GEOLOGY AND LANDSLIDE SUSCEPTIBILITY ASSESSMENT IN SOUTH OF ARING 6, GUA MUSANG, KELANTAN

by

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A report submitted in fulfilment of requirements for degree of Bachelor of Applied Science (Geoscience) with Honours

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DECLARATION

I declare that this thesis entitled **"GEOLOGY AND LANDSLIDE SUSCEPTIBILITY ASSESSMENT IN SOUTH OF ARING 6, GUA MUSANG, KELANTAN"** is the result of my own research except as cited in the references. This thesis has not been accepted for any degree and is not currently submitted in candidature of any other degree.

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Date : ____________________

APPROVAL

"I/ We hereby declare that I/ We have read this thesis and in my/our opinion this thesis is sufficient in terms of scope and quality for the award of Bachelor of Applied Science (Geoscience) with Honour"

Signature : ________________

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Date : ________________

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GEOLOGY AND LANDSLIDE SUSCEPTIBILITY ASSESSMENT IN SOUTH OF ARING 6, GUA MUSANG, KELANTAN

ABSTRACT

The research is entitled "Geology and Landslide Susceptibility Assessment in South of Aring 6, Gua Musang, Kelantan". This study is focused on the landslide hazard assessment using Geographic Information System (GIS) application. The study area is bounded between coordinates 4º 53'0" N to 4º53'30" N of latitude to 102º 21'30" E to 102º 24'30" E of longitude. The objectives of this research are to produce a geological map of the study area in the scale of 1: 25000 which is covered 25 km^2 of the study area. The factor that triggered landslide susceptibility of the study area is analysed through this research. This research also involved the study of geomorphology, lithostratigraphy, structural geology and historical geology. All the data of these study are obtained from secondary data such as research on previous research, satellite imagery, Google Earth, and aerial photograph. In order to produce landslide susceptibility map, the method of Weighted Linear Combination (WLC) is used in this research. Eight parameters are chosen as landslide causative factors and the landslide susceptibility zonation map is generated from GIS application. The rainfall intensity is a factor that triggered the occurrence of landslide in the study area. From the analysis and interpretation of landslide, there is three classes of landslide zonation such as low, medium and high zones. The slope is the most influence hazard because of the hilly area in the study area. The increase value of the lineament density and drainage density also influenced the landslide occurrences in the study area.

GEOLOGI DAN PENILAIAN KERENTANAN TANAH RUNTUH DI SELATAN ARING 6, GUA MUSANG, KELANTAN

ABSTRAK

Penyelidikan ini bertajuk "Penilaian Kerentanan Geologi dan Tanah runtuh di Selatan Aring 6, Gua Musang, Kelantan". Kajian ini difokuskan pada penilaian bahaya tanah runtuh menggunakan aplikasi Sistem Maklumat Geografi (GIS). Kawasan kajian dibatasi antara koordinat 4º 53’0” N hingga 4º53’30” N latitud hingga 102º 21’30” E hingga 102º 24’30” E garis bujur. Objektif penyelidikan ini adalah untuk menghasilkan peta geologi kawasan kajian dalam skala 1: 25000 yang meliputi 25 km2 dari kawasan kajian. Faktor yang mencetuskan kerentanan tanah runtuh di kawasan kajian dianalisis melalui penyelidikan ini. Penyelidikan ini juga melibatkan kajian geomorfologi, litostratigrafi, geologi struktur dan geologi sejarah. Semua data kajian ini diperoleh dari data sekunder seperti penyelidikan mengenai penyelidikan sebelumnya, citra satelit, Google Earth, dan foto udara. Untuk menghasilkan peta kerentanan tanah runtuh, kaedah “Gabungan Linear Berwajaran” (WLC) digunakan dalam penyelidikan ini. Lapan parameter dipilih sebagai faktor penyebab tanah runtuh dan peta zonasi kerentanan tanah runtuh dihasilkan dari aplikasi GIS. Keamatan hujan adalah faktor yang mencetuskan kejadian tanah runtuh di kawasan kajian. Dari analisis dan tafsiran tanah runtuh, terdapat tiga kelas zonasi tanah runtuh seperti zon rendah, sederhana dan tinggi. Lereng adalah bahaya yang paling berpengaruh kerana kawasan berbukit di kawasan kajian. Nilai peningkatan kepadatan garis dan ketumpatan saliran juga mempengaruhi kejadian tanah runtuh di kawasan kajian.

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LIST OF SYMBOLS

°	Degree
’	minutes
’’	Seconds
%	Percent
×	Multiply
Σ	Sum
σ	Sigma

LIST OF ABBREVATIONS

km	kilometer
km^2	kilometer square
mm	millimeter
N	North
E	East
W	West
SE	South East
DEM	Data Elevation Model
GIS	Geographic Information System
WLC	Weighted Linear Combination
FELDA	Federal Land Development Authority
KESEDAR	Lembaga Kemajuan Kelantan Selatan/ South Kelantan Development Authority
RKT	Rancangan Kemajuan Tanah
UMK	Universiti Malaysia Kelantan
LHZ	Landslide Hazard Zonation
FGV	Felda Global Ventures
FGVM	Felda Global Ventures Malaysia
IGRSM	Institution Geospatial Remote Sensing Malaysia
JPS	Jabatan Pengairan dan Saliran

CHAPTER 1

INTRODUCTION

1.1.1 General Background

The research is entitled "Geology and Landslide Susceptibility Assessment in South of Aring 6, Gua Musang, Kelantan". Generally, landslide is a common disaster that in an urban area. However, in rural area also landslide exposed to occur. Aring is a rural area that is located at Gua Musang which is prone to landslide hazard because mostly in Aring area mostly exposed to the agriculture activities which is palm oil plantation especially at hilly area. Therefore, this research is focusing on landslide susceptibility assessment as to produce the updated geological map and landslide susceptibility causative factors of the study area can be investigated.

According (Varnes, 1978), landslide is a process involved in slope movements comprises a continuous event from cause to effect. This landslide can cause economic effects which is more costs are needed to fix the effects of a landslide compare remove the cause. Landslides can also refer as the events or movement of soil masses, rocks or combinations which is occur on the slopes (Avanzi *et al.*, 2004).

Landslide susceptibility assessment is important to be developed for each contribute. This is because this phenomenon is one of the most common hazards occurrence in each year that can contribute a large number of victims and causes the losses of economic in the world.

Landslide susceptibility assessment represents a conditional probability based on time and spatial occurrence, and landslide magnitude or a given geo-environmental setting. The GIS software is applied in producing landslide susceptibility map as this software is used in data analysis and interpretation of landslide susceptibility map. The uses of Digital Elevation Model (DEMs) in Geographic Information System (GIS) application can provide strategies to identify and overcome the landslide occurrence. Hence, the terrain parameters for geomorphology of the landslide assessment can be extracted. Therefore, as to reduce the landslide hazard on particular study area, landslide assessment should be investigated by using Weighted Linear Combination (WLC) to prevent this landslide occurrence.

1.1.2 Study Area

a. Location

Area of study which is Aring 6 located at the Southern end of Kelantan state as shown in Figure 1. This area is as wide as 25 km^2 which is cover approximately 5 km × 5 km that focus on an area of Aring. This area bounded between coordinates 4º 53’0” N to 4º53’30” N of latitude to 102º 21’30” E to 102º 24’30” E of longitude. Aring is one of the plantation areas which is located at Gua Musang district, in Kelantan state, Malaysia.

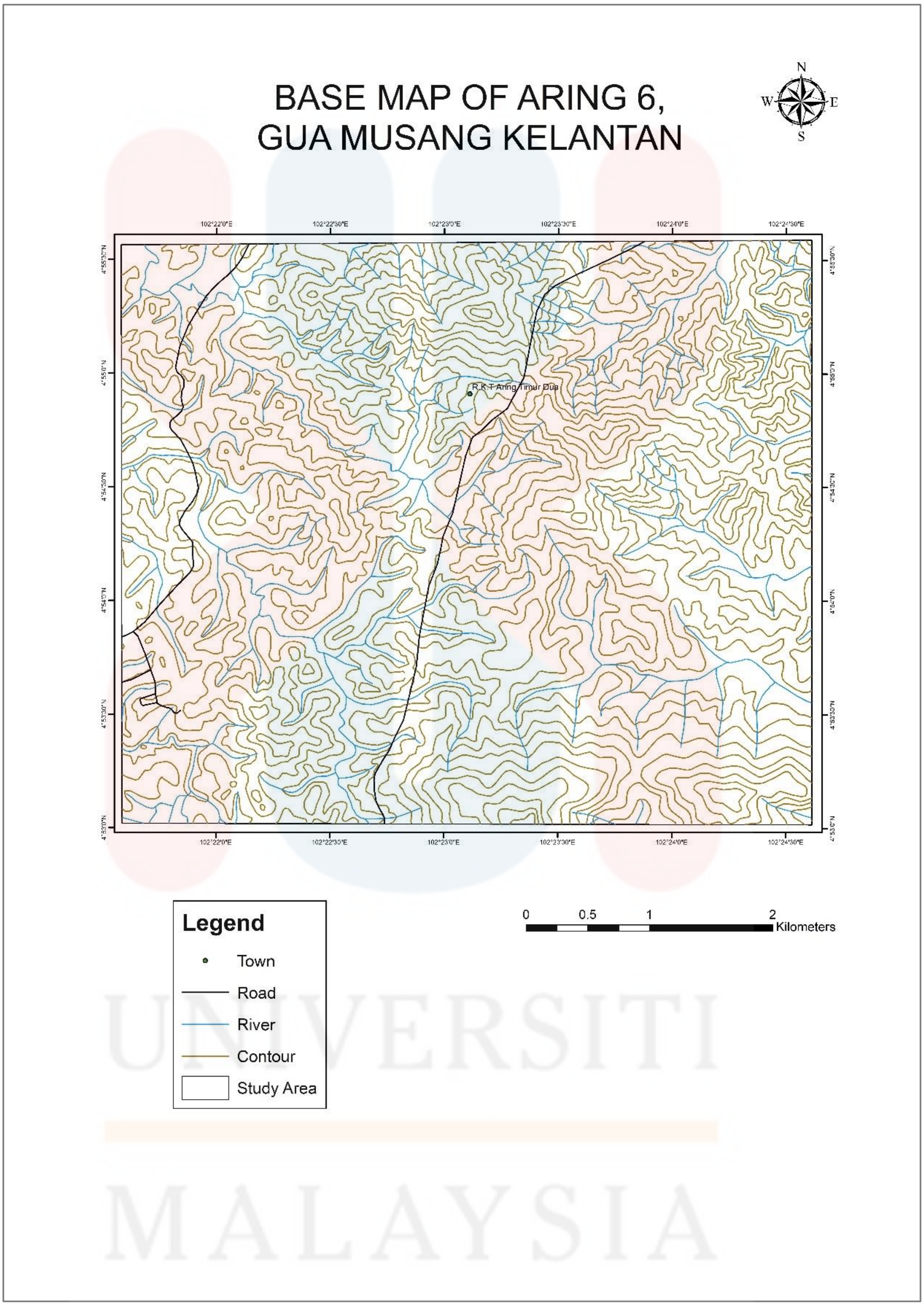


Figure 1.1 Base map of study area.

b. Road Connection/ Accessibility

The study area is located in South of Aring 6, Gua Musang, Kelantan. This location can be access through Federal Route 8. This route can be passable from Kuala Lumpur- Kota Bharu highway which is 402.7 km federal highway in Malaysia. In Kelantan, this route can be accessed from Kuala Krai and it take 2 hours 12 minutes by driving to reach the study area. Moreover, this road connects Bentong in south to Kota Bharu in north. From Universiti Malaysia Kelantan (UMK), the road can be access through Dabong route. The travel took 1 hour 45 minutes to reach the study area. Both routes can be access via car and motorcycle.

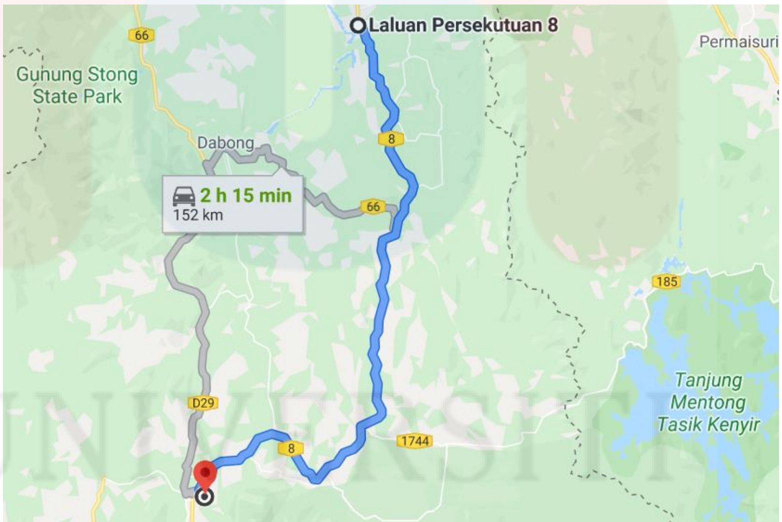


Figure 1.2 Travel distance from Federal Route 8 to Aring 6.

(Source: Google Map)

Figure 1.3 Travel map from UMK to Aring 6.

(Source: Google Map)

c. Demography

In 2010, the population in Gua Musang is about 90,057 of people with 46.2% of males and 53.8% of females respectively. Figure 1.2 shows the sex population of Gua Musang in 2010.

Gua Musang is the largest district in Kelantan, it can be divided into three subdistrict which is Bertam, Chiku, and Galas with 23,141, 26,093 and 36,955 the number of census respectively. Table 1.1 shows the subdivision statistics in Gua Musang (2010). Mostly, the residents in Gua Musang are in range 15 to 64 years with 62%, followed by age from 0 to 14 years with 35.3%. There are different ethnics live in Gua Musang area such as Malay, Chinese, Indian and another group. This population is highly dominated by Malay residential. Figure 1.3 shows the population distribution in Gua Musang area.

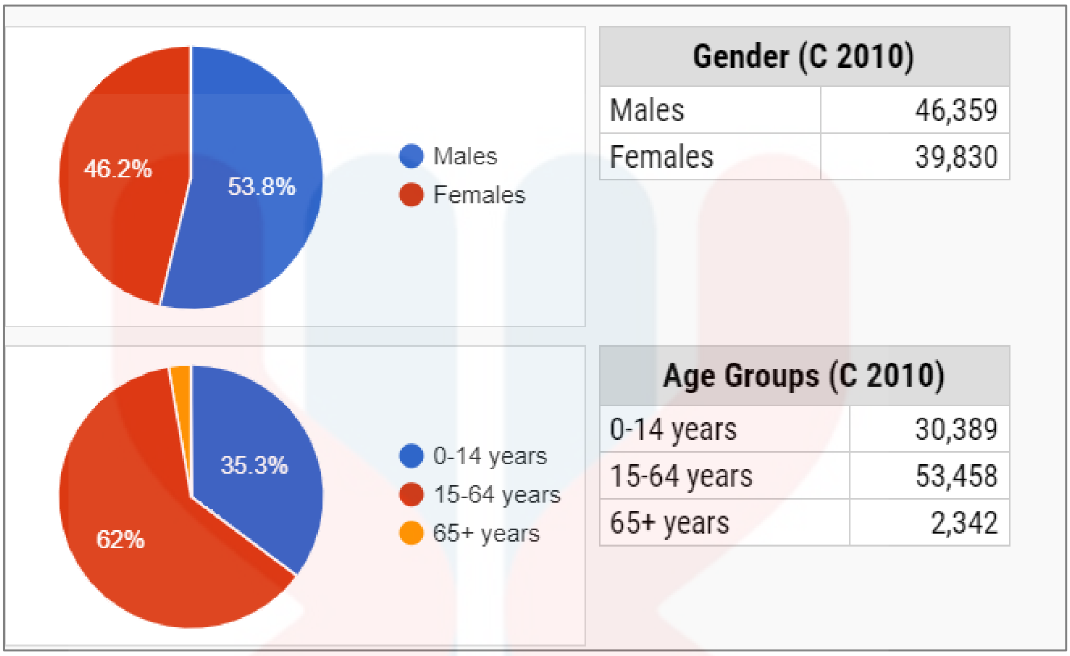


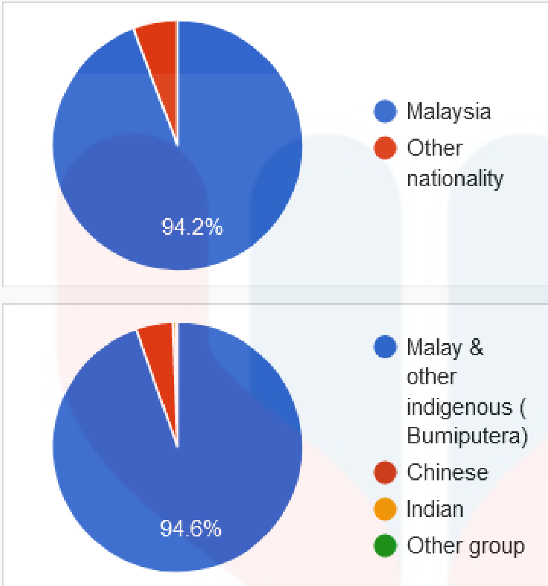
Figure 1.2 Sex population in Gua Musang (2010).

(Source: Department of Statistics Malaysia)

Table 1.1 Subdivision in Gua Musang (2010).

Name	**Status**	**Population (Census: 2000/07/05)**	**Population (Census: 2010/07/06)**
Gua Musang	District	76,655	90,057
Bertam	Mukim	16,923	23,141
Chiku	Mukim	26,251	26,093
Galas	Mukim	31,814	36, 955
Malaysia	Federation	23,274,690	28,334,135

(Source: Department of Statistics Malaysia)



Nationality (C 2010)	
Malaysia	81,204
Other nationality	4,985

Ethnic Group (C 2010)	
Malay & other indigenous (Bumiputera)	76,823
Chinese	3,870
Indian	350
Other group	161

Figure 1.3 Population distribution in Gua Musang area.

(Source: Department of Statistics Malaysia)

d. Land Use

Gua Musang district is located in the south of Kelantan State. This area has 7,979.77 km^2 of total area which is the largest district in Kelantan which is boarded by Thailand State of Kelantan bordering Thailand in the north, the state of Perak in the west, the state of Pahang in the south and the state of Terengganu in the east.

In Aring 6, the land use is mainly use in agriculture sector which is palm oil plantation. Most of the population in Gua Musang belongs in the settler community. The land use of the study area is administered by Federal Land Development Authority (FELDA) and The South Kelantan Development Authority (KESEDAR). Both agencies responsible to develop the resettlement of rural area into newly develop area.

e. Social Economic

Social economy of Gua Musang, Kelantan is usually developed by a few agencies such as FELDA, FELCRA and KESEDAR. However, in Aring area is only organize by FELDA and KESEDAR. These agencies play an important role for development of economic of rural area through agriculture activities and agro-based industry. The agriculture activities such as oil plantation and rubber estate are the main social economic in Kelantan. The development of social economy such as agriculture activities can reduce the total of unemployed in Gua Musang area. Therefore, it contributes improving the income and well-being of rural area communities.

1.3 Problem Statement

Based on the previous study, that is lack of researchers that conducted the landslide susceptibility assessment in Gua Musang area. This is because of landslide is a big threat to the communities which is can cause the destruction to properties for the settlement area. Since Aring is rural area which is the agriculture is the main social economic, and this area is prone to landslide hazard occurrence.

As this research is focusing on the assessment of landslide susceptibility, some factors of landslide hazard occurrence can be identified. In order to prevent the occurrences of this disaster, landslide susceptibility analysis need to be done for human precaution and also implementing several method of landslide hazards. Therefore, the Weighted Linear Combination (WLC) is used to produce landslide susceptibility map.

Through this research, a geological survey can be conducted and data information about the geologic features which is obtain from secondary data from previous researchers, the map will be interpreted and then analysed using GIS application. Thus, a new updated landslide susceptibility assessment map can be produced.

1.4 Objective

The objectives of the study on this research are:

i. To update geological map in study area in the scale 1: 25,000.

ii. To analyze the landslide susceptibility factors of Aring 6, Gua Musang Kelantan.

iii. To produce landslide susceptibility zonation map of Aring 6, Gua Musang, Kelantan.

1.5 Scope of Study

This research is focused on the assessment of landslide susceptibility and the factors of landslide occurrence in the study area. The uses of secondary data in GIS application are needed through this research which is can obtain from several certain agencies such as USGS and Jabatan Pengairan dan Saliran (JPS).

Through the uses of secondary data, the GIS application is used for interpreting and analysis the landslide susceptibility assessment map. By using the data analysis, the map landslide susceptibility zonation map can be produced which the place of study area can be classified as low, medium, and high zonation hazard**.**

In addition, there are eight parameters used to produce landslide susceptibility map such as included slope, drainage density, lineament density, lithology, aspect, land use, vegetation and soil cover. These parameters are generated and overlay by using the GIS application.

1.6 Significance of Study

The significance of this research is to analyze the landslide susceptibility factors of the study area. This research will also produce a new updated and landslide susceptibility zonation map of the study area with a scale 1: 25 000. This will give more details on geological information about the study area and this research is also believed to be beneficial to enhance the previous research.

Besides, by producing the landslide susceptibility zonation map also, the most potential slope failure of the study area can be identified. This can give some benefits to local community especially for agriculture and construction planning. The landslide assessment may also provide the geotechnical engineer some details for designing and recommending slope remediation. It also helps to reduce the likelihood of potential failure.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter comprised of all the previous studies and researches that had been conducted by other researches. It is can obtain from the several sources such as journals, books, and internet. Through this study, it enables to have the general information about the study area such as regional geology and tectonic setting, structural geology, stratigraphy, and historical geology of the region. Not only that, this chapter also covers the GIS application that is used in producing landslide susceptibility map. The uses of parameters with WLC can help to produce the landslide susceptibility zonation map.

2.2 Regional Geology and Tectonic Setting

There are three longitudinal belts in Peninsular Malaysia, which are Western, Central and Eastern. These belts consist dissimilar geological characteristics and geological development. Based on the mineralization, Scrivenor (1982) proposed a division of the peninsular into a central gold belt in between tins belts to east and west which is the division has evolved into the present Central, Eastern and Western Belts respectively. Figure 2.1 shows the regional geological map of Kelantan.

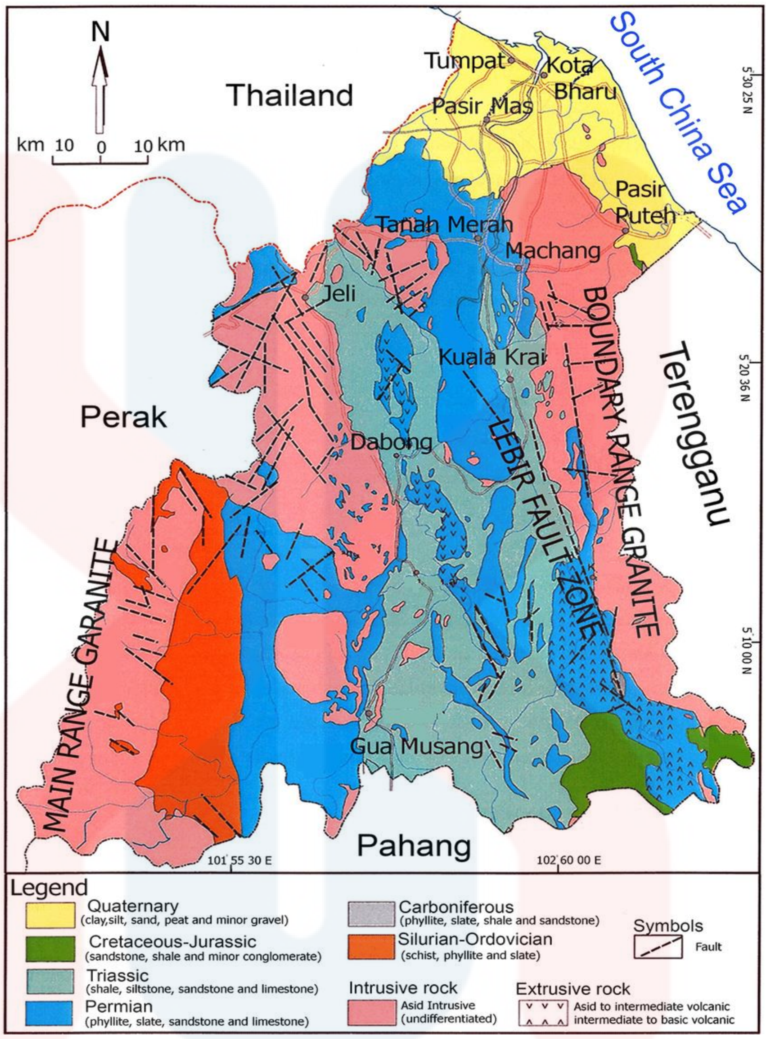


Figure 2.1 Regional Geological Map of Kelantan.

(Source: Hashim, M., Mishbari, S., & Pour, A.B., 2017)

The regional geology of Kelantan is central zone which is consists of sedimentary and metasedimentary rocks. This zone is bordered on the west and east by the granites of the Main Range and Boundary Range respectively. Based on (Metcalfe and Hussin, 1995; Abdullah et al.,2009), this belt consists of thick Permian-Triassic marine carbonates, volcaniclastics, shales and andesitic volcanics. The found of Gua Sei and Gua Bama in central belt is assumed from the age Late Permian-Triassic which is based unequivocal conodont and foraminifera faunas (Metcalfe, 1995; Sone et al.,2004, 2008).

Carboniferous ages for the Kepis Beds in Negeri Sembilan are unconfirmed and Carboniferous strata in the Raub Group probably belong to the Bentong-Raub Suture complex and again are largely unconfirmed. In Kelantan, the sediments of the Gua Musang Group or Aring Formation are mainly composed by argillaceous rocks accompanied with variable amounts of carbonaceous and calcareous material. According Kamal Roslan (2006), the southern Kelantan area can be divided into four areas such as Kuala Betis, Gua Musang, Aring and Gunung Gagau. The study area is located in area which is located within the central belt of Peninsular Malaysia.

Based on Aw (1990), there are four unit's area named of Gua Musang Group which are Aring Formation, Telong Formation, Nilam Marble Formation and Koh Formation. The grouping of listed formations is divided within the same group according the basis of lithologic unit. The combination of these formation contributes the formation of the Gua Musang Group as it shows the similarities in the existing of lithology as well as the age equivalent to the rock unit located in Gua Musang area.

2.3 Stratigraphy

In South of Kelantan, Gua Musang formation was mapped by Yin (1965). It consists of calcerous-argilleceous sequence of crystalline limestone with interbedded argillite and subordinate sandstone and volcanic. Gua Musang Formation describes Middle Permian to Late Triassic argillite, carbonate, and pyroclastic or volcanic facies within Gua Musang group. Figure 2.2 shows the Mesozoic stratigraphic column of Central Belt while Table 2.1 shows stratigraphic sequence of Gua Musang.

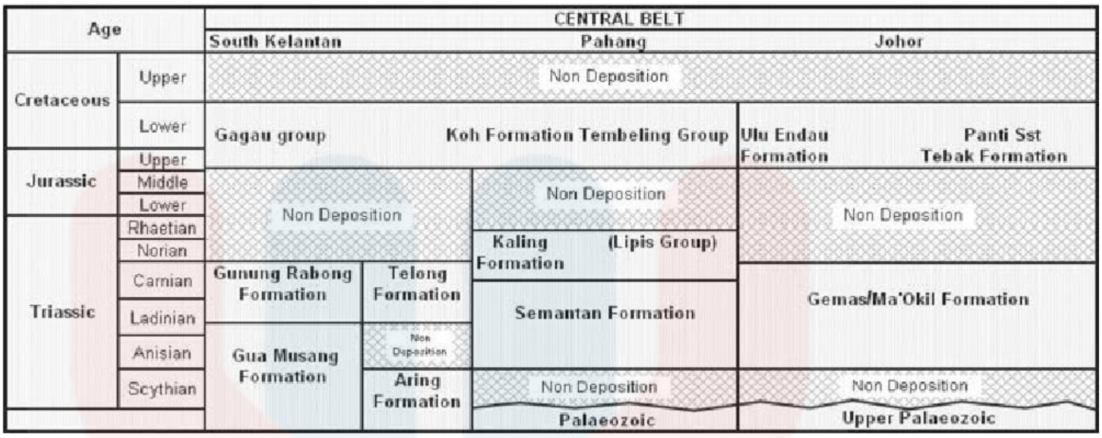


Figure 2.2 Mesozoic stratigraphic column of Central Belt.

(Source: After Khoo, 1983)

Table 2.1 Stratigraphic sequence of Gua Musang.

Age	Type of Rocks
Middle Triassic	Limestone, together with shale and volcanic rock
Early Triassic	Argillitic limestone, shale and volcanic rock
Late Permian	Shale and siltstone
Middle Permian	Limestone with some shale

(Source: Yin,1965)

2.3.1 Aring Formation

Aring Formation is origin from the name of Sungai Aring, South of Kelantan. Based on Aw (1990), the predominantly pyroclastic sequence in the Sungai Lebir Valley, lower reaches of Sungai Aring, and Sungai Relai in South Kelantan. Aring Formation is assumed begin from the age ranging from Late Carboniferous to Early Triassic which is indicated by fossil evidences. As dated by foraminifera and bivalves' fossils, this age of this formation is assumed started from Late Carboniferous to Early Triassic.

2.3.2 Telong Formation

Telong Formation is originated from the name of Sungai Telong, South Kelantan. The age of this formation is assumed from Late Permian to Late Triassic. The lower boundary overlies Gua Musang while the top boundary overlain by Koh Formation. This area is located at Sungai Telong which is the upper reaches of Sungai Aring in south Kelantan. This formation can be correlated with Gunung Rabung Formation in Kelantan, the Gunung Semanggol in Kedah and also Lapisan Gemas in the south.

2.3.3 Nilam Marble Formation

Nilam Marble Formation originated from the name is Sungai Nilam of Sungai Chiku. The age of the formation is assumed started from upper or lower Permian to Late Triassic. The boundary of this formation is unexposed bottom and top boundary. The rock that presents in this formation includes calcitic marble interbedded with tuff and argillite. The area of this formation also located at upper reaches of Sungai Nilam.

2.3.4 Koh Formation

Koh Formation is named after the tributary of Sungai Koh. Aw P.C. (1972) formalized the Koh Formation for a redaceous - arenaceous unit sequence in Sungai Aring area of southeast Kelantan. Mudstones are interbedded in the sequence while the bottom sequence is argillaceous limestone. The age of this formation is deduced by correlation with the Tembeling Formation as Late Triassic to Jurassic period. The fossils are not found at this formation. However, this formation is assumed younger than the overlapping Telong Formation.

2.4 Structural Geology

Based on stratigraphic column in Central Belt in Figure 2.2, it shows the presence of a regional unconformity between Triassic and younger Mesozoic sequence. According Tjia (1989), this Central Belt is bordered by Bentong Suture in the west and by the Lebir Lineament in the east.

In Late Palaeozoic, the continental Gondwana sliver in the west was separated by Bentong Suture. Metcafe (1988), also believe docking of the Western belt along the Suture was only completed in Late Triassic. Based on Tjia (1984), there was the right lateral of wrench motion within the Bentong Suture. The structure of faults also found at this Central Belt. The Lebir Lineament located in the north of the left of Lebir fault, but the lineament is poorly defined and comprises in the wide zone of north south faults.

2.5 Historical Geology

Aring is located in Gua Musang area and well known by its fossil availability. In 1990, most of fossils have been reported by Aw and suggest the Aring Formation is assumed from Late Carbon to Early Triassic. These are based on fossil evidences found in Aring area which are fusulinite fossils. This formation is deposited around the ocean.

The Aring Formation also represented by the argillite and predominantly acidic. Based on palaeontologists' studies, there are many fossils found from Early Permian until the end of the Triassic. According to Dony Adriansyah Nazaruddin & Ahmad Rosli Othman (2014), Aring is well known for its Tertiary fossils within the Central Belt in Peninsular Malaysia. The fossils such as ammonoids, bivalves, gastropods, and phylum brachiopods are found in Aring area.

2.6 Research Specification

This research is focusing on landslide susceptibility assessment and involved some parameters and a method to achieve the objectives. GIS application is used in this research as to get the more details about the landslide occurrence that occur at study area. In this research, the method of Weighted Linear Combination (WLC) in producing landslide susceptibility map is applied.

Based on past research on landslide susceptibility zonation study using remote sensing and GIS technology in the Ken-Betwa River Link area, India (Avtar, R., et al.,2011), the WLC method is applied in this research. The result from the landslide susceptibility map of this study proved that the classes of hazard zones are classified into four classes which is high, moderate, low and very low landslide zones. WLC method can determine the degree of landslide influence event of the selected parameters by using GIS application. The obtained information by this study may be used by decision-makers to mitigate the instability of the slopes during major construction work involving the Ken-Betwa River Connection Project. Thus, it is believed this method can be applied in the Aring area as this method can provide the more details and accurate results as where a landslide occurred.

2.6.1 Landslide

Landslide is referred as a wide variety processes that result in the downward and outward movement of slope-forming materials including rock, soil, artificial fill, or combination of these. The landslide occurrence may move by falling, toppling, sliding, spreading, or flowing.

According Varnes (1978) system, the term for landslide can be divided into two classes. First term describes the type of material while the second term can be described as type of movement. This hazard also can be adaptable with variables which is rate of movement and the water, air, or ice content of landslide material. Table 2.2 shows the landslide classification by Varnes (1978).

Table 2.2 Landslide classification

TYPE OF MOVEMENT		TYPE OF MATERIAL		
		BEDROCK	ENGINEERING SOILS	
			Predominantly coarse	Predominantly fine
FALLS		Rock fall	Debris fall	Earth fall
TOPPLES		Rock topple	Debris topple	Earth topple
SLIDES	ROTATIONAL	Rock slide	Debris slide	Earth slide
	TRANSLATIONAL			
LATERAL SPREADS		Rock spread	Debris spread	Earth spread
FLOWS		Rock flow (deep creep)	Debris flow (soil creep)	Earth flow
COMPLEX		Combination of two or more principal types of movement		

(Source: Varnes,1978).

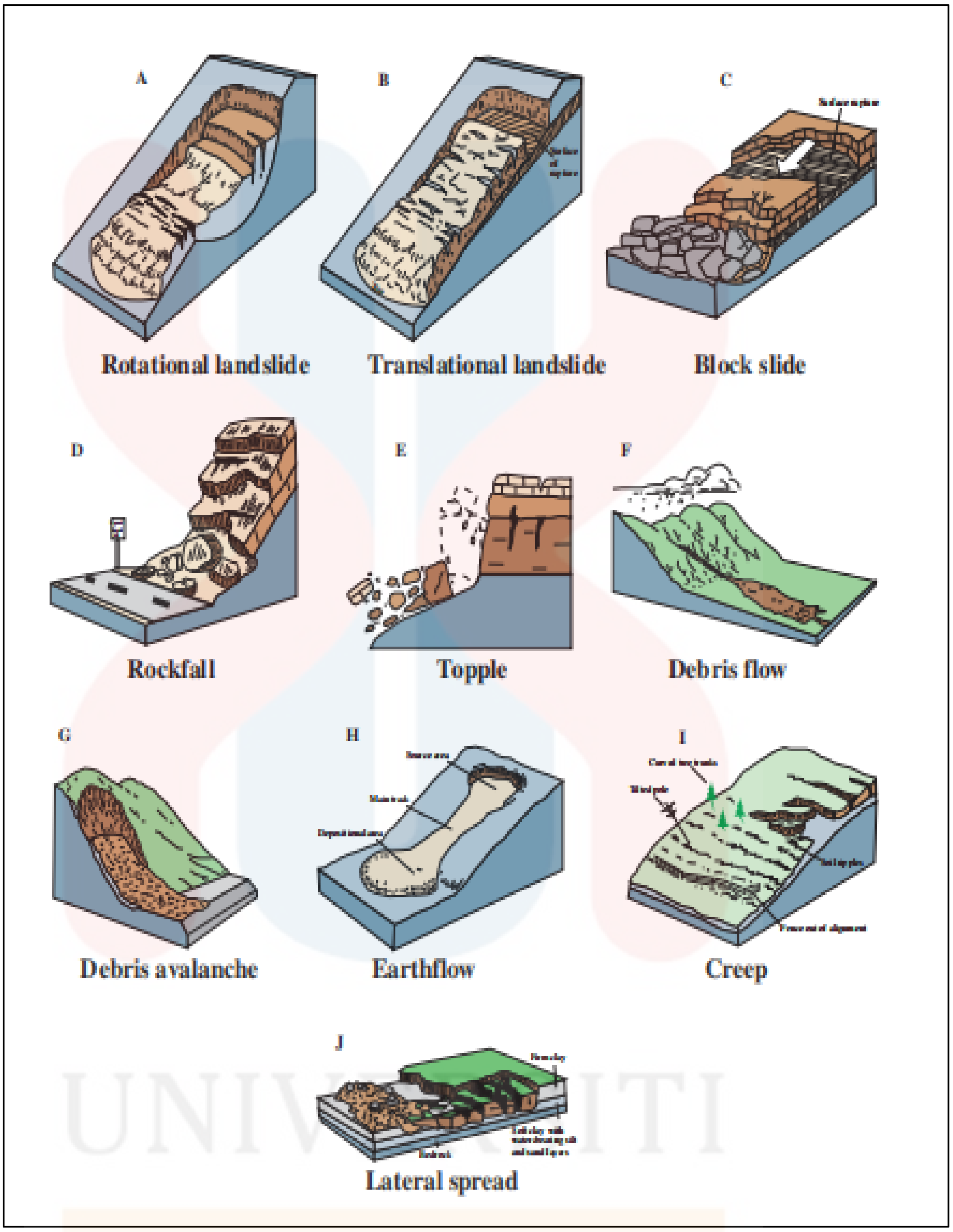


Figure 2.3 Type of landslide (Varnes,1978).

2.6.2 Landslide Trigger Factors

There are some factors that triggered the landslide occurrence. This is including internal, external and human factors. The internal factors of landslide are related to the soil and rock materials. These factors are including soft weak rock properties or rock strata, geological structure, topography, or vegetation. These factors can also reduce the binding of frictional force of rock particles.

External factors can be related with the rainfall intensity and earthquakes. Human factors are the major cause of the landslide occurrence. For instances are unplan construction such as build the houses on slope and improper management of mining which is can affect the slope stability.

Geological factors are known as the additional factors that triggered landslide. Generally, the geological factors such as weak, weathered, sheared material, the presence of cracks and joints, the contrast in permeability or stiffness of the slope forming material may pose a risk of landslide. The unstable slopes resulting from weak soil cohesion are the main cause that contribute the landslide to occur.

2.6.3 Rainfall Distribution

Based on previous investigation on landslide study, landslides in Malaysia usually occur in rainy seasons as Malaysia having hot and humid climate and this hazard occur during heavy rainfall events in rainy seasons. This is because of rainfall intensity is one of the external factors that cause the occurrence of landslide. Kelantan region highly exposed to the monsoon season. The rainfall distribution in Gua Musang is extremely highly in a month especially around November,27 with an average total accumulation of 3.6 inches. However, the least amount of rainfall distribution in Gua Musang is around February 10, with an average total accumulation of 3.6 inches.

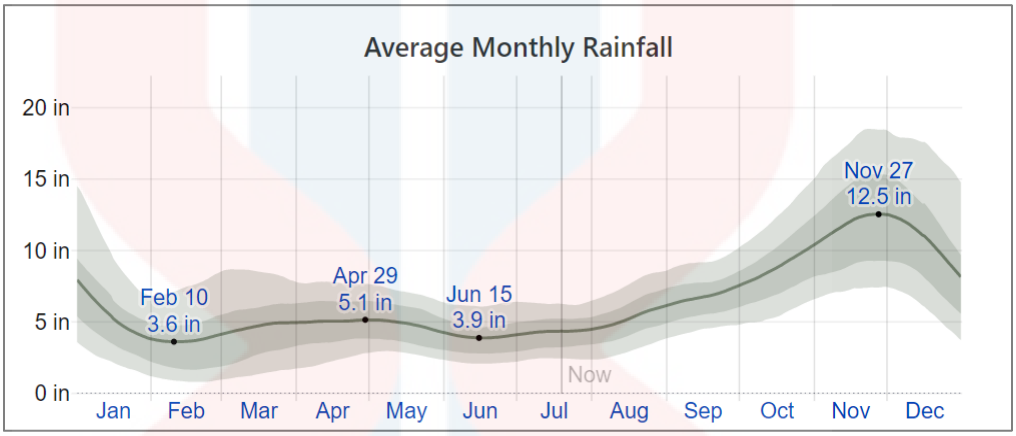


Figure 2.4 Average monthly rainfall in Gua Musang.

(Source: Water Spark, website)

2.6.4 Landslide Susceptibility Assessment

The secondary data such as journal article, previous study from some researchers, books, data from any or certain agencies are required in producing landslide susceptibility map. The GIS application is used in interpreting of landslide susceptibility map with secondary data collection. The uses of secondary data such as digital elevation map is needed in this research.

Digital Elevation Model (DEMs) is the spatial variation in elevation. DEMs frequently used to generate the maps such as slope, drainage density, lineament density and aspect map. The map of lithology, land use, vegetation and soil cover are generated using shapefile data of the study area. Slope is used as major parameter in evaluating stability of an area. Landslide often occurs on a steeper slope, because either friction is increased by the force of gravity.

2.6.5 Geographic Informational System (GIS)

GIS is referred as a system designed to capture, store, manipulate, analyse, manage and present all types of geographical data. Landslide hazard zonation (LHZ) map such as low, medium and high area of landslide can be produced through GIS software.

The information from the aerial photograph is added and overlaid with the information that already prepares to show the difference between feature that occupy the same geographic. In addition, the data such as geological data, surface cover and slope, characteristics of study area are collected, manipulate and integrate using GIS application. Through this application, the WLC method is used to identify and analyse the area that vulnerable to landslide occurrence. Therefore, GIS application may help in doing landslide risk assessment.

Generally, Weighted Linear Combination (WLC) is a qualitative method that used in the landslide susceptibility assessment. WLC of a measurement scale is applied to diverse and dissimilar inputs to create an integrated analysis. The weights of this method are used as to allocate the relationship between landslide predominant factors with the landslide occurrence. The weightage and score of each parameter for landslide causative factors are determined and analysed. The weightage (Wi) will multiple with area (km^2) to obtain the score (Sij) as to determine the most influence to landslide causative factors. All the maps will be generated from DEM data, or satellite imagery to produce landslide susceptibility zonation maps.

CHAPTER 3

MATERIALS AND METHODOLOGIES

3.1 Introduction

To complete this study, several methods were used to make sure the research of study can be done in an orderly and systematically way.

3.2 Material/Equipment

The equipment such as secondary data which is can obtain form certain agency, data from previous researchers, books or journal articles are required in this research. The GIS application which is ArcGIS software is used in producing, and interpreting the landslide susceptibility assessment map.

3.2.1 GIS Software

GIS software used to digitize map of the study area and produce landslide susceptibility map of the study area.

3.2.2 Satellite Imagery

Use to produce the topography map of the study area by using satellite and also provide different type of map. Satellite imagery also can help in field investigation process which is determining the landslide susceptibility and the potential of the landslide occurrence in study area.

3.2.3 Secondary Data

i. Digital Elevation Model (DEMs)

Digital Elevation Model (DEMs) data is required to create the slope, aspect and drainage density maps. This data can be obtained or collected from USGS agency. To generate these maps, the raw data such as contour data and elevation are needed. Therefore, DEM data can contribute the producing the landslide susceptibility assessment map.

3.3 Methodology

In a geology research, several methods require to produce landslide susceptibility assessment map. Thus, the research methodology had been listing down and flow chart also has been shown in Figure 3.1.

3.3.1 Preliminary Studies

This stage is important as to know the geological condition of the study area, preliminary researches need to be collected. Preliminary study also can be performed by doing some studies about the study area from differences kind of sources such as journal review, books, articles and review based on previous map.

In addition, preliminary study also used to recognize all the geologic features in study area. This stage is important to find the suitable secondary data to produce landslide susceptibility map.

3.3.2 Data Collection

The raw data such as contour or slope map are needed to produce landslide map. Generally, the slope and contour are used to generate the DEM data. These data can create the inventory data which is a list of datasets with metadata that describe the contents, properties and some useful information. The inventory data can determine the level of landslide zonation hazard of the study area. The scoring of data such as slope, drainage density, lineament density, lithology, land use, vegetation, soil cover and aspect map are applied. These parameters are overlay by using GIS application. So, it is important to reclassify and the converted the raster data into polygon data as to produce the landslide susceptibility map.

3.3.3 Data Preparation

In order to produce landslide susceptibility map, the base map of the study area was produced first. This base map help in gaining some information about the geological feature and landform of the study area. The thematic map such as slope, drainage density, aspect, lineament density, land use, soil cover, vegetation and lithology maps are also prepared. Each of thematic map was interpreted to produce landslide susceptibility map. From the topographical sheet and satellite data, the drainage density map can be prepared. The landslide and image of the study area was collected from the Google Earth and online research in order to estimate area of prone landslide susceptibility.

3.3.4 Data Processing

The geological data which is obtained from the secondary data and thematic map are the processed by using ArcGIS Software. These processed data also can be used to produce the landslide zonation map in study area.

3.3.5 Data Analysis and Data Interpretation

Data obtained secondary data was needed for data analysis. The collected data was analysed using GIS application which is by Weighted Linear Combination (WLC) method. GIS analysis can create, export and interpret the data from the study area. By using WLC, the process of examining an aerial photo or digital remote sensing image were done. This is one of the interpretation images which can identify manually the features in that image. The parameters that are used in producing landslide susceptibility assessment map included slope, aspect, lineament density, lithology, land use, soil cover, vegetation and also drainage density. This is because the parameters help in determining the weightage and score of landslide susceptibility through WLC method in the study area.

WLC method is applied by converting the feature class to the polygon. Then, all the parameters are overlay using overlay intercept in ArcGIS software. Therefore, the parameter maps can be analysed and interpret. The result of the landslide zonation map can be classes as low, medium, and high zone. Through this data analysis also, the final updated landslide susceptibility assessment map of study area will be produced.

3.3.6 Report Writing

Report writing was done after performing the literature review, data collection, data preparation, data analysis and interpretation of landslide susceptibility at the study area. Therefore, a complete report was produced.

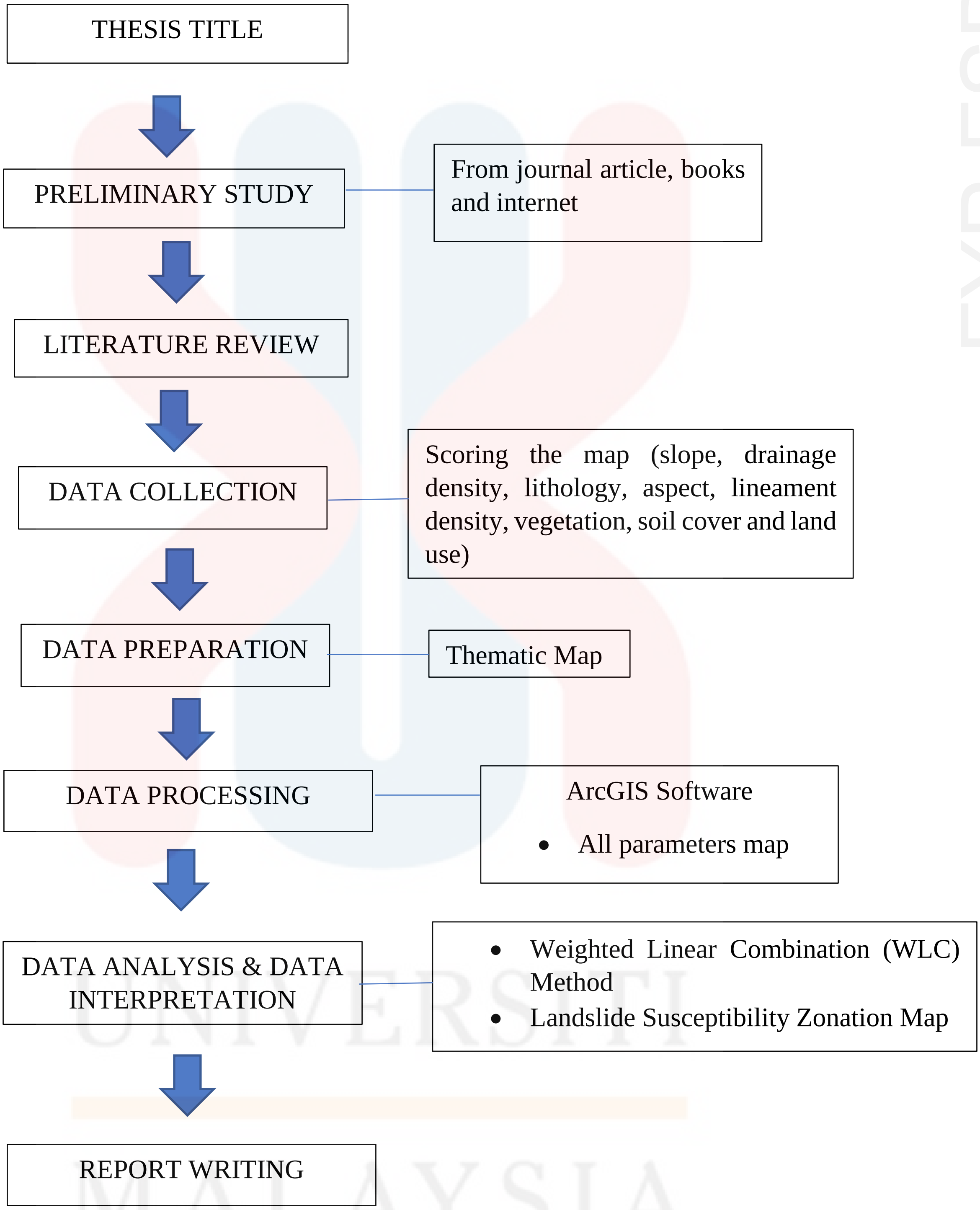


Figure 3.1 Research Flow Chart

CHAPTER 4

GENERAL GEOLOGY

4.1 Introduction

a. Brief content of chapter

General geology is the most important chapter which is discuss about the accessibility, geomorphology, lithostratigraphy, structural geology and historical geology of the study area. All the information is obtained from the interpretation of Google Earth, terrain map and satellite imagery. These information are needed as to explain the occurrence of historical geology with its formation and their associated structure.

b. Accessibility

The study area is located in South of Aring 6, Gua Musang, Kelantan. Based on the google maps, there is the main road connected the study area. This road can be accessed through Jalan Felda Aring which is from FGVM Aring 3 office. There is also the paved and unpaved road in this study area. Based on observation from the Google Earth, the paved road is connected with unpaved road. This is due to the occurrence of landslide that disconnected to the main road. Usually, the unpaved road which is known as estate road is accessed by heavy transportation such as four-wheel drive (4WD), lorry and light transportation such as motorcycle and car. These are mainly used by the workers to access the palm oil plantation. Furthermore, outside of the study area, this road is leading to the Tasik Kenyir which is connected to the Terengganu state.

c. Settlement

Based on interpretation from Google Earth, the settlement is not available in this study area. This is because most of the area is covered by oil palm plantation especially at the hilly area. The nearest settlement of Aring 6 is Kampung Hong, which is located around 3 km from the study area.

Besides, there is also the existing of the Felda Aring 3 which is located around 2 km from the study area. From the base map of the study area, there is the existing of the R.K.T Timur Dua Aring which is the office managed by Felda Global Ventures (FGV). The other office can be found at west of study area which is FGVM Aring 3 office. The Aring area is generally monitored by FGV as this agency managed the palm oil plantation. Figure 4.1 shows the FGVM Aring 3 office outside the study area.

Figure 4.1 FGVM Aring 3 outside of the study area.

(Source: Google Earth)

d. Vegetation

The vegetation of the study area is fully covered with palm oil plantation as the settlement area do not exist at this study area. This palm oil plantation is ventured by Felda Global Ventures (FGV) which is one of the largest palm oil producer and oil palm plantation operator. Figure 4.2 shows the palm oil plantation of the study area.

Figure 4.2 Palm oil plantation in study area

(Source: Google Earth)

4.2 Geomorphology

Geomorphology is referred as a study about landform and its process that related to the origin of the Earth and also the Earth`s evolution such as hills plains beaches, sand dunes and others. Geomorphology process will be included the study of topography, drainage pattern, and watershed of the study area. In geomorphology, the landforms and its processes are investigated. The endogenic (internal) and external (endogenic) process also made up the different type of formation and deformation of landform. The endogenic process occurs as the factors of agents supplying energy for actions that located within the Earth and endogenic factors are origins located well below the Earth`s surface.

4.2.1 Geomorphologic classification

The interpretation geomorphology of study area is obtained from topography map interpretation and satellite imagery that resulted in producing a geomorphological map. This map is used as reference to manage the natural resources and help in variety types of planning and development activities such as road construction.

The geomorphology of the study area can be classified into three classes which is low lands, low hills and hills. This can be identified based on the range of elevation on study area between 300 m to 60 m and the 300 m is the highest peak of elevation.

Most of the study area is covered by low hills landform some hills and minority of the study area is covered by lowlands as the palm oil plantation is the main activities in this area. Each of the landform of study area is classified as table 4.1 below. All of the information is gained through satellite imagery interpretation and based on landform map which is produced by ArcGIS software.

Table 4.1 The classification of landform

Landform	**Elevation (m)**
Low Lands	0 - 50
Low Hills	50 - 200
Hills	200 - 500

(Sources: IGRSM, 2016)

The classification of landform is categorized based on Institution Geospatial Remote Sensing Malaysia, IGRSM. The elevation of low lands landform is ranged from 0 – 50 m. The elevation of the low hills is ranged from 50 m – 200 m and the Hills landform is ranged from 200 m to 500 m.

Figure 4.3 shows the landform map in the study area. From this map, it can be seen study area is mainly covered by low hills landform which is the elevation value is range from 50 m to 200 m.

Besides GIS application, the landform in the study area can also be observed from satellite imagery and aerial photograph. Through this observation, it can be concluded most of the landform area is covered by palm oil plantation. Figure 4.4 shows the 3D map in the study area.

The geomorphological or landform characteristics is very important as it can estimate the massive landslide potential of the study area. Knowing the geomorphological features is crucial for the identification of a large estimate of the potential for landslides in the study area.

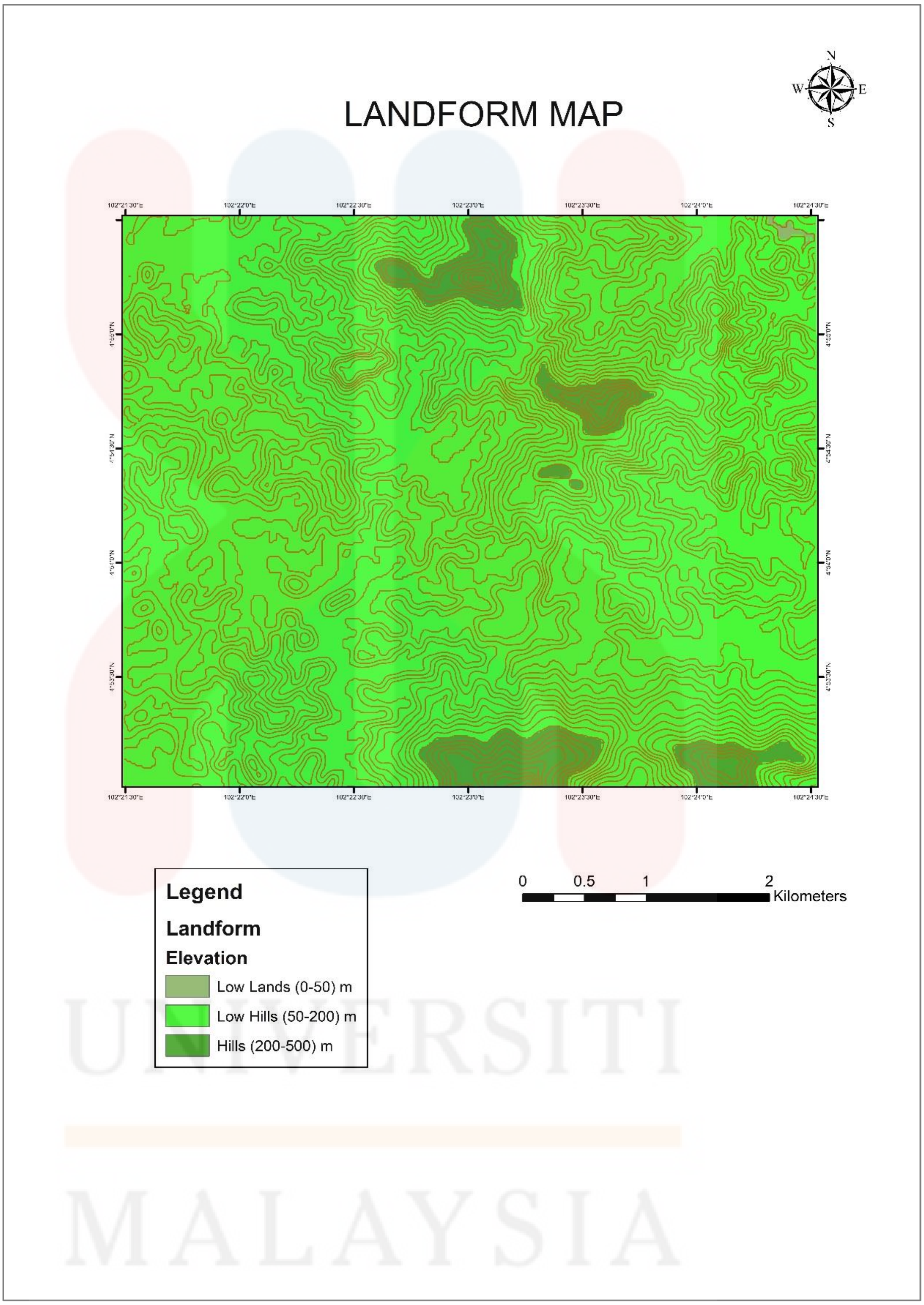


Figure 4.3 Landform Map

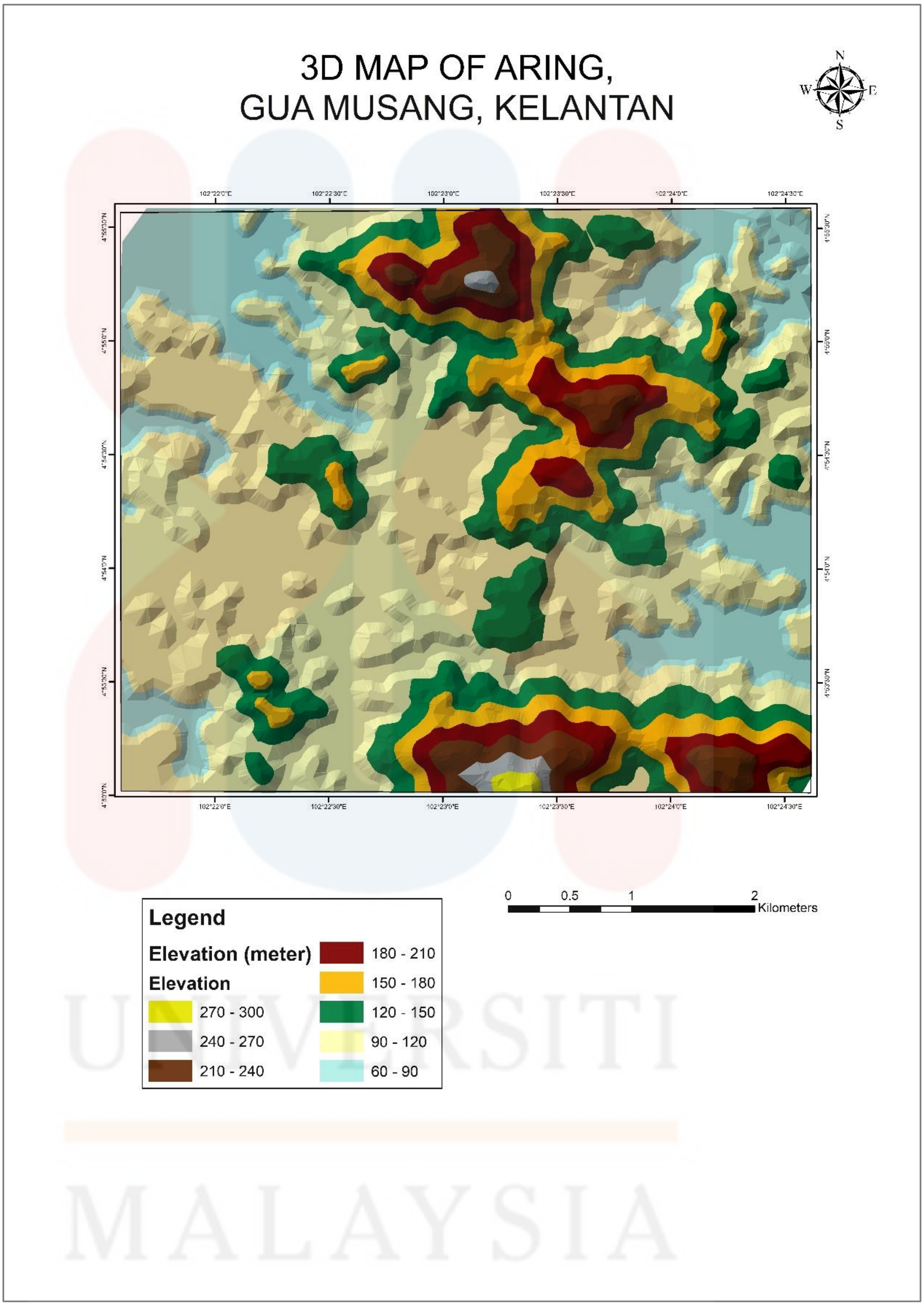


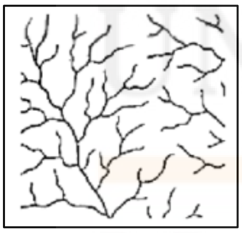
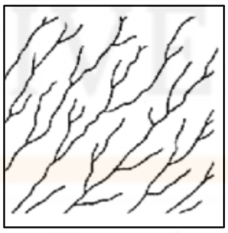
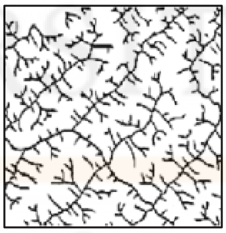
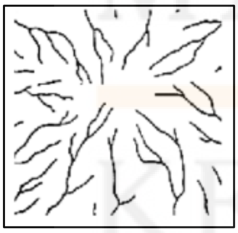
Figure 4.4 3D map of study area

4.2.2 Drainage Pattern

Drainage system is referred as a system which develop to form a space from water that flows from rainfalls on the Earth`s surface which provide efficiency for water move from land. Drainage pattern is a topographical feature where the runoff of stream or groundwater flow that can be classified as topography barriers called watershed. Drainage pattern is also controlled by topography, slope, structural control, nature of rock and geological history of the region. The design of tributaries within a catchment area depends mostly on the type of rock and structures present in the area.

There are some types of drainage pattern such as dendritic, parallel, trellis, rectangular, radial, annular, multi-basinal and contorted (Table 4.2). However, there are two types of drainage pattern that can be observed from the study area which is dendritic and parallel. This may indicate the river had branched in many direction and flow in with the direction of the valley. Figure 4.5 shows the drainage pattern map of study area.

Table 4.2 Types of drainages pattern

 Dendritic	 Parallel	 Trellis	 Rectangular
 Radial	 Annular	 Multi-basinal	 Contorted

(Source: After Howard, 1967, p. 2248).

Dendritic drainage pattern is the most common form and it found based on shape like resembles a tree and they form where river follows the slope of the terrain. Dendritic is the common major of the drainage pattern of the study area. The dark blue colour of drainage pattern in Figure 4.5 indicated the dendritic drainage pattern.

This pattern is developed in regions underlain by homogenous material lithologies, horizontal or very gently dipping resulted of stream to flow in all direction without fixed preference. This is due to the similar resistance of subsurface geology with weathering. Therefore, there is no apparent control over the direction the tributaries take.

The light blue colour of tributaries in Figure 4.5 indicated the parallel drainage pattern. Generally, parallel drainage pattern is caused by steep slope where the streams are swift and straight with very few tributaries which flow in the same direction. This pattern frequently can be found on uniform sloping and dipping rock beds. It is also developed in outcropping resistant rock bands. This pattern also indicates the presence of a major structure known as major rock. In the study area, there is the major faults found which is normal fault. This fault cuts across and area of steeply folded bedrock.

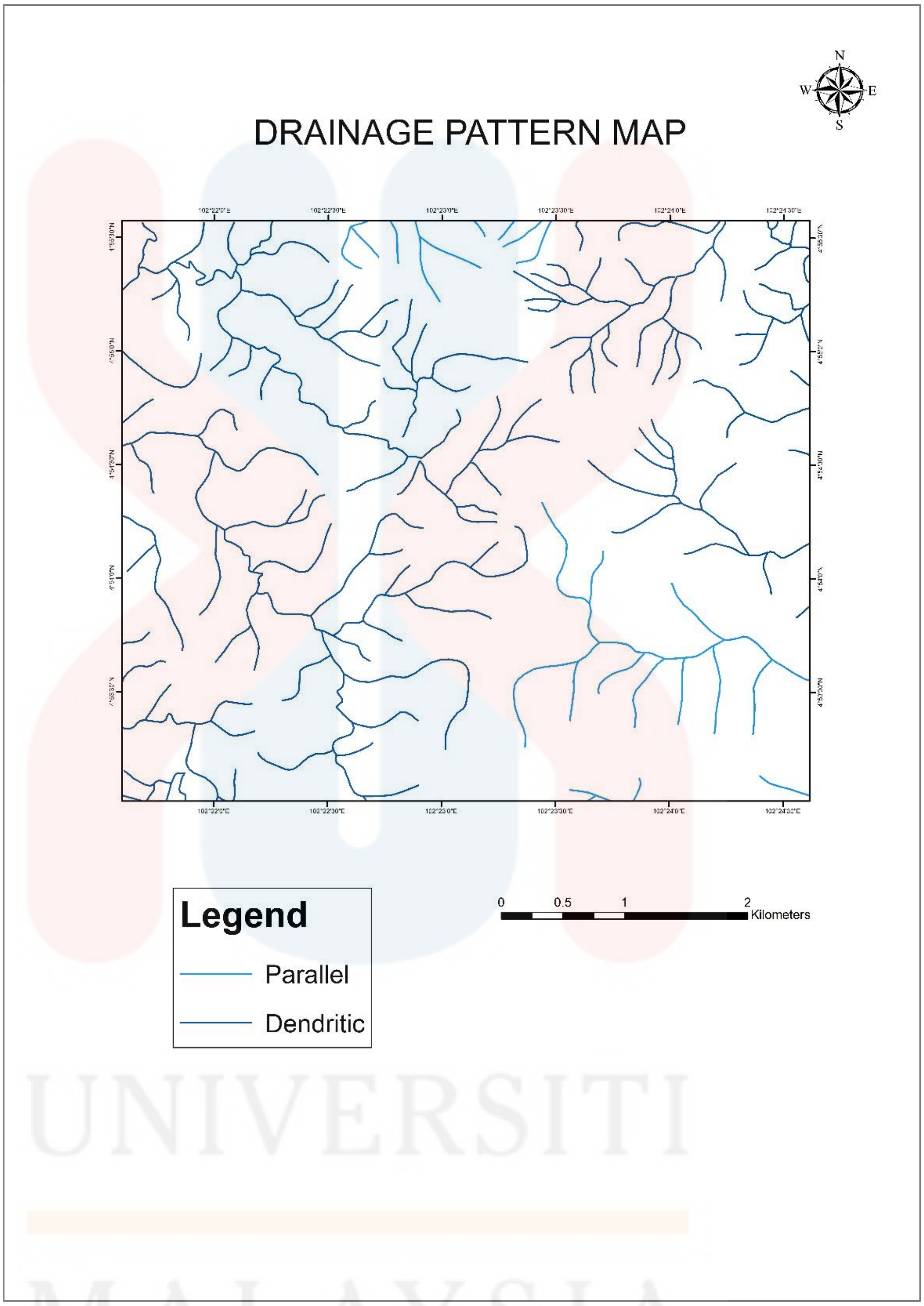


Figure 4.5 Drainage pattern of study area.

Watershed is the place where all of water will flow into and will be accumulate. It is also known as the area or ridge of land that separates the waters to flow to different basins, rivers or seas. The watershed also consists of streams, reservoirs, lakes and wetlands and all the underlying groundwater. The watershed map is created by GIS application. This map can be used to determine where the water entering the storm drain comes from.

From the Figure 4.5, there are three types of the watershed that is colourized to differentiate the watershed. Watershed has been flowing from the hilly area to tributaries and will accumulate at the river. For watershed 1, the name of tributaries is Sungai Merkir. There is Sungai Payong and Sungai Nuar in watershed 2. For the watershed 3, the river exit is Sungai Janggit.

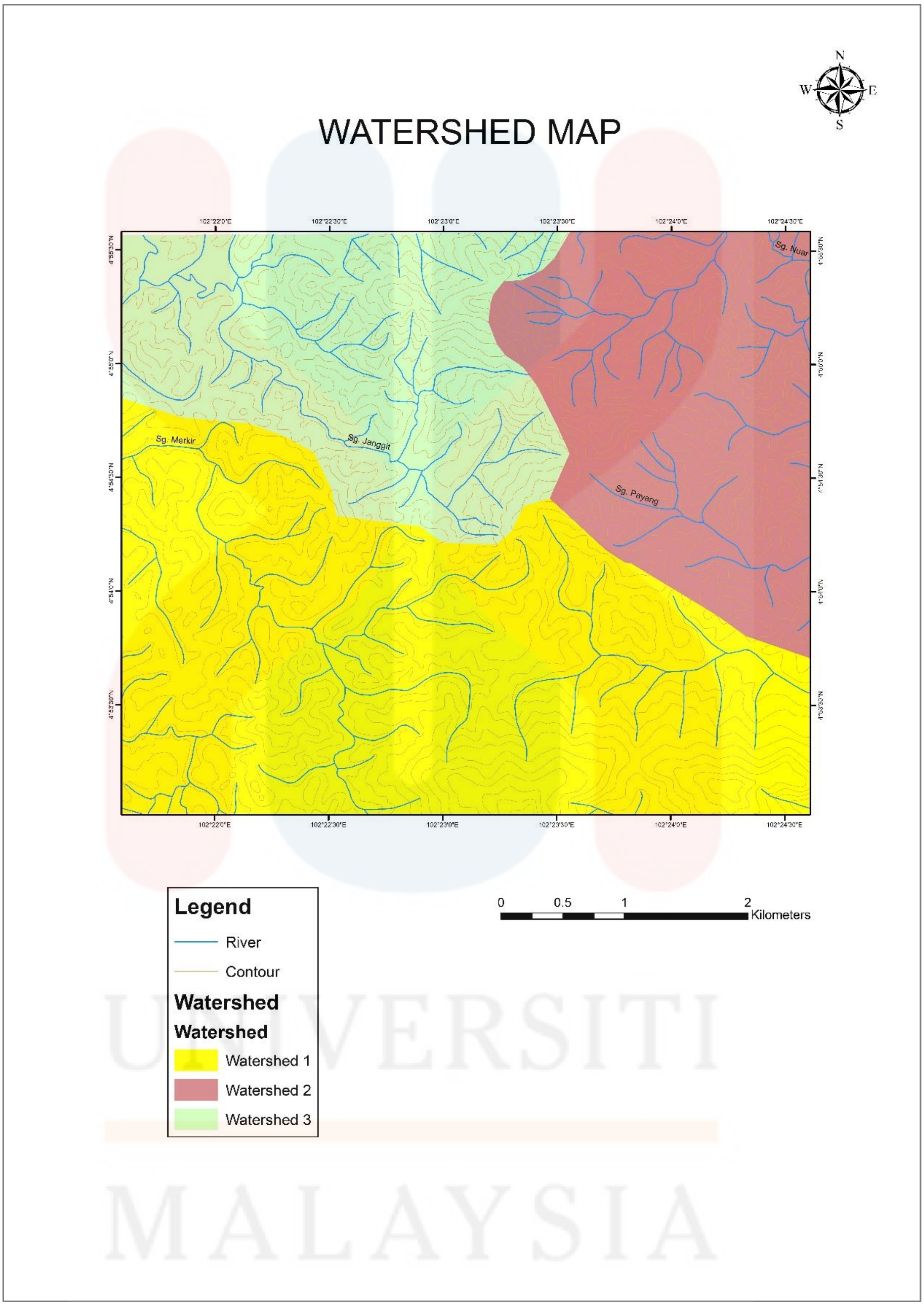


Figure 4.6 Watershed Map

4.3 Lithostratigraphy

4.3.1 Stratigraphy

Stratigraphy is branch of geology concerned with the study of rocks layers which is known as strata and also layering known as stratification. The subfield of the stratigraphy can be related with lithostratigraphy and also biostratigraphy. Table 4.3 below shows the stratigraphic column of the study area. This stratigraphic column indicated the age of the rocks which is oldest rock unit lies at the bottom while the youngest rock unit lies at the top.

The type of formation of study area is Aring Formation. Aring Formation is ranging from Upper Carboniferous to Lower Triassic. In the Palaeozoic era, the oldest rock is tuff. This rock is ranging from Upper Carboniferous to Lower Permian. The andesite rock is ranging from Lower Permian to Upper Permian in Palaeozoic Era. In Mesozoic era, the shale is ranging at age Lower Triassic. From the stratigraphic column, the layer of shale, andesite and tuff are unconformable to each other. Figure 4.7 shows the geological map of study area.

Table 4.3 Stratigraphy column of study area.

Era	Period	Epoch	Lithology	Formation	Explaination
Mesozoic	Triassic	Lower	Shale		Fine-grained shale
Paleozoic	Permian	Upper- Lower	Andesite	Aring Formation	Consist of andesite, adesitic breccia, auto breccia and banded hornfels
	Carboniferous	Upper	Tuff		Dominating with lapili tuff with some fine grained, tuff and granodiorite.

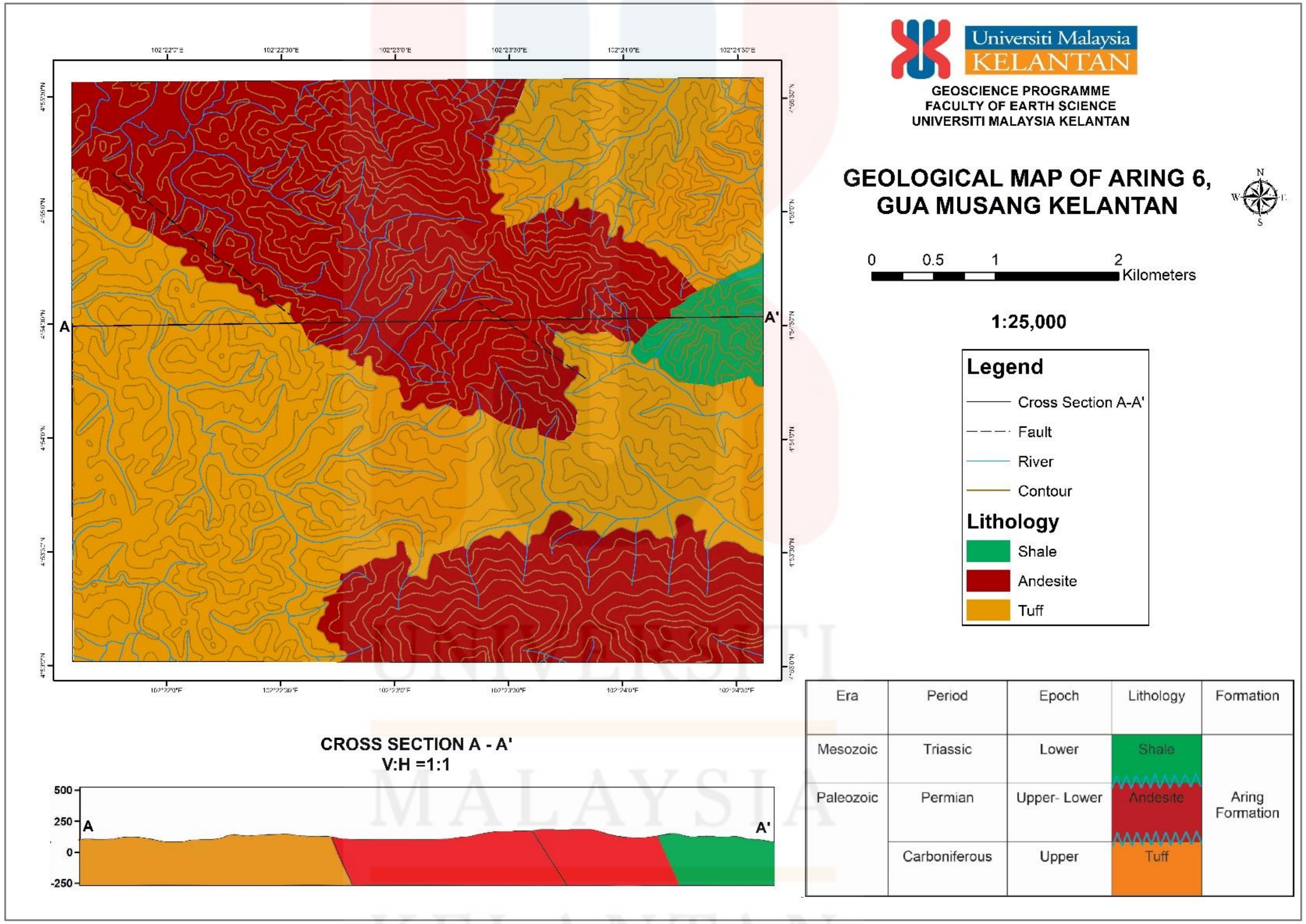


Figure 4.7 Geological map in the study area

4.3.2 Unit Explanation

Based on stratigraphic column in Table 4.3, there are three types of unit can be found in the study area. These units are included tuff unit, andesite unit and shale unit. Based on previous research on this study area, this area is primarily composed of volcanic rock which have shallow marine depositional environment.

a. Tuff unit

Tuff unit is dominated in this study area approximately 55% of the total extent of study area. Tuff unit is dominated with lapilli tuff with some fine-grained texture. There is also variety of types of tuff with its composition and size fragment can be found from this study area.

Based on the previous findings (Najwa Nabila Mahat, 2018), the colour of tuff is milky white. It is composed very fine-grained ash. Figure 4.8 shows the classification of pyroclastic rocks using fragment composition (after Pettijohn,1975). Basically, the classes of can be divided into three classes which is vitric tuff, lithic tuff, and crystal tuff.

The tuff in the study is classified as vitric tuff. Vitric tuff is known as pumice and glass tuff. Crystal tuff is referred as crystal fragments while lithic tuff is referred as rock fragments. Thus, it is classified as vitric tuff as it composed of glass and ash dominated material. The colour of rock is very light grey with oxidation of manganese mineral in rock fracture. The rock is compacted and consolidated with aphanitic texture. Figure 4.9 shows the outcrop and hand specimen of tuff.

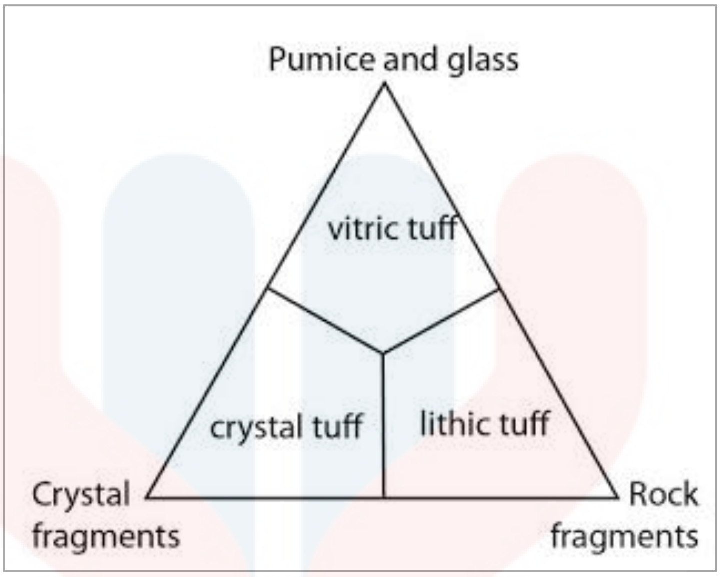


Figure 4.8 Classification of pyroclastic rocks using fragment composition (after Pettijohn ,1997)

Figure 4.9 a) outcrop of tuff, b) Hand specimen of tuff**.**

(Source: Najwa Nabila Mahat, 2018)

There is also lapilli tuff in the study area. The colour of rock is very light grey colour. It is matrix which is dominated with mostly fine-grained to glassy and contain big fragments. Lapilli tuff is felsic composition with medium sized fragment which is compact and consolidated. Figure 4.10 shows the outcrop and hand specimen of lapilli tuff.

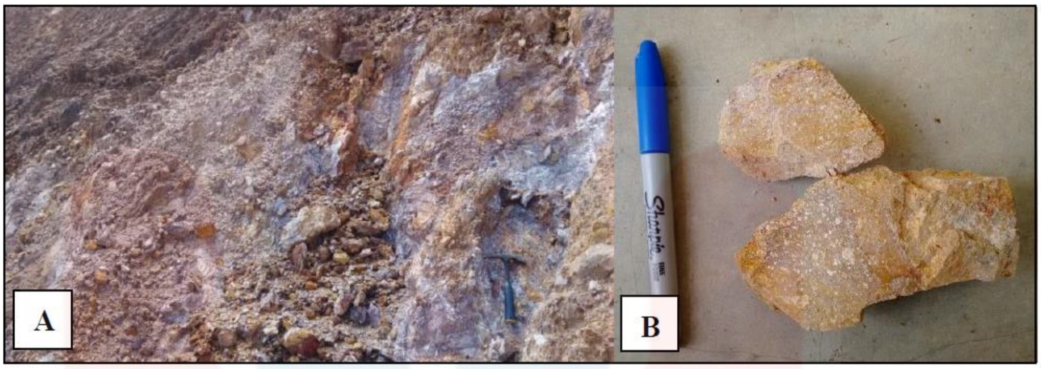


Figure 4.10 a) Outcrop of lapilli tuff, b) Hand specimen of lapilli tuff.

(Source: Najwa Nabila Mahat,2018)

Besides tuff, there is also diorite rock exist in the study area. Based on previous research (Najwa Nabila Mahat, 2018), the colour of rock is white and black with phaneritic texture. This rock is classified as intermediate intrusive rock which is massive, compacted, very hard and has non-metallic luster. Figure 4.11 shows the outcrop and hand specimen of diorite.

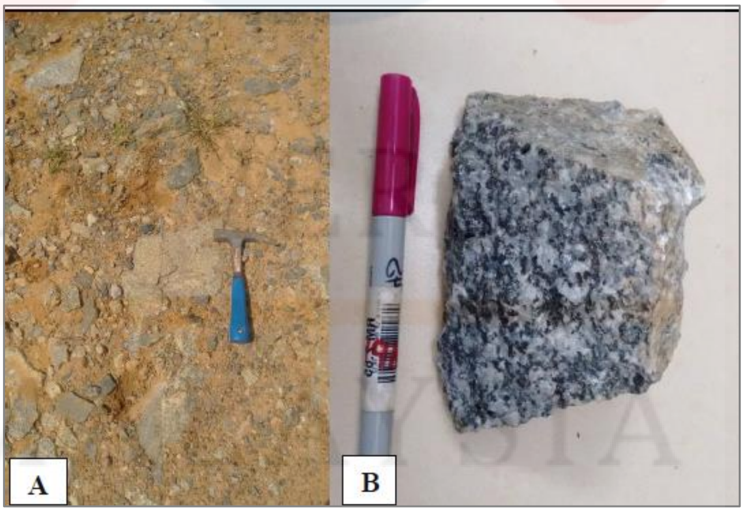


Figure 4.11 a) Outcrop of diorite, b) Hand specimen of diorite

(Source: Najwa Nabila Mahat, 2018)

b. Andesite unit

Andesite is an extrusive volcanic rock of intermediate composition. The texture of andesite is fine-grained and usually in light to dark grey in colour. The mineral rich in andesite are plagioclase feldspar mineral. Not only that, the minerals such as pyroxene, biotite or amphibole also may consist in andesite rock. Usually, quartz and olive minerals do not contain in this rock.

Based on (Najwa Nabila Mahat, 2018), the texture of andesite in the study area is aphanitic to porphyritic texture. This rock is found in form of volcanic breccia. Figure 4.12 shows the andesite boulder and hand specimen of andesite. This colour of rock is light grey. It is aphanitic texture which indicated as intrusive igneous rock. As shown in Figure 4.12, the texture of rock is massive, compacted and very hard.

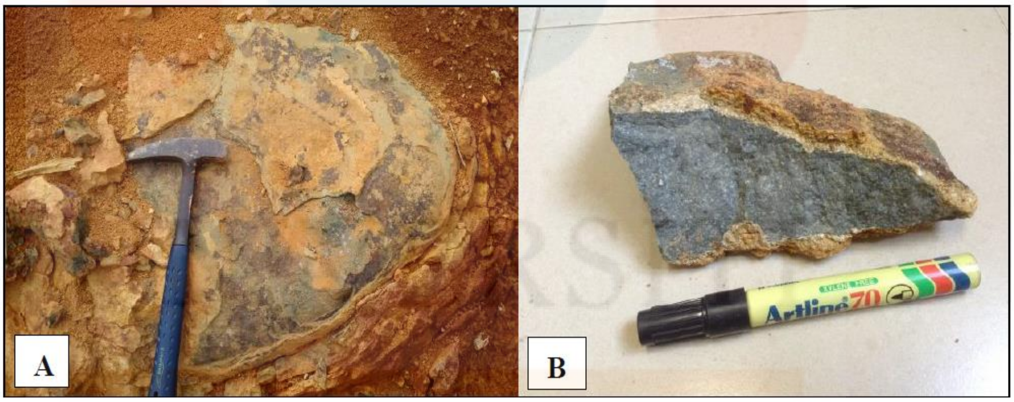


Figure 4.12 a) Andesite boulder, b) Hand specimen of andesite.
(Source: Najwa Nabila Mahat,2018)

Not only that, there is also the large of andesite outcrop exits in the study area as shown as in Figure 4.13. Based on previous research, this outcrop consists of andesite breccia, andesite lava and fine layer lamination of metasediment deposited at wall of outcrop. From the observation in Figure 4.13, this colour is grey.

Figure 4.13 Andesite outcrop

(Source: Najwa Nabila Mahat, 20180

Figure 4.14 shows the outcrop of andesite breccia and hand specimen of andesite breccia. Basically, volcanic breccia can be distinguished based on the colour and shape of fragment of the rock. The colour of rock fragment for the andesite breccia is light grey to greenish colour. This rock is composed of angular fragment and fine-grained matrix.

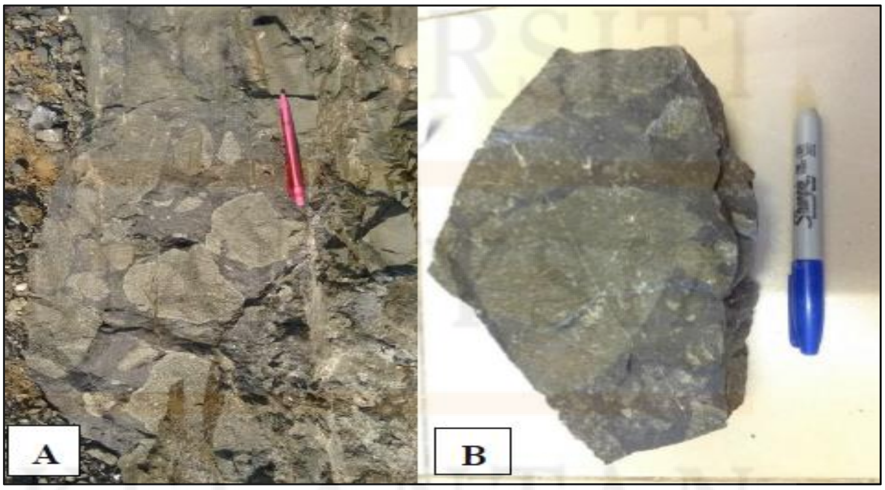


Figure 4.14 a) Outcrop andesite breccia, b) Hand specimen of andesite breccia.

(Source: Najwa Nabila Mahat,2018)

c. Shale unit

Shale is one type of sedimentary rock with a fassility properties. The shale unit only cover 5% of total extent of study area. Figure 4.15 shows the outcrop and hand specimen of shale. The fissile properties of shale are referred as tendency or its ability to split along flat planes of weakness known as "parting surface". This fissile property is occurred due to sedimentary or metamorphic processes.

The mineral composition of shale is made up of major minerals such as quartz and calcite. There is also the minor of the mineral of the shale such as pyrite, iron oxide and feldspar.

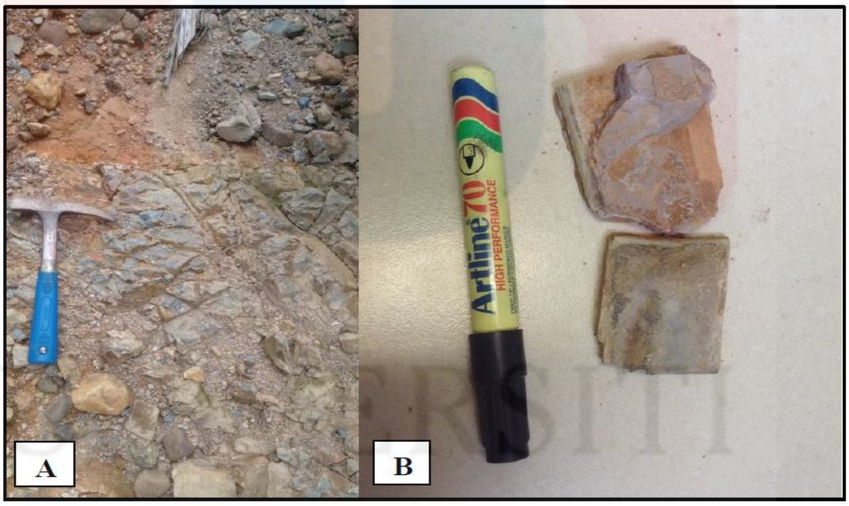


Figure 4.15 a) Outcrop of shale, b) Hand specimen of shale.

(Source: Najwa Nabila Mahat,2018)

4.4 Structural Geology

Structural geology is the study of the three-dimensional distribution of rock units, with their surface and the composition of the interior with their past geological event and deformation histories. The structural geology is important because it can determine the historical information of formation and deformation in the rocks. All the structural geology of the study area are interpreted by using satellite imagery or aerial photograph.

4.4.1 Lineament Analysis

Generally, the interpretation of lineament analysis of the study area is obtained from the satellite imagery, google earth and aerial photograph. Lineament analysis is important as to analysis the correlative structures that have obvious surface expression. Figure 4.16 shows the terrain map of study area that is used for lineament analysis.

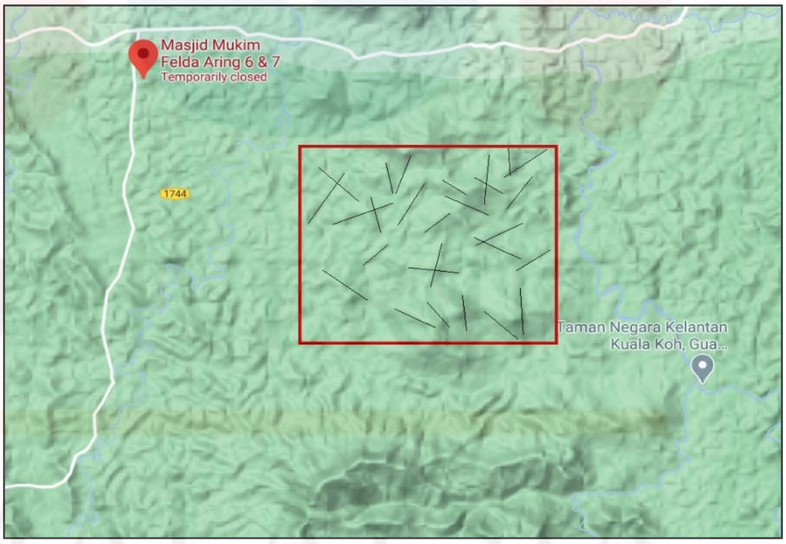


Figure 4.16 Terrain map of study area for lineament analysis.

This lineament analysis is also used to generate the rose diagram using software such as GeoRose software. From the lineament orientation by rose diagram, the maximum stress force and minimum force can be determined. The major stress is determined by the most of stress come from in the direction. The long lineaments measured also can be indicated as the continuity faults or other structures.

Figure 4.17 shows the lineament rose diagram of study area. The biggest force with the highest distribution of the lineament is N 40° E and the low distribution of the lineament is 100° towards SE. The highest distribution is indicated as the shear and the direction of the shear is to left. From the lineament rose diagram, it can be interpreted there is the major structure of faults which is left strike slipe fault may exist in the study area. Therefore, this can be related with the minor fault which is normal fault in the study area. The normal faults can be observed from the hill shade map.

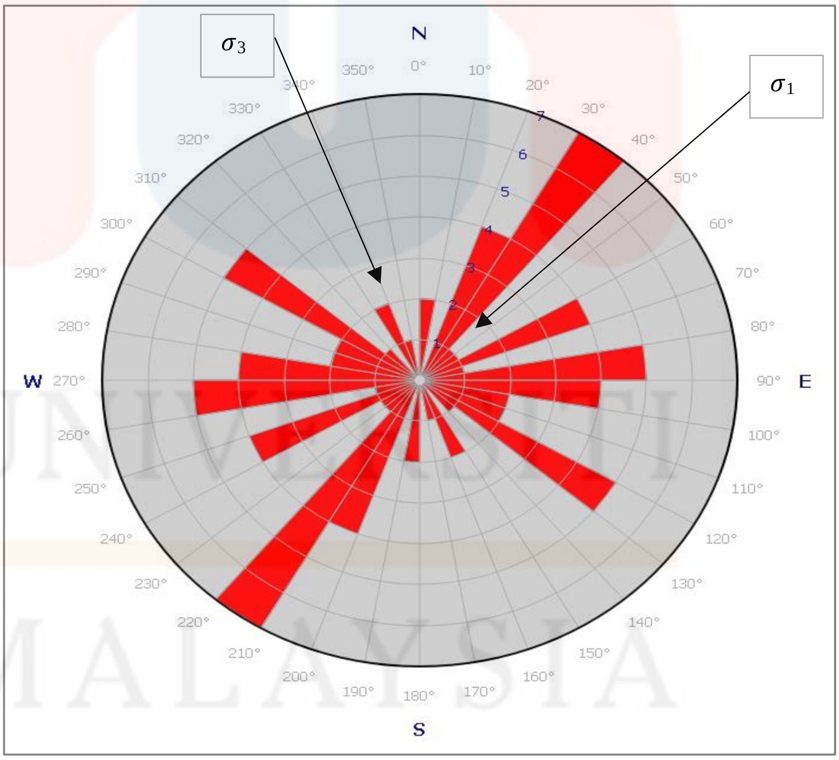


Figure 4.17 Lineament Rose diagram.

Figure 4.18 shows the lineament map of study area. This lineament is obtained through hill shade map with difference range of shade.

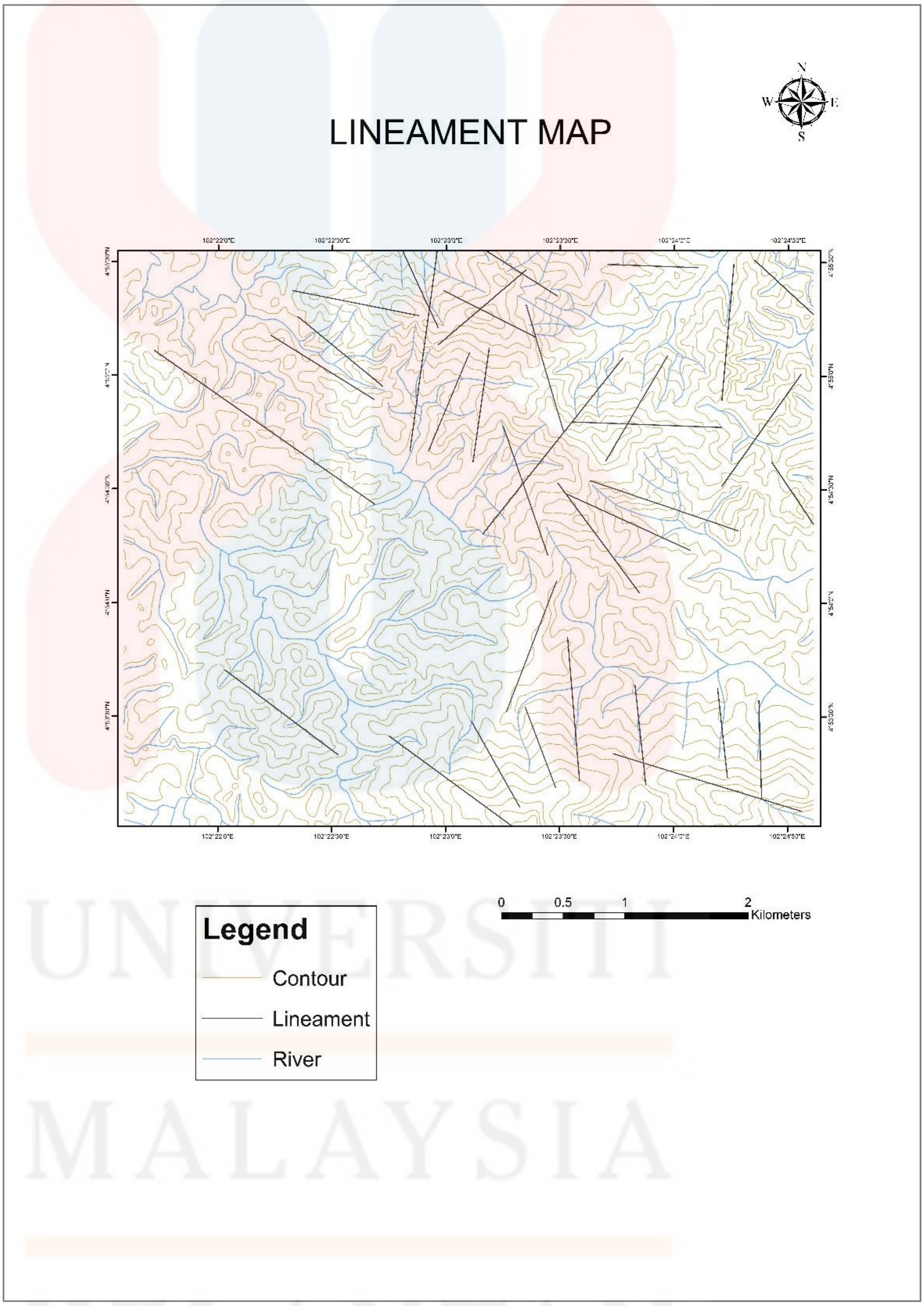


Figure 4.18 Lineament map of study area.

There is also negative and positive lineament of the rose diagram. The negative lineament represents valleys, rivers, and faults while the positive lineament represents ridge and range. Figure 4.19 shows the rose diagram for negative lineament and Figure 4.20 shows positive lineament of rose diagram. These lineaments are important as to identify the geological structure of the study area.

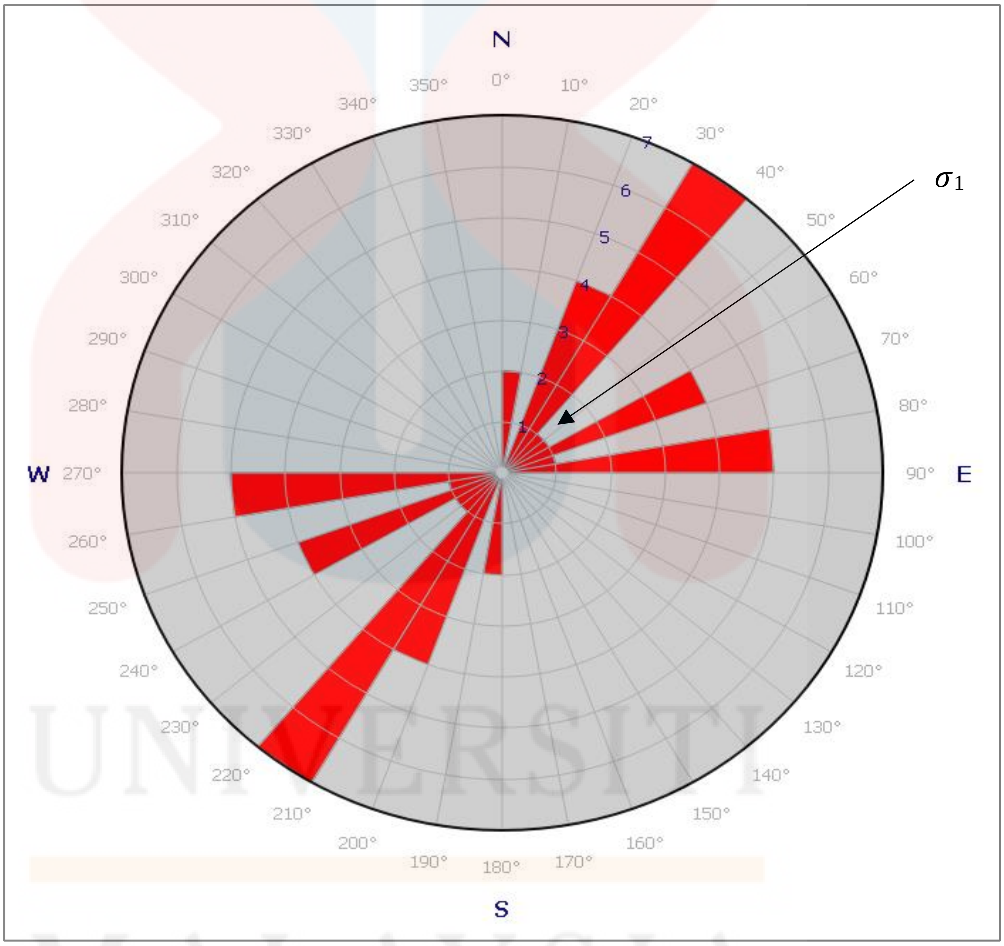


Figure 4.19 Rose diagram for negative lineament.

Based on Figure 4.19, it can be interpreted the maximum stress force is at N 40° E while the minimum stress force is N 5° E. Figure 4.20 shows the rose diagram for positive lineament.

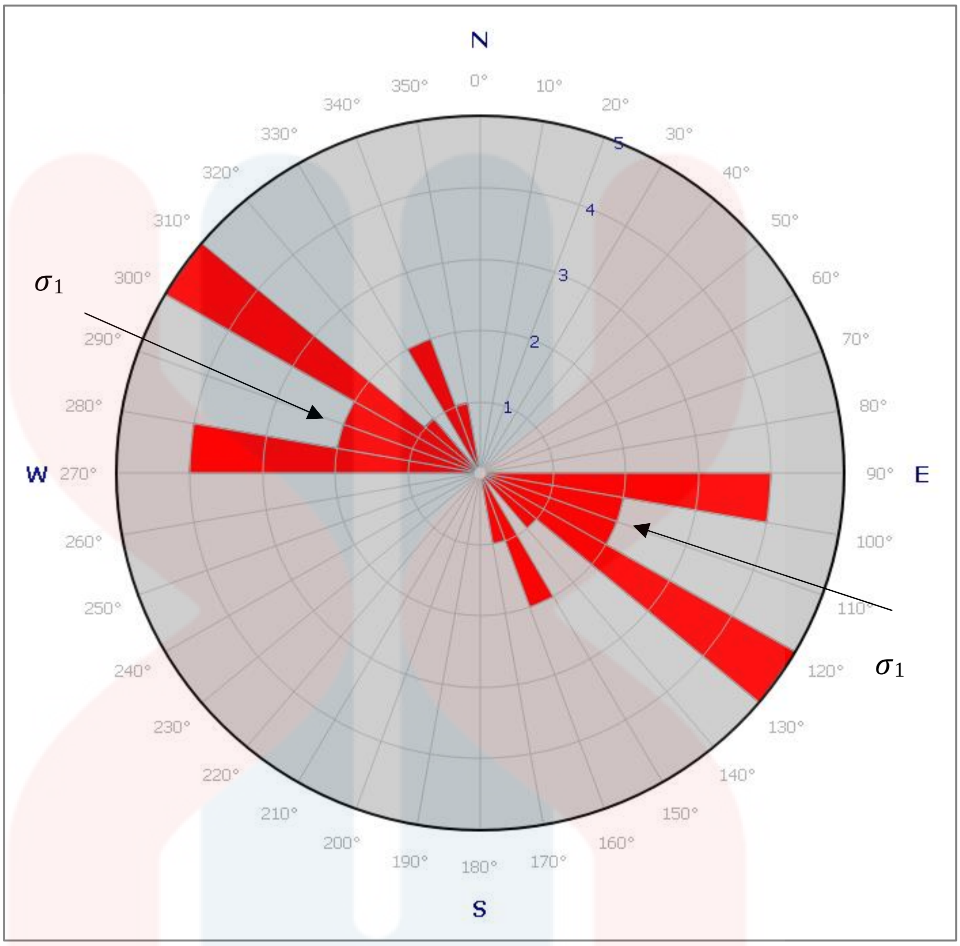


Figure 4.20 Rose diagram for positive lineament.

Based on Figure 4.20, it can be interpreted the orientation of maximum force is at N 300° W while the orientation of the minimum force is at N 330°W which is perpendicular to the major principal stress.

4.5 Historical Geology

The historical geology of the study area is started from Upper Carboniferous to Lower Carboniferous which is known as Aring Formation. This formation is recognized based on its boundary as it is tectonized upper contact with Telong and Koh Formation.

Generally, the volcanic facies such as agglomerates, tuffs, volcanic breccias and agglomerate of Aring Formation are interlaminated, interbedded with limestone or tuffaceous shale (Abdullah, 1993; Leman 1995). The facies of Aring Formation can be related with the three rock units found in the study area which is tuff unit, andesite unit and also shale unit.

Mostly the study area is covered by the tuff unit. In the Palaeozoic era, tuff is ranging from Upper Carboniferous to Lower Permian. This rock is unconformable with andesite unit. In this era also, the andesite unit is ranging from Lower to Upper Permian. Thus, tuff is classified as the oldest rock unit in the study area. In Palaeozoic era also, andesite unit is ranging from age of Lower Permian to Upper Permian. For Mesozoic era, the shale unit which is the youngest rock is ranging at the age of the Lower Triassic. There is the minority the distribution of the shale in this study area.

In aspect of depositional environment, Aring area is covered by shallow marine environment. There is no fossil evidence found in this study area. However, the distribution of the fossil can be observed near to the study area which indicated shallow the depositional environment.

Based on interpretation of the study area via the Google Earth, the geomorphological process and human activities in the study area causes the changing of the landscapes. This can contribute the potential risk to the slope failure that induced the landslides occurrence and will be discuss further in Chapter 5.

CHAPTER 5

LANDSLIDE SUSCEPTIBILITY ASSESSMENT

5.1 Introduction

This chapter will be focussed on landslide susceptibility assessment of Aring 6, Gua Musang, Kelantan. The landslide susceptibility will be determined and analysed by using Weighted Linear Combination (WLC) method.

There are eight parameters used in determining landslide causative factors such as slope, aspect, drainage density, lithology, lineament density, vegetation, soil cover and land use. These are generated and analysed from GIS application. These parameters are selected based on the analysis on types of landslide and the characteristics of the study area.

In WLC method, weights are allocated based on the relationship of landslide predominant factors with the landslide occurrence. Therefore, each of average weightage of each parameter are used to determine the landslide susceptibility of the study area.

5.2 Parameter of Landslide Causative Factor

In this study, the maps such as slope, aspect, and drainage density are generated from DEM data. Each of the parameters are used and classified based on the weightage of parameter of landslide causative factor. The others parameters such as lithology, vegetation, soil cover and lineament density also used in landslide assessment. These parameters will be contributed to the potential or failure of the landslide. Figure 5.1 shows the weightage of parameter of landslide causative factor.

Table 5.1 Weightage of parameter of landslide causative factor.

No	Parameter	Weightage (Wi)
1	Slope	6
2	Drainage Density	8
3	Lineament Density	7
4	Aspect	1
5	Land use	4
6	Lithology	5
7	Vegetation	3
8	Soil Cover	2

5.2.1 Slope

Slope is derived from the DEM and it is the most important parameters in determining the landslide susceptibility of study area. In the study area, the degree of slope is varying from 2° to 34°. This is because oil palm plantation is the main agriculture activities in Aring 6, Gua Musang, Kelantan and the vegetation area are the main cause that affected in the degree of slope. Table 5.2 shows the classification of slope as landslide susceptibility factors.

Table 5.2 Classification of Slope

No	Slope (°)	Description
1	0 -2°	Flat/ almost flat
2	3 - 7°	Gently sloping
3	8 - 13°	Sloping
4	14 - 20°	Moderately steep
5	21 – 55°	Steep

The slope map from Figure 5.1 is generated by using DEM data. This classification of slope is made based on the Institution of Geospatial and Remote Sensing Malaysia, IGRSM (2016). Generally, there are five classes of slope such as flat or almost flat, gently sloping, sloping, moderately slope and steep. The maximum slope of the study area is 34° which indicated steep slope.

Table 5.3 shows the weightage and score for slope that is used for landslide analysis. The chosen weightage is 6 and multiple with area (km^2) to obtain the score of each slope classification. From this table, the lowest score is 0 -2° which is categorized as flat or almost flat slope. The highest score of the study area is dominated at steep slope with 54 value of score. This is because, the higher of weightage and score indicate, the higher the influence of slope as landslide causative factor.

Table 5.3 Weightage and score for slope.

No	Slope (°)	Rank	Weightage (Wi)	Area (km^2)	Score (Weightage × Area)
1	0 -2°	1	6	3	18
2	3 - 7°	3	6	5	30
3	8 - 13°	5	6	3	18
4	14 - 20°	7	6	5	30
5	21 – 55°	9	6	9	54

Figure 5.1 shows the slope map of study area. From the slope map, it can be analysed, most of the study area is dominated by steep and flat slope. This is because of the hilly area of study area is used for palm oil plantation. Besides DEM data, the slope is determined through the satellite imagery, Google Earth or aerial photograph.

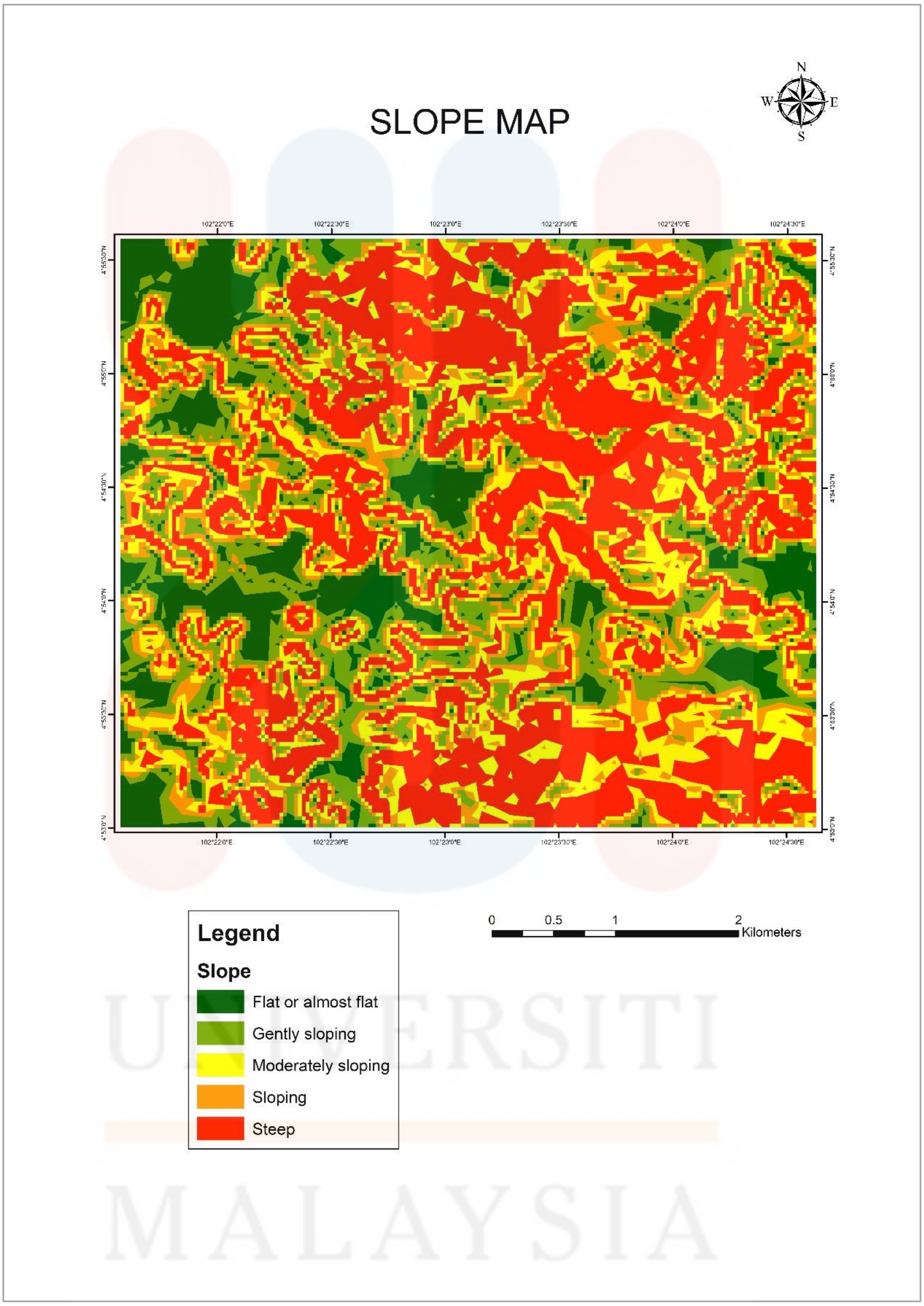


Figure 5.1 Slope map of study area.

5.2.2 Drainage Density

The meaning of drainage density is derived from the formula of the total length of the streams and river in a drainage basin divided by the total area of the drainage basin. Equation 5.1 shows the formula of the drainage density.

$$Drainage\ Density = \frac{Stream\ Length}{Area} \quad (5.1)$$

Drainage density is affected by climate and physical characteristics such as topography, soil infiltration and vegetation of the drainage basin. This parameter is important as it related to the dynamic nature of the stream segments and area in morphometry analysis of drainage networks. Some factors can be related with drainage density parameter such as geology, relief and climate and it may affected the functional relationship of the drainage density. This is because the parameter related with the rate of erosion as it depends on the dominant hillslope transport process through landslide.

There are four classes of drainage density such as low, medium, high and very high. Table 5.4 shows the weightage and score for drainage density and Figure 5.2 shows the map of drainage density of study area. This map is extracted from DEM data in ArcGIS and the raster map is converted into polygon.

Table 5.4 Weightage and score for drainage density.

No	Drainage Density	Rank	Weightage (Wi)	Area (km^2)	Score (Weightage × Area)
1	Low	3	8	14	112
2	Medium	5	8	9	72
3	High	7	8	1	8
4	Very High	9	8	1	8

From the Table 5.4, the low drainage density with 112 value of score and this indicates the lower possibility of landslide occurrence. The value of for high and very high drainage density is same with 8. This indicated the higher possibility of landslide occurrence of the study area.

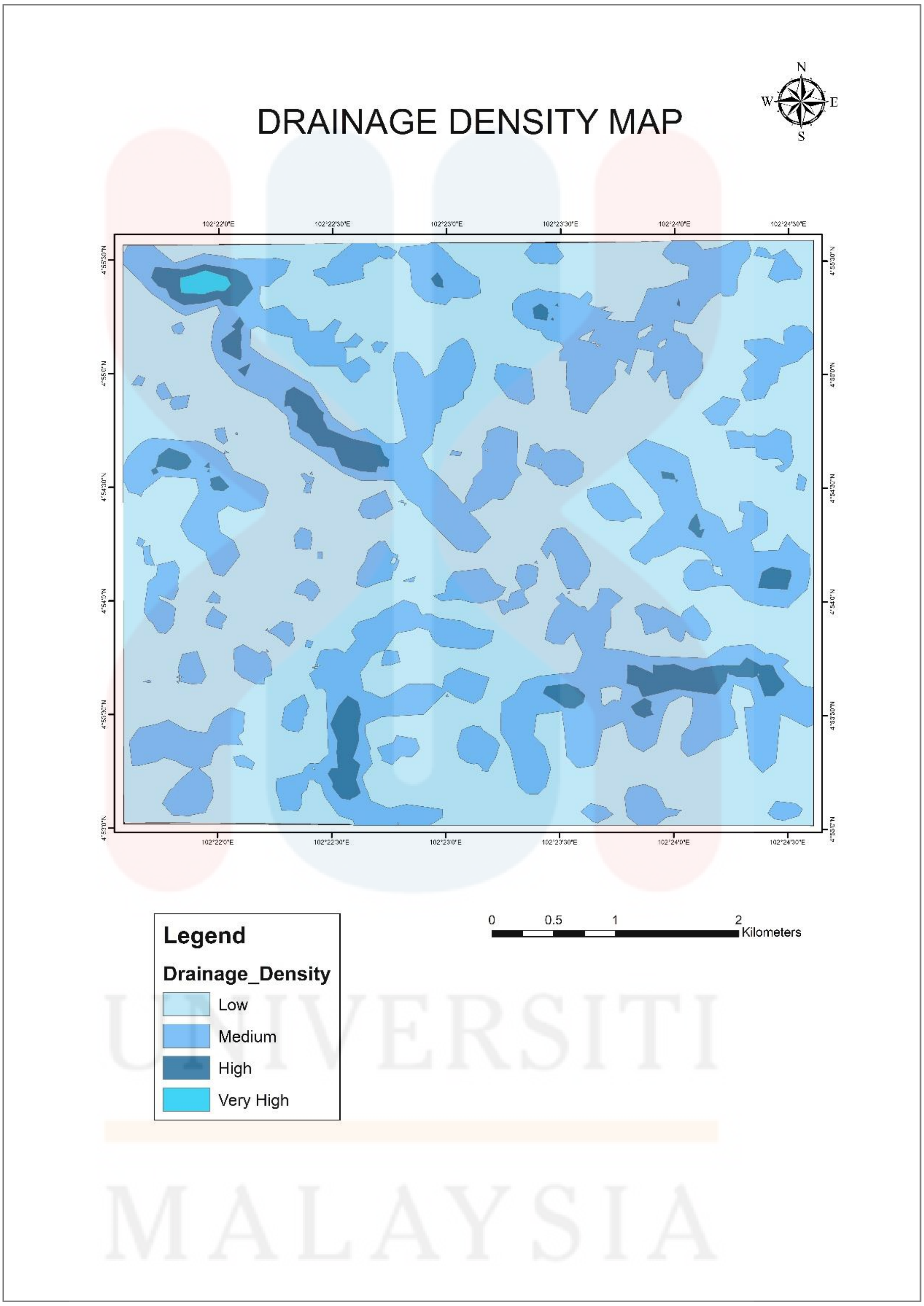


Figure 5.2 Drainage density map.

5.2.3 Lineament Density

Lineaments is the structurally controlled linear features that can be identified by the relatively linear alignments. Lineaments indicates that there are the presence of the faulting and fracturing that resulting in the increased of the secondary permeability and porosity. By measuring the density of the lineament, the susceptibility of landslides hazard can be determined.

There are 3 groups of lineaments that are recognized in the study area that is low group, moderate group, and also the high group. The low score group is the lowest influence to the landslide susceptibility while the high score group influenced the most to the landslide occurrences. The weightage of lineament density is 7 and will be multiply by the area (km^2) that is shown in the table 5.5 below. Figure 5.3 shows lineament density map of study area.

Table 5.5 Weightage and score for lineament density.

No	Lineament Density	Rank	Weightage (Wi)	Area (km^2)	Score (Weightage × Area)
1	Low	4	7	19	133
2	Medium	6	7	5	35
3	High	8	7	1	7

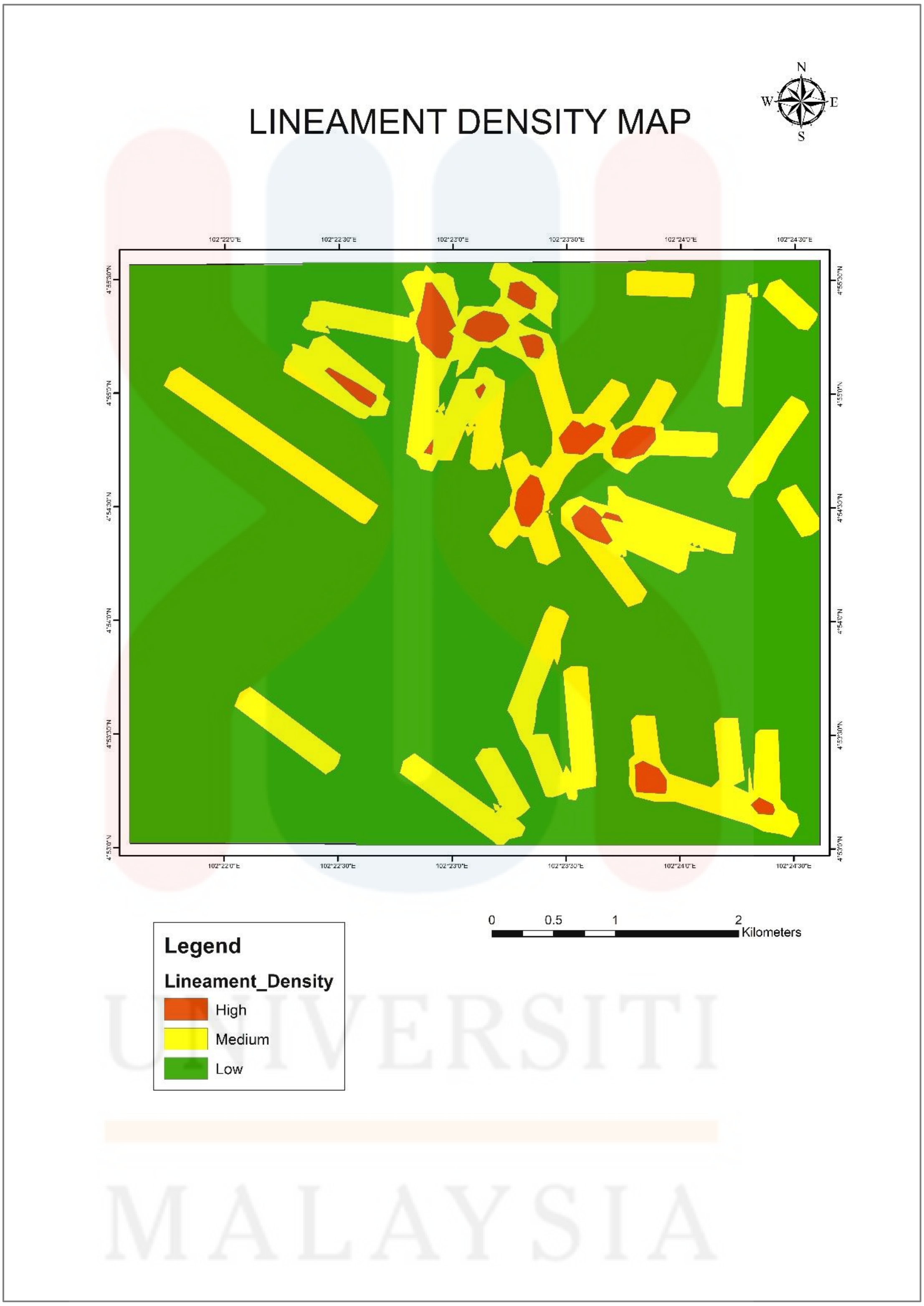


Figure 5.3 Lineament density map.

5.2.4 Aspect

Generally, the parameter of aspect is divided into a few classes such as flat, North, Northeast, East, Southeast, South, Southwest, West, Northwest and North. Generally, aspect map can display the aspect which is direction and slope which is steepness of a continuous surface as this aspect map is generated from DEM data. The degraded vegetation area due to palm oil plantation will receive direct sunlight and thus can increase occurrence of landslide. Aspect can also influence the amount of rainfall and moisture content in soil and thereby influences the stability of the slope. Table 5.6 shows the weightage and score for aspect and Figure 5.4 shows the aspect map of the study area.

Table 5.6 Weightage and score for aspect.

No	Slope Direction	Rank	Weightage (Wi)	Area (km^2)	Score (Weightage × Area)
1	West	4	1	3	3
2	South	9	1	2	2
3	Flat	1	1	2	2
4	Northwest	3	1	2	2
5	Northeast	5	1	4	4
6	North	2	1	3	3
7	Southeast	8	1	3	3
8	East	7	1	3	3
9	Southwest	6	1	3	3

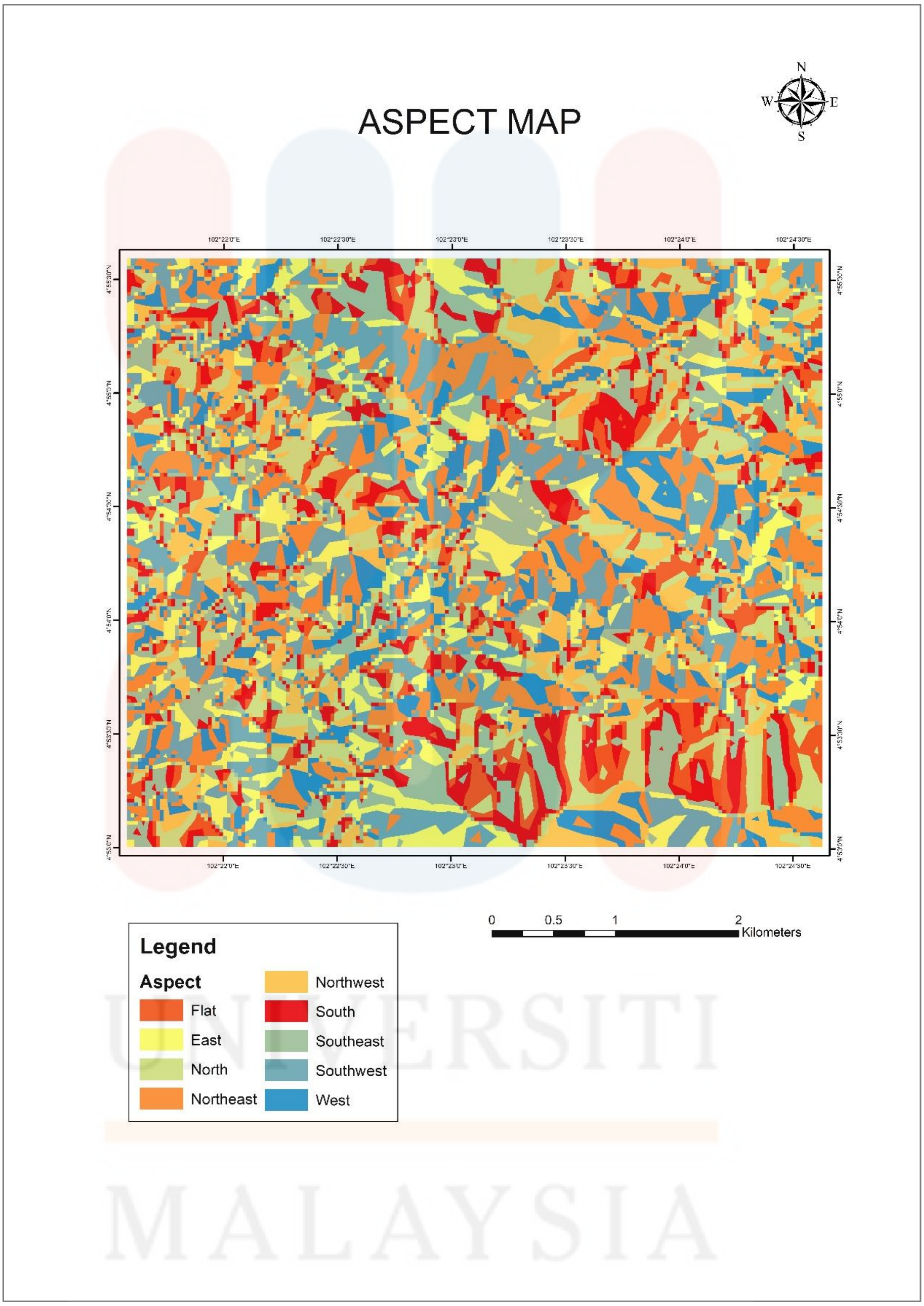


Figure 5.4 Aspect map of study area.

5.2.5 Land Use

Generally, land use of the study area has been changes due to the economic agriculture activities. The study area is dominated by palm oil plantation as this area has been controlled and monitored by FGV. The land use of the study area can affect the changes in the geological environment especially for stability of the slopes. The steeping of slope that caused by the undercutting on the hill slopes can cause the higher potential for the landslide occurrence in the study area.

The land use map of the study area is generated by shapefile data which is known as geospatial vector data format by using GIS application. The weightage for the land use parameter is 4. Table 5.7 shows the weightage and score for land use. Palm oil has the higher score which is 96. It is covered 24 km^2 of the study area while unpaved road only covered 1 km^2 with 4 value of score in the study area. From Table 5.7 also, it can be analysed the palm oil contribute the higher potential to the landslide vulnerability. Figure 5.5 shows the land use map in the study area.

Table 5.7 Weightage and score for land use.

No	Land use	Rank	Weightage (Wi)	Area (km^2)	Score (Weightage × Area)
1	Unpaved road	1	4	1	4
2	Palm oil	3	4	24	96

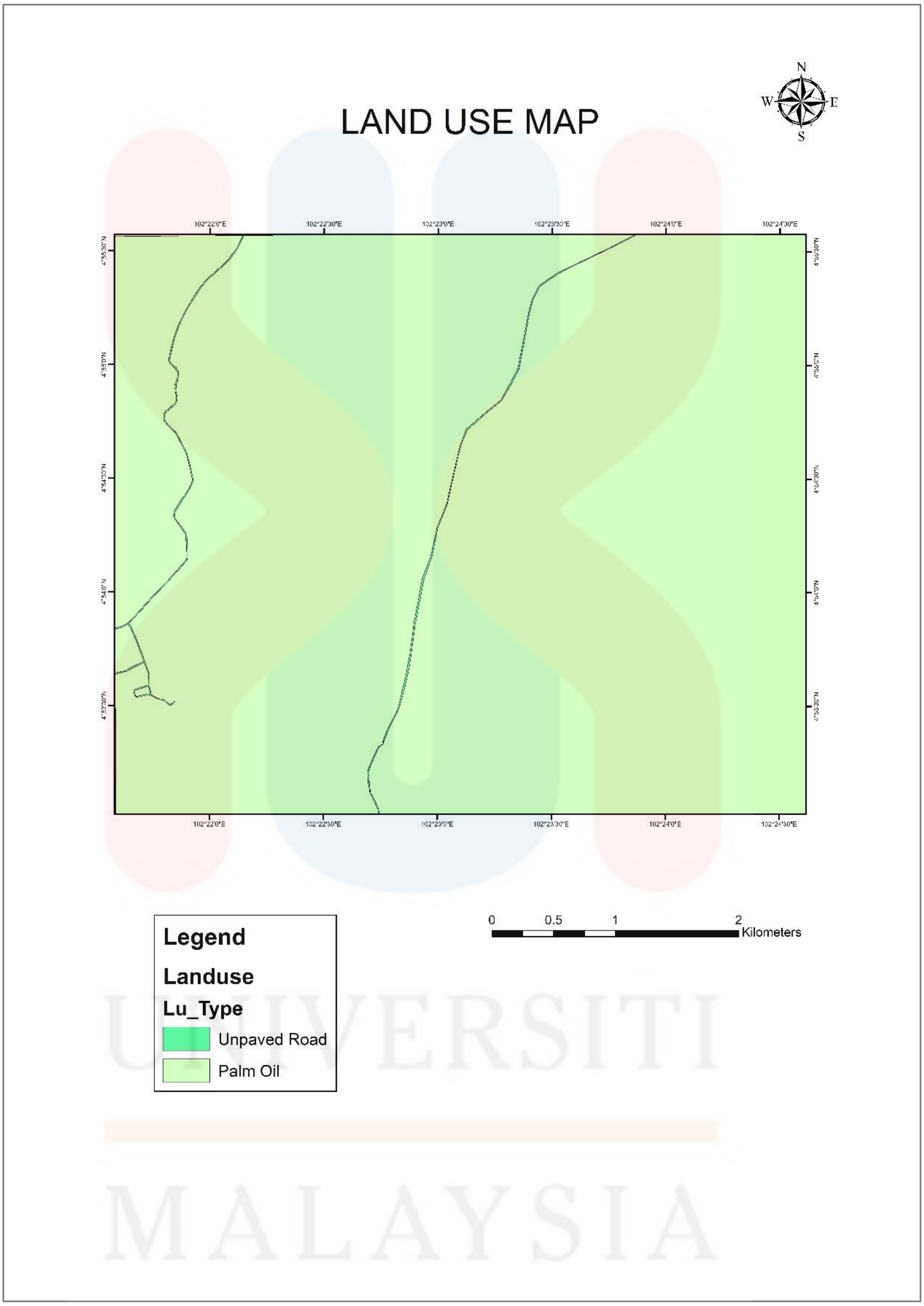


Figure 5.5 Land use map in the study area.

5.2.6 Vegetation

Vegetation is one of the important parameters especially in controlling the soil erosion. It is also help to stabilize the slope by providing mechanism strength to the subsoil. The vegetation map of the study area is generated by using the satellite imagery. The vegetation of the study area is grouped into three classes which is dense, moderate and low vegetation. Table 5.8 shows the weightage and score for vegetation.

Table 5.8 Weightage and score for vegetation.

No	Vegetation	Rank	Weightage (Wi)	Area (km^2)	Score (Weightage × Area)
1	Dense	1	3	11	33
2	Moderate	3	3	9	27
3	Low	6	3	5	15

Based on Table 5.8, the value score for dense vegetation is 33 and moderate vegetation is 27 value of score. Both area of vegetation covered 8 km^2 and 12 km^2 of area respectively. The score value for low vegetation is 15. Each of rank for dense, moderate and low vegetation is classified as 1, 3, 6 respectively. The lower vegetation of the study area can cause the higher potential for the landslide occurrence. The lack of vegetation covered of an area can cause a reduction in soil cohesion and shear strength in the soil profile resulting the slope become more susceptible to landslide vulnerability. Figure 5.6 shows the vegetation map in the study area.

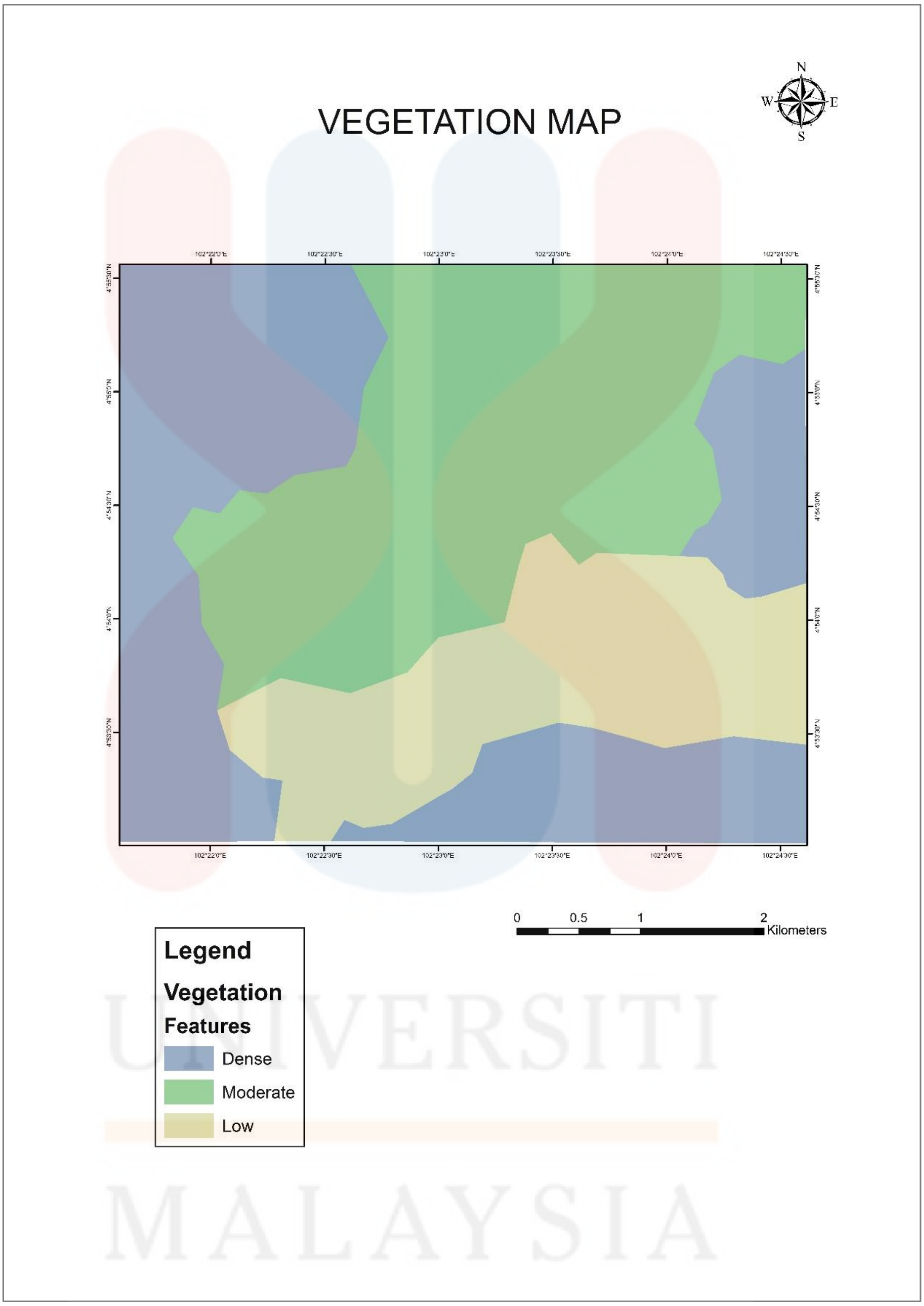


Figure 5.6 Vegetation map in the study area.

5.2.7 Lithology

Lithology is an important parameter in landslide susceptibility analysis because different types of lithologies can also influenced to landslide occurrences of the study area whether the area is prone to landslides or it is low vulnerability of the hazard. The lithology of the study area can be divided into three main units which is tuff, andesite and shale unit. The age of the lithology of the study area is started from Upper Carboniferous to Lower Triassic. The lithology map of the study area is extracted from the geological map in the scale of 1: 25 000. This area is covered 25 km^2 of the study area. The weightage of lithology parameter is 5 and will be multiple by area to obtain the value of the score. Table 5.9 shows weightage and score for lithology.

Table 5.9 Weightage and score for lithology.

No	Lithology Class	Rank	Weightage (Wi)	Area (km^2)	Score (Weightage × Area)
1	Shale	3	5	1	5
2	Andesite	5	5	10	50
3	Tuff	7	5	14	70

Based on table 5.9 below, it is showing the distribution of lithology class in the study area which is from oldest to the youngest rocks. The oldest rock is tuff which has the higher score lithology class with 70 value. By comparison, shale is the youngest of the lithology class with 5 value of score. The higher of score for lithology class, the higher potential for the vulnerability of landslides. Each of lithology unit behave differently to the landslide occurrence. It is also depending on the texture, composition and degree of weathering which can influence the stability of slope. Figure 5.7 shows lithology map in the study area.

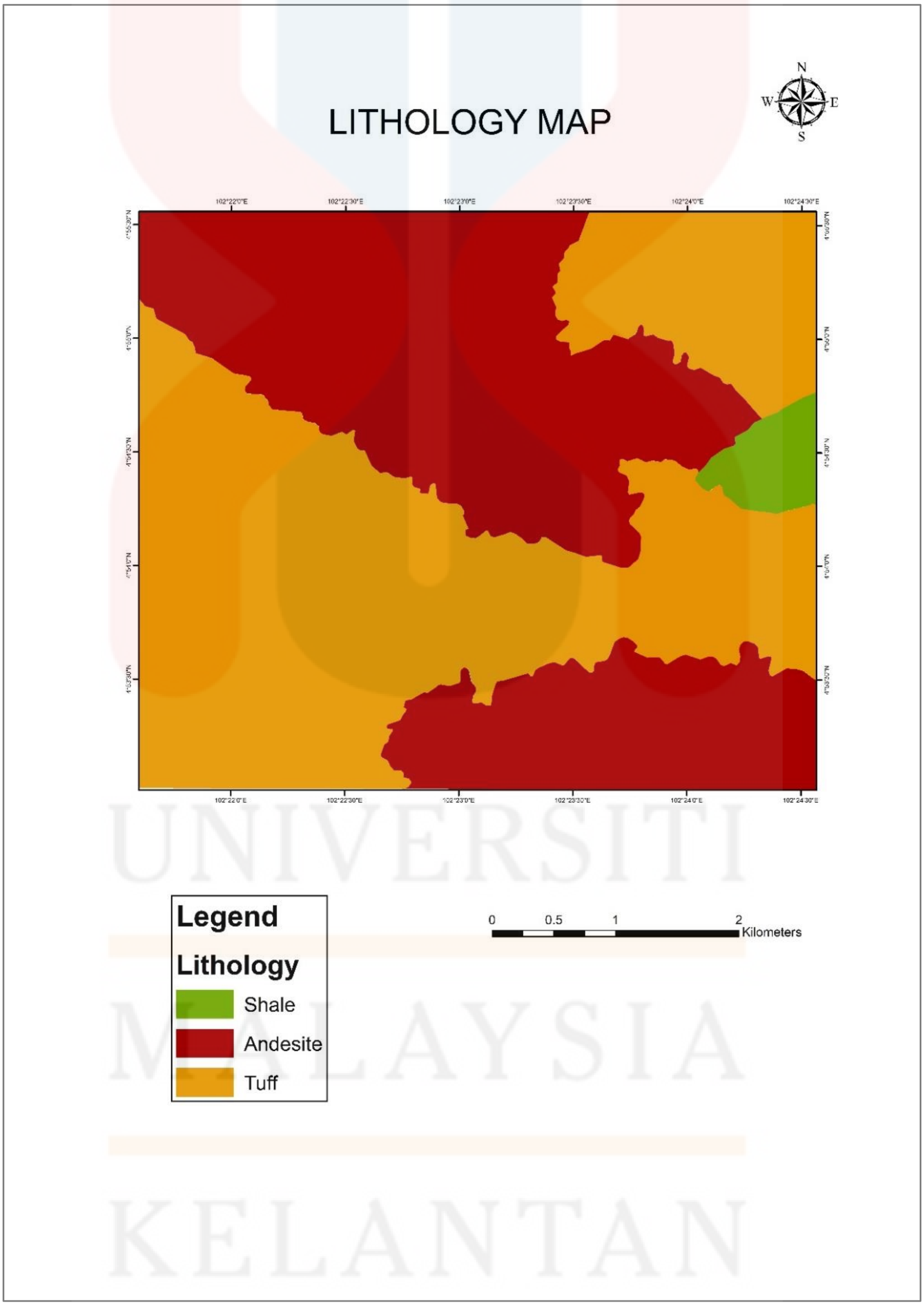


Figure 5.7 Lithology map in the study area.

5.2.8 Soil Cover

The secondary data is used to produce a soil map in the study area. The map of Generalized Soil Map of Peninsular Malaysia (1976) is overlay with the satellite imagery in Google Earth Pro of the study area.

The sub type of the soil cover in the study area is categorized as soils of the rolling to low hilly land. It is dominated by yellow-grey podzolic soils with Laterites and red yellow podzolic soils on the residual material from argillaceous and mixed sediments, and acid igneous rock. Table 5.10 shows the weightage and score for soil cover. Figure 5.8 shows the soil cover in the study area.

Table 5.10 Weightage and score for soil cover.

No	Soil Cover	Rank	Weightage (Wi)	Area (km^2)	Score (Weightage × Area)
1	Red yellow podzolic soils.	3	2	11	22
2	Yellow-grey Podzolic soils with Laterites	5	2	14	28

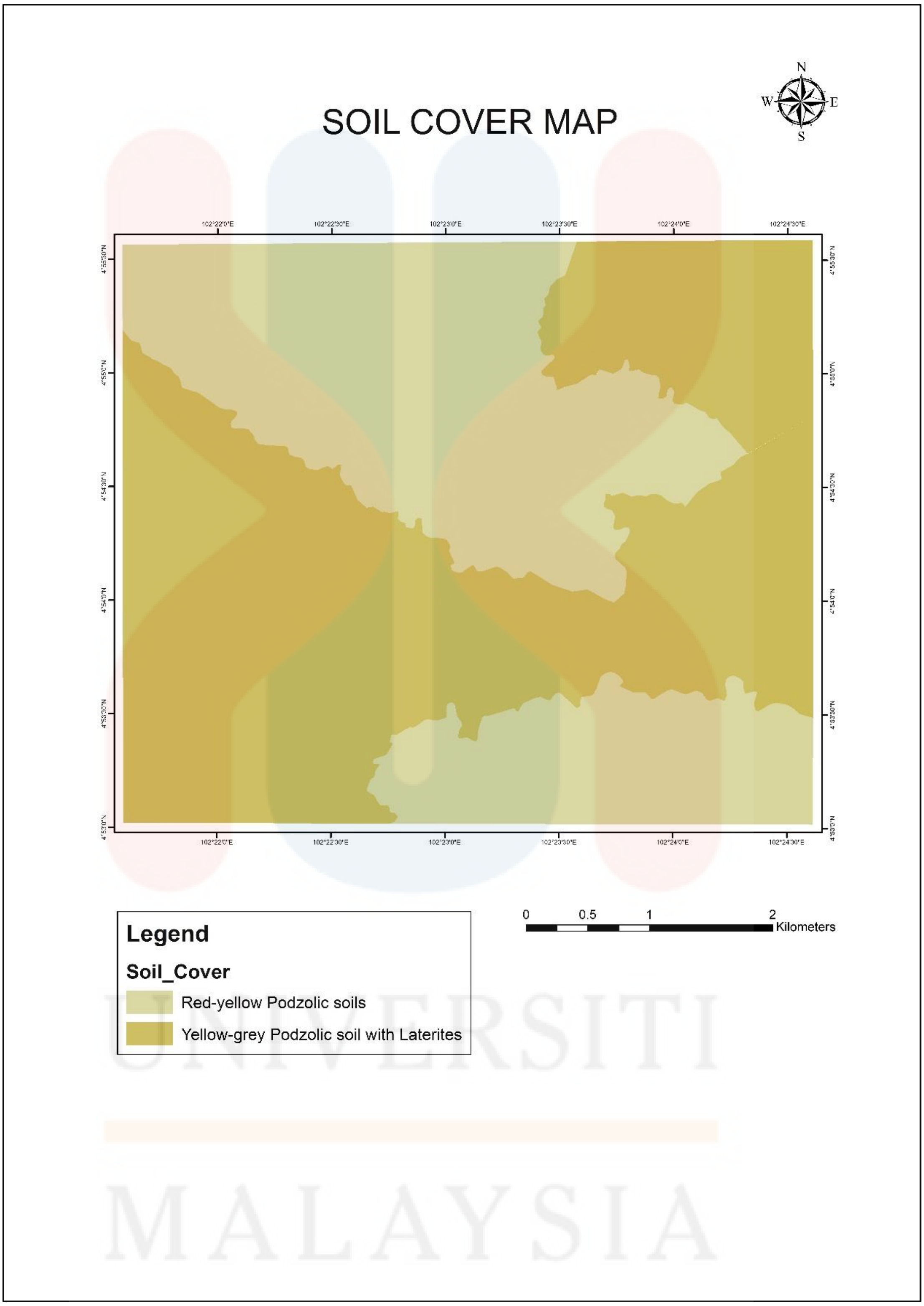


Figure 5.8 Soil cover map in the study area.

5.3 Factor Triggered Landslide

Malaysia is one of the countries that have some issues of natural disaster such as typhoon, flood, and landslide due to it has an equatorial climate and high temperature and humidity. As the study is focused on landslide susceptibility assessment the factor that triggered the occurrence of landslide is identified.

The selected study area is located at Aring 6, Gua Musang, Kelantan, the rainfall intensity is identified as the main factor that triggered the occurrence of landslide. This is due to geological nature of hills and heavy precipitation during monsoon season and affect the heavy rainfall distribution.

5.3.1 Rainfall Intensity

In Malaysia, rainfall intensity is a factor that triggered to landslide occurrences. This factor can be assume based on the wet conditions and mostly occur at the higher mean of the rainfall. Table 5.11 shows the maximum and minimum of rainfall in Aring area (mm) from 2014 until 2019. This data is sufficient to show the rainfall intensity that induced the slope failure and tend the landslide hazard to occur.

The total maximum and minimum of rainfall data in Table 5.11 below covered the whole Aring area. In 2014, Aring area received the highest maximum of rainfall distribution which is 295.5 mm. Majority the minimum rainfall distribution for all years is 0.0 mm.

Table 5.11 Total maximum and minimum rainfall distribution in Aring area (mm).

Description/ Year	Maximum and Minimum Rainfall Distribution in Aring Area (mm)					
	2014	**2015**	**2016**	**2017**	**2018**	**2019**
Maximum	295.5	116.0	75.0	87.5	107.0	70.5
Minimum	0.0	0.0	0.0	0.0	0.0	0.0

(Source: JPS, Ampang, 2020)

Table 5.12 shows the rainfall distribution in Aring, Gua Musang, Kelantan (mm) in year 2014 - 2019. These data are obtained from Jabatan Pengaliran dan Saliran (JPS), Ampang. Based on rainfall distribution along 2014 until 2019, it can be interpreted that the highest rainfall distribution is at 2014 with 3081.5 mm of total rainfall distribution.

In 2015, Aring area received 1331.5 mm which indicated the lowest rainfall distribution. This rainfall distribution is closely related with landslide occurrence. The higher rainfall distribution of an area, the higher the potential the landslide occurrence as it can contribute the slope failure and cause the landslide hazard to occur.

Table 5.12 Rainfall distribution of Aring, Gua Musang, Kelantan (mm).

Months	**Rainfall Distribution of Aring, Gua Musang, Kelantan (mm)**					
	2014	**2015**	**2016**	**2017**	**2018**	**2019**
January	170.5	9.5	110.5	-	299.0	69.0
February	5.5	21.0	237.0	151.5	81.0	39.5
March	247.5	89.5	1.0	56.5	65.5	69.0
April	137.5	48.0	0.0	77.5	103.5	57.0
May	150.0	201.5	243.0	449.0	126.5	231.0
June	206.5	11.0	207.5	264.5	197.0	263.0
July	348.5	1.0	82.0	181.0	100.5	105.0
August	126.5	123.5	0.0	205.5	292.0	0.0
September	120.5	103.5	199.0	215.5	342.5	239.0
October	222.2	69.0	267.0	137.5	155.5	137.5
November	310.5	325.0	281.0	332.5	280.5	473.5
December	1036.5	329.0	235.0	226.5	470.5	270.5
TOTAL	3081.5	1331.5	1863.0	2297.5	2514.0	1954.0

5.4 Landslide Susceptibility Analysis

Landslide susceptibility map is generated as to show the area of landslide with different level of hazard such as low, moderate and high hazard zones. The selected parameters of landslide causative factors such as slope, drainage density, lineament density, aspect, land use, lithology, vegetation and soil cover are produced and the raster data are converted into polygon. After that, all the parameters are overlay using the GIS application as to produce a landslide susceptibility map of the study area using overlay method. Each of the parameters are calculated with the weightage respectively by using the equation 5.2 below.

$$S = \quad W_iX_i \tag{5.2}$$

where S is susceptibility, W_i is weightage of each parameter, and Xi is the criterion score of factors.

Figure 5.9 shows the landslide susceptibility map of the study area. Based on this map, it shown the zone for low hazard was covered 24% of the area percentage of the study area. Majority of the study area is covered by moderate zone with 60% area percentage and minority of the study is covered by high hazard zone with 10% area percentage of the study area. Based on landslide susceptibility map, the green area indicated the low hazard zones. There is the lower potential of landslide to occur in these areas. The area is dominated by yellow area which is indicated as moderate hazard zones. The potential of landslide susceptibility of this area is medium. The red area is indicated as the high hazard zones. The landslide frequently occurs at this area. The risk of the landslide potential of this area is about >75%.

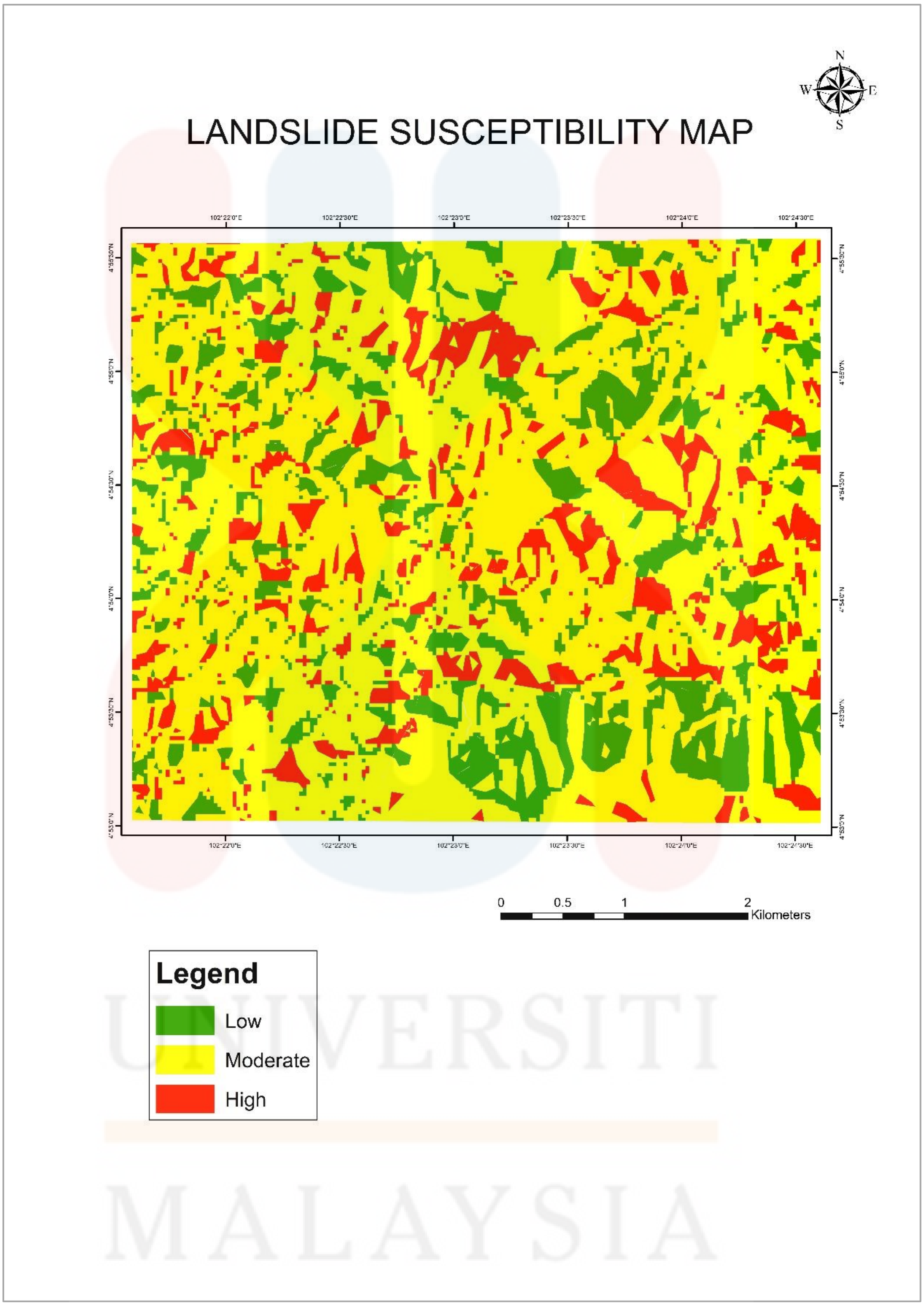


Figure 5.9 Landslide susceptibility map of study area.

The parameters such as slope, drainage density, and lineament density highly influence in landslide susceptibility analysis. The increases in the degree of slope, drainage density and lineament density can influence the degree of landslide occurrence increases.

Besides, the higher degree of slope angle can indicate the higher instability potential and can cause the landslide susceptibility zonation at the higher rank. For instance, the higher slope of the study is 34° and this indicate the steep slope. Therefore, the possibility of landslide occurrence at this degree of slope is higher.

In addition, the parameters such as lithology, vegetation, land use, soil cover and aspect are moderately influence to landslide susceptibility occurrences. The weathered of the rocks is the main factors that contribute the high relative to instability of the slope. The dense vegetation covered of the study area contribute the lower potential the landslide to occur. The abundance the use of the land use with the agriculture especially in hilly area is also cause the instability of slope in the study area.

In aspect of the soil cover, the texture of the coarse-grained and granitic soils is mainly causing the landslide compare with fine-grained texture of soil. This is because of the abundant air spaces between the grains in coarse-grained soil that make the soil become loose. The soil texture in fine-grained soil is the most compact and more permeable resulting the soil become strength and the reduce the risk of landslide to occur. Moreover, the aspect is known as the indirect factors affecting the vulnerability of the slope. Thus, it is moderately affecting the landslide occurrence. Table 5.13 shows the susceptibility class of landslide hazard in the study area.

Table 5.13 Susceptibility class of landslide hazard in study area.

Susceptibility Class (Zone)	Risk	Area Percentage (%)
Low	0 – 50%	24
Moderate	50% - 75%	60
High	>75%	10

Based on the Table 5.13 above, the class of susceptibility for landslide hazard is depends on the risk percentage. The lower the susceptibility class, the percentage of risk for landslide occurrence decrease and vice versa. Table 5.14 shows the score analysis for landslide susceptibility in the study area.

Table 5.14 Score analysis for landslide susceptibility.

Susceptibility Class (Zone)	Risk	Score	Score Percentage (%)
Low	0 – 50%	2	33
Moderate	50% - 75%	3	56
High	>75%	4	11

Based on Table 5.14, the score percentage for low, medium and high hazard zones are 33%, 56% and 11% respectively. This score percentage is generated by using GIS application with 2, 3 and 4 value of score. The lower score percentage can decrease the landslide influence in the study area and the higher score percentage can increase landslide influence in the study area.

Generally, the increase the value of drainage density and lineament density also can affect the increase the landslide occurrence in the study area. Furthermore, the landslide susceptibility is also influenced by slope as the stability of an area is depending on the stability of the slope. The steeper slope can increase the degree of the landslide occurrence.

Besides the parameters of landslide causative factors, the rainfall intensity in the study area also triggered the landslide occurrence. If the heavy rainfall pouring at the study area, the exposed areas with the steep slopes and high elevations are particularly susceptible to landslides hazard. This is due to the influence of gravity acting in weakened materials that make up a sloping area of land.

CHAPTER 6

CONCLUSION AND SUGGESTION

6.1 Conclusion

This chapter will be discussed and concluded all the obtained result from the landslide susceptibility assessment. All the information were gained from secondary data such as interpretation from satellite imagery or aerial photograph and using DEMs data to produce the maps by using GIS application.

From the general geology assessment, a geological map of Aring 6, Gua Musang, Kelantan in scale of 1:25 000 was produced. This geological map provided all the geological information in the study area such as the geomorphology, lithostratigraphy, structural geology and historical geology.

In aspect of lithostratigraphy, there were three main rock units exists in the study area such as tuff, andesite and shale. Tuff was categorized as the oldest rock while shale unit was the youngest rock. Aring Formation is name of formation in the study area. This formation was ranging from Upper Carboniferous to Lower Triassic.

For geomorphology aspect, most of the study area was covered by hill. There were three classes of landform in the study area such as low lands, low hills and hills as referred IGRSM elevation classification. The landform of study area was dominated with low hills with ranges of elevation from 50m to 200m. Commonly, this area was covered by palm oil plantation which was the main agriculture activities in Aring 6, Gua Musang, Kelantan. There was also no presence of settlement area of the study area as this area dominated by palm oil estate. Therefore, these criteria were analysed in landslide susceptibility assessment.

In addition, a map of landslide susceptibility of Aring 6, Gua Musang, Kelantan was produced. There were eight parameters used as landslide causative factors for the landslide assessment. These parameters were included slope, drainage density, lineament density, aspect, lithology, land use, soil cover, and vegetation and these played the important role for landslide susceptibility assessment. Some of the parameters were generated from DEM data by using GIS application. The generated map such as slope, aspect, lineament density and drainage density maps were reclassified and converted from raster into polygon. All the parameters are needed in term of polygon data as it easy to overlay. Thus, a map of landslide susceptibility assessment in the study area was produce. The weighted and score of each parameter were determined and analysed.

Generally, there are three classes of landslide zone hazard such as low, moderate, and high hazard zone. These classes of the landslide susceptibility zones closely related with the selected parameters as the main cause the factors of landslide occurrence. The area percentage for low hazard zone is 25%, 65% of moderate hazard zone, and 15% of high hazard zone.

Besides the parameters used as landslide causative factors, rainfall intensity also triggered the occurrence of the landslide. The rainfall distribution in Aring area could infiltrate more water on the landslide materials.

In conclusion, based on the landslide susceptibility assessment in the study area and the analysis of parameters for landslide causative factors, this research is important as it can give awareness to the people about the landslide susceptibility hazard. Both the geological and landslide susceptibility zonation map are needed as to plan a proper mitigation to control the occurrence of the landslide. Therefore, the future strategic planning in the study area is needed as to avoid the negative impacts of this hazard especially for humans, animals and environment.

6.2 Suggestion

The landslide susceptibility assessment of the study area should be done to reduce the occurrence of landslide. There are a few methods can be used to study the landslide susceptibility assessment for instance is Weighted Linear Combination (WLC) method. This assessment can be done by using ArcGIS application as this application can analyse and determined the level of hazard zones in the study area. Therefore, the further studies about the landslide occurrence need to be continued and update for the future guidelines. It is important as the serious oncoming problems in the future can be avoid.

Since this research is fully used the secondary. The obtained data may be not accurate especially for the lithologies part. Therefore, the geological mapping need to be conducted as to produce the updated geological map and the more accurate data of the study area. This need to be evaluated to improve the final result of the analysis and minimize the error.

Furthermore, the selected parameters of landslide causative factors are important as these can influence the production of the landslide susceptibility zonation map. The difference parameters may give the different result of the landslide susceptibility map.

Last but not least, the proper planning and mitigation should be done before running any economic activities such as agriculture and construction especially in Aring area. This can reduce risk of landslide to occur and loss of properties.

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