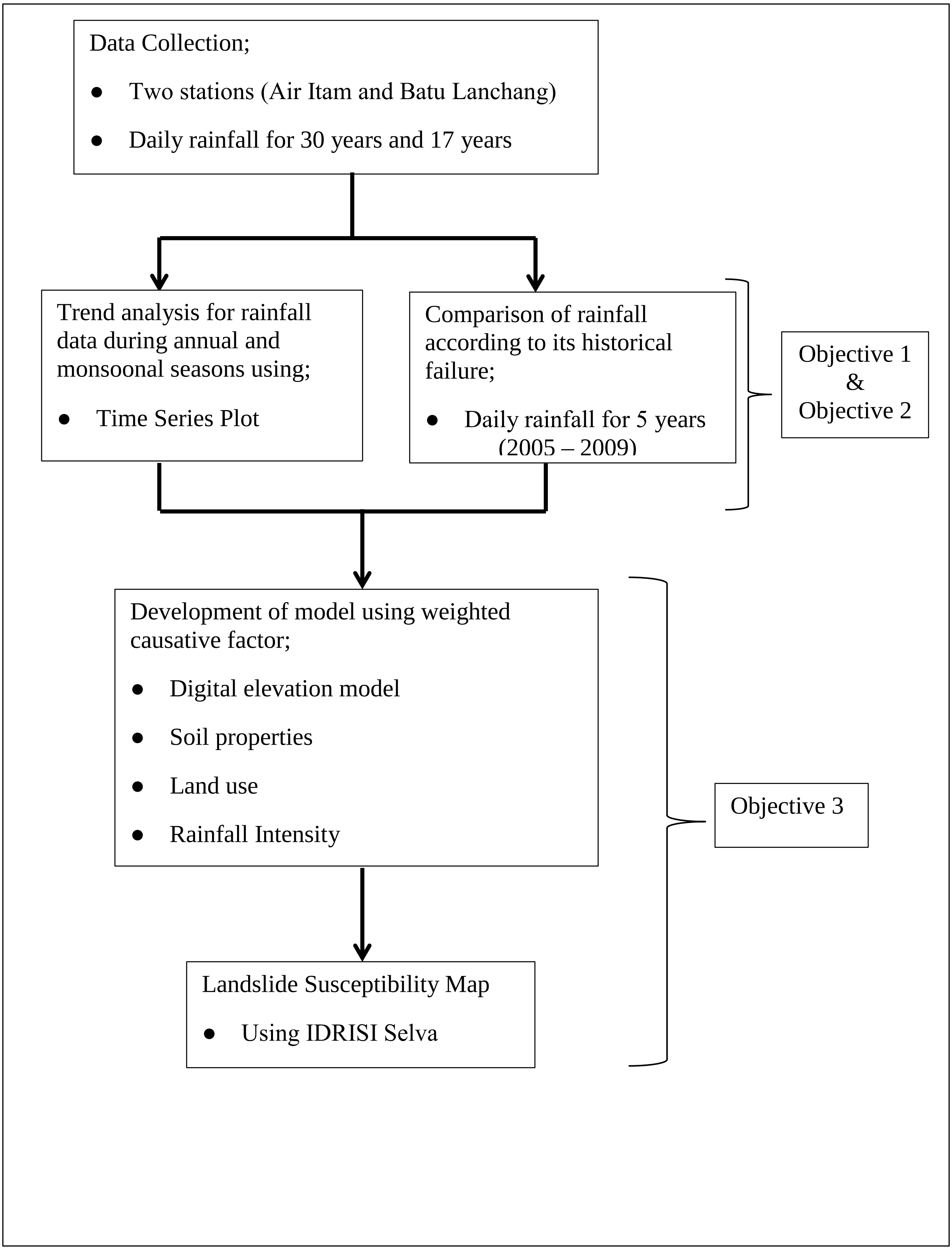

Figure 3.1: Methodology Flow Chart

3.3 Location of the Study Area

Table 3.1: List of the Station

Station	Station ID	Latitude	Longitude
Air Itam	5302003	05° 24’ 07”	100° 16’ 41”
Batu Lanchang	5403001	05° 24’ 09”	100° 17’ 58”

Figure 3.2: Location of the Study Area

3.4 Trend analysis for rainfall data during annual and monsoonal seasons

Daily rainfall data records from 1984 to 2013 for Air Itam stations and from 1997 to 2013 for Batu Lanchang stations as shown in Figure 3.2. The rainfall data first underwent the computational of descriptive statistic to observe the main characteristics of the observed data and plotted a graph using Time Series Plot to know which year has the highest rainfall according to the annual and seasonal trend.

3.4.1 Descriptive Statistics

This study carries out a statistical analysis of the long-term rainfall data for Air Itam and Batu Lanchang. Descriptive statistics help to simplify large amounts of data in a sensible way. Statistical analysis of rainfall records for long periods is essential to visualize raw data especially there is a lot of data used in the study. Statistical Product and Services Solution (SPSS 18) software was used to obtain statistical description. Descriptive statistics used in this study are minimum, maximum, mean and coefficient of variation (CV).

3.4.2 Minimum and Maximum

The minimum is the smallest value in the data set. This number is the data value that is less than or equal to all other values in our set of data. The maximum is the largest value in the data set. This number is the data value that is greater than or equal to all other values in our set of data.

3.4.3 Mean

The mean is just the average. To compute the mean is by add up all the values and divide by the number of values in the data set. The equation of mean is defined in equation (3.1)

$$\overline{x} = \frac{\sum_{i=1}^{n} x_i}{n} \qquad (3.1)$$

Where,

x = concentration of parameter

n = total number of parameter

3.4.4 Coefficient of variation

The standard formulation of the Coefficient of Variation (COV) is the ratio of the standard deviation to the mean. The coefficient of variation to be less than 1 are considered to be low-variance, whereas those with a COV higher than 1 are considered to be high variance (ReadyRatios, 2013). The equation of C0V is defined in Equation (3.2).

$$COV = \frac{\sigma}{\bar{x}} \quad (3.2)$$

Where,

σ = Standard deviation of parameter

$\bar{x}$ = mean concentration of parameter

3.5 Time Series Plot

A time series plot is a graph that you can use to evaluate patterns and behavior in data over time. Time series plots are especially useful for comparing data patterns of different groups. A time series plot displays observations on the horizontal axis against equally spaced time intervals on the vertical axis. Time series plots are often used to examine daily, weekly, seasonal or annual variations, and effects of a process change.

3.5.1 Variation of the Long-term Rainfall Series

The total annual rainfall plots for two stations were complete. Later, the seasonal plots were used to study the monsoonal rainfall trends.

3.5.2 Annual Plot

The annual total plot for Air Itam and Batu Lanchang stations were plotted. The total rainfall data for Air Itam is from 1984 to 2013 meanwhile rainfall data for Batu

Lanchang is from 1997 to 2013. This plot is used to observe the pattern of annual total rainfall located in the two stations.

3.5.3 Seasonal Plot

Two monsoonal seasons were taken into analysis considerations namely Southwest Monsoon and the Northeast Monsoon respectively. Besides, two transition periods known as the intermonsoon period between the two monsoons were taken into consideration as well.

3.6 Development of Model

Landslide hazard mapping model utilising weighted landslide causative factors was performed using current IDRISI Selva 17.0 software. The landslide-causative parameters were prepared in GIS layers as inputs to the quantitative model.

The final landslide susceptibility map was formulated using mathematical overlay module. The results were divided into five categories; very high risk, high risk, moderate, low risk and very low risk. From statistical extraction processes on the landslide susceptibility map, landslide model predicted about 29% of very high risk, 26% of high risk, 24% of moderate, 21% of low risk and 18% of very low risk, respectively. The applications of GIS can reduce time and cost and the analytical work becomes easy and quick especially in landslide susceptibility mapping.

3.6.1 Selection of parameter

Parameters (factors) used in landslide mapping of Penang Island are digital elevation model, land use, soil properties, and rainfall intensity. Since rainfall plays an important role in landslide occurrence, the average rainfall data were collected between 2005-2009 from the Department of Irrigation and Drainage Malaysia.