GEOLOGY AND LANDSLIDE HAZARD ZONATION BY USING GIS OF GEDANGSARI AREA, GUNUNGKIDUL, YOGYAKARTA, INDONESIA

by

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

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2021

DECLARATION

I declare that this thesis entitled "GEOLOGY AND LANDSLIDE HAZARD ZONATION BY USING GIS OF GEDANGSARI AREA, GUNUNGKIDUL, YOGYAKARTA, INDONESIA" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently 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 Honours"

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Date ……………………………………………………….

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GEOLOGY AND LANDSLIDE HAZARD ZONATION BY USING GIS OF GEDANGSARI AREA, GUNUNGKIDUL, YOGYAKARTA, INDONESIA

ABSTRACT

Gunungkidul is located in Central Java Province, Indonesia which are vulnerable to geological hazard such as floods and earthquake. However, it is also susceptible to landslide in some areas of Gunungkidul which contributes to damage and loss. The study area is located in Gedangsari Area of Gunungkidul with the area covered of 5km^2 which aligned along latitude 7° 49’ 30’’S to 7° 52’ 00’’S and longitude 110° 34' 00’’E to 110° 36' 30’’E. This research aims to update a geological map of Putat Area with scale of 1:25 000 and to produce a landslide hazard map. The factors that triggered the landslide in Gunungkidul, Special Region of Yogyakarta were also analysed. The research involves the study of geomorphology, stratigraphy, structural geology and historical geology of the study area. The study area composed of three formations which is Nglanggeran Formation, Semilir Formation and Kebobutak Formation which were divided into six lithology units. The parameters that caused the occurrence of landslide were determined and the landslide susceptibility map was produced using Weightage Overlay Method (WOM) in ArcGIS software. Results showed that the zonation map was classified into three zones which is low, moderate and high zone. The factor that triggered the landslide were identified which is heavy rainfall intensity and earthquake. As a recommendation, the ability to detect landslide susceptibility led to a better understanding of landslide mechanisms for the research area, thus leading to an enhanced identification of the most likely failure sites within a landslide-prone area.

Keywords: Landslide Hazard, Weightage Overlay Method, GIS, Yogyakarta

GEOLOGI DAN ZONASI BAHAYA TANAH RUNTUH DENGAN MENGGUNAKAN SISTEM MAKLUMAT GEOGRAFI (SMG) DI KAWASAN GEDANGSARI, GUNUNGKIDUL, YOGYAKARTA, INDONESIA

ABSTRAK

Gunungkidul terletak di Provinsi Jawa Tengah, Indonesia yang rentan terhadap bencana seperti banjir dan gempa bumi. Walaubagaimanapun, ia juga terdedah kepada tanah runtuh di beberapa kawasan di Gunungkidul yang menyumbang kepada kerosakan dan kerugian. Kawasan kajian terletak di Kawasan Putat Gunungkidul dengan kawasan yang diliputi 5km^2 yang selaras pada 7° 49’ 30’’S hingga 7° 52’ 00’’S dan longitud 110° 34’ 00’’E hingga 110° 36’ 30’’E. Kajian ini bertujuan untuk mengemas kini peta geologi Kawasan Putat dengan skala 1:25 000 dan menghasilkan peta kerentanan tanah longsor. Faktor-faktor yang mencetuskan tanah runtuh di Gunungkidul, Daerah Istimewa Yogyakarta juga dianalisa. Kajian ini melibatkan kajian geomorfologi, stratigrafi, geologi struktur dan geologi sejarah kawasan kajian. Kawasan kajian terdiri daripada tiga formasi iaitu Formasi Nglanggeran, Formasi Semilir dan Formasi Kebobutak yang dibahagikan kepada enam unit litologi. Parameter yang menyebabkan berlakunya kejadian tanah runtuh ditentukan dan peta kerentanan longsoran dihasilkan menggunakan Kaedah Perlapisan Berwajaran (WOM) dalam perisian ArcGIS. Keputusan menunjukkan bahawa peta kerentanan dibahagikan kepada tiga zon iaitu zon kerentanan rendah, sederhana dan tinggi. Faktor yang menyebabkan tanah runtuh itu ialah intensiti hujan dan gempa bumi. Sebagai kesimpulan, keupayaan untuk mengesan kerentanan tanah runtuh membawa kepada pemahaman yang lebih baik mengenai mekanisme tanah runtuh untuk kawasan penyelidikan, dan membawa kepada pengenalan yang lebih baik kepada lokasi yang berkemungkinan untuk gagal di kawasan rawan tanah runtuh.

Kata kunci: GIS, Kaedah Perlapisan Berwajaran, Bahaya Tanah runtuh, Yogyakarta

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LIST OF ABRIVIATIONS

DEM Digital Elevation Model

GIS Geographical Information System

GPS Global Positioning System

SMG Sistem Maklumat Geografi

USGS US Geological Survey Earth Resources and Science Center

WOM Weighted Overlay Methods

LIST OF SYMBOLS

%	Percentage
>	Greater than
<	Less than
ºC	Degree Celsius
º	Degree
×	Multiplication
Σ	Sum
Ϭ	Sigma

CHAPTER 1

INTRODUCTION

1.1 Research Background

A disaster is an event or series threatening and disturbing events the life and livelihood of the people who caused, both by natural factors and / or non-factors natural and human factors that result casualties, environmental damage, property loss and psychological impact (BNPB, 2012).

Landslide is one of the geohazard which can be delegated catastrophic events. It happens when the shear qualities of the material that structure the slope are surpassed by gravitational and different kinds of shear stress within a slope. It can happen normally yet in moderate rate. Human activity or land use change can change the natural distribution of the land. Sometimes, more than one sort of moment happens inside a single landslide. According to Nagle (1998), landslide is any perceptible down slope movement of mass bedrock, regolith, or both.

The landslide may be triggered by the earthquakes which affect the rock falls, debris flows, barrier lakes, floods and tsunamis. Most of the cases recorded worldwide, landslide is one of the most widespread natural hazards that happen after earthquake. However, this phenomenon can be triggered by the high intensity of rainfalls and the high seismic activities.

1.2 Problem Statement

The study area is located in Gedangsari, Special Region of Yogyakarta. Therefore, based on the description above can be formulated several problems such as the dominant factor causing the level of possible soil hazard landslides in the study area and the potential hazards of landslides in the study area.

This research is intended to obtain data on the area that may pose potential landslide hazards. Further studies have to do to help the local society. In addition to help further recognizable of potential landslide hazard in the research area and to update the existing geological map of Gedangsari to see the changes of the geological features.

1.3 Objectives

The main objectives of the study are:

i. To study the causing factors of a landslide in the study area.
ii. To identify the potential landslide hazards in the study area.
iii. To establish a geological map of the lithology in the study area with the scale of 1: 25000.

1.4 Expected Outcome

Secondary data identification would be conducted for this research. Expected results for secondary data identification and processing using ArcGIS in Gedangsari are geomorphology, landform, slope assessment, landslide, drainage pattern and lithology. The geological map of Gedangsari would represent regions of the study area. The landslide hazard of the area will be identified and will be explained.

1.5 Scope of the Study

The study of the geology in Gedangsari, Special Region of Yogyakarta will be carried out in the Gedangsari area. The total area for this research is 25km². Secondary data identification will be done due to find the geological features such as landform, lineament and drainage pattern in the study area.

Furthermore, this study also provides the landslide hazard assessment map of the study area. To establish a landslide hazard map, the GIS raster-based analysis was done by using Weighted Overlay Method produced by raster-based GIS using parameter such as lithology of rocks, slope and secondary data. The secondary data of rainfall intensity will be collected from United States Geological Survey (USGS)

1.6 Significance of the Study

This research will produce recent geological features in the study area with an updated latest geological and geomorphological part of the study. All the data information will be gathered and produced the latest geological map. The map can be used by geologist, government, and local society as a contribution to the effort to explore and environmentally develop planning.

Next, by produce the landslide hazard map, the most potential slope can be identified. By accomplished and providing easy, continuous and accurate information about landslide occurrence, the key to this landslide disaster can be control (Shahabi & Hashim, 2015). The accuracy of the maps of landslide hazard is important and can reduce the life and property losses. Most of the time, the mountainous area is simply considered as most-prone area to natural disaster (Kavzoglu et. al, 2014). Even so, the development and urbanization still on going and widespread. With the exact accuracy of the map, it can help disaster planners, local authorities, contractors and decision-makers into consideration before decided on development especially in Gedangsari area, Yogyakarta.

1.7 Study Area

Secondary data identification and research will be conduct in Gunungkidul located at the southeast part of the province of Special Region of Yogyakarta, Indonesia which positioned on the island of Java. One of the North Zone areas with the altitude of 200-700 m above sea level is Gedangsari.

Figure 1.1 shows the study area at Hargomulyo area, Gedangsari, Yogyakarta, Indonesia which over approximately 25 km^2 which comprises between with latitude 7° 49’ 30” S to 7° 52’ 00” S and longitude 110° 34’ 00” E to 110° 36’ 30” E. Morphologically, the study area mainly at mountainous area.

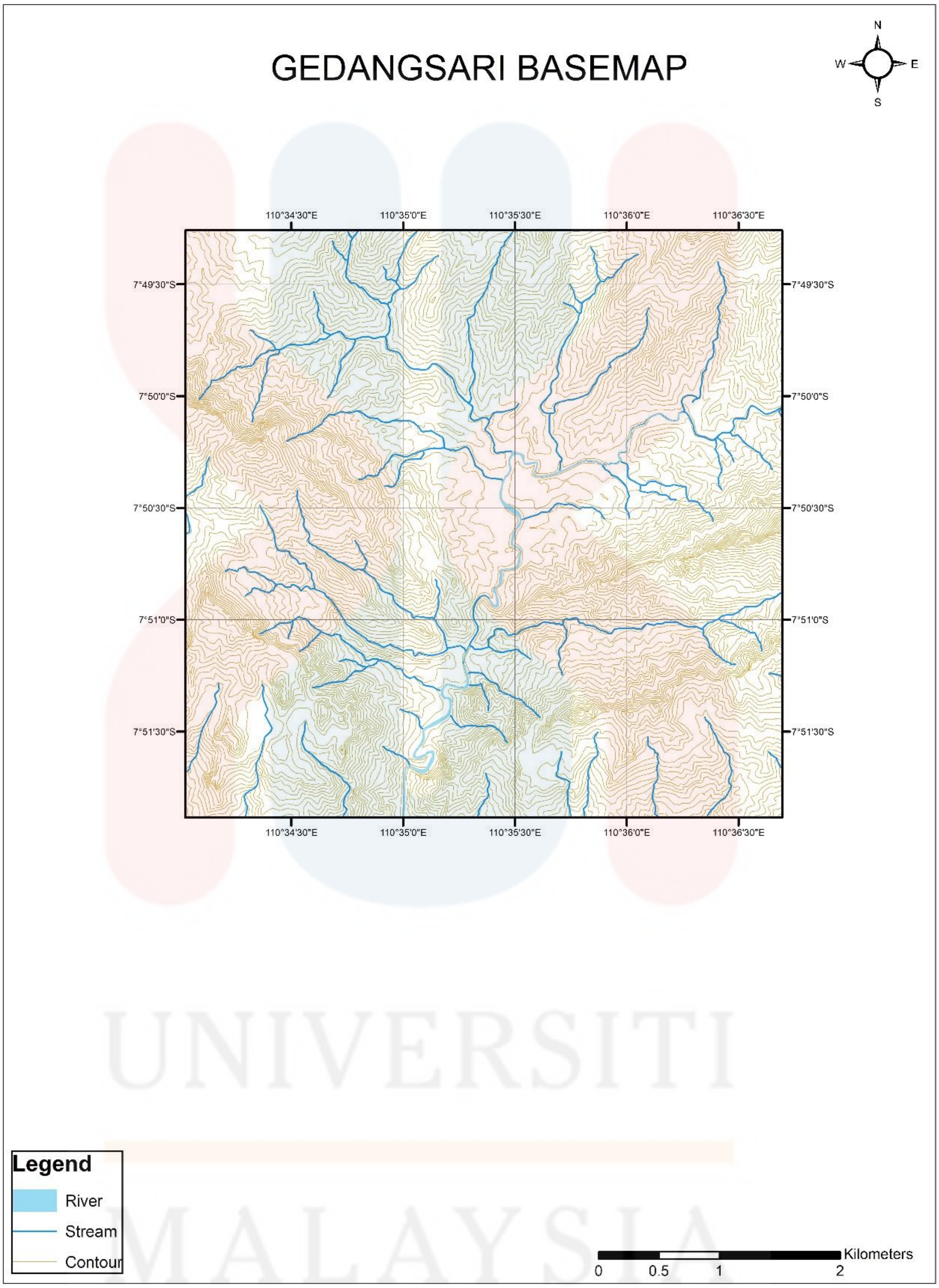

Figure 1. 1: Base map of the study area.

1.7.1 Demography

In Yogyakarta, Javanese is most of the populace with most noteworthy number of local individuals. Yogyakarta have the enormous number of immigrants from everywhere inside Indonesia because of the City have the huge number of schools and colleges. Other than that, Yogyakarta have moderately ease of living contrasted with different urban communities in Indonesia which add to the huge populace of understudies and tourism. With the measure of 768 523 individuals in Gunung Kidul Regency in 2019, it adds to the economies.

There are 18 districts in Gunung Kidul that and Gedangsari District. Table 1.1 shows the statistic of Gunung Kidul population in 2019, which Gedangsari District have 39.632 people in total. There are 10 village in the study area which separate with 3 district which is Desa Hargomulyo, Desa Kedungpoh, Desa Mertelu, Desa Ngalang, Desa Nglegi, and Desa Pengkol, Desa Sampang, Desa Terbah, and Desa Watugajah as shown in Figure 1.2, while in Table 1.2, it shows the statistics data of the villagers of 5 main village in the study area collected from each Village Head's Office *(Kantor Kepala Desa).*

Table 1. 1: The statistic of Gunung Kidul population in 2019
(Sources: Badan Pusat Statistik Kabupaten Gunung Kidul Tahun 2019)

District	**Gender**		
	Male	Female	Total
Wonosari	43.462	44.206	87.668
Nglipar	16.627	16.980	33.607
Playen	30.090	31.233	61.323
Patuk	16.942	17.508	34.450
Paliyan	16.270	16.838	33.108
Panggang	14.518	15.159	29.677
Tepus	18.088	18.845	36.933
Semanu	29.788	30.465	60.253
Karangmojo	28.026	28.873	56.899
Ponjong	28.031	28.704	56.735
Rongkop	14.851	15.089	29.940
Semin	28.393	28.756	57.149
Ngawen	17.469	17.648	35.117
Gedangsari	19.717	19.915	39.632
Saptosari	19.641	19.950	39.591
Girisubo	12.740	13.147	25.887
Tanjungsari	14.461	15.008	29.469
Purwosari	10.281	10.804	21.085
TOTAL	379.395	389.128	768.523

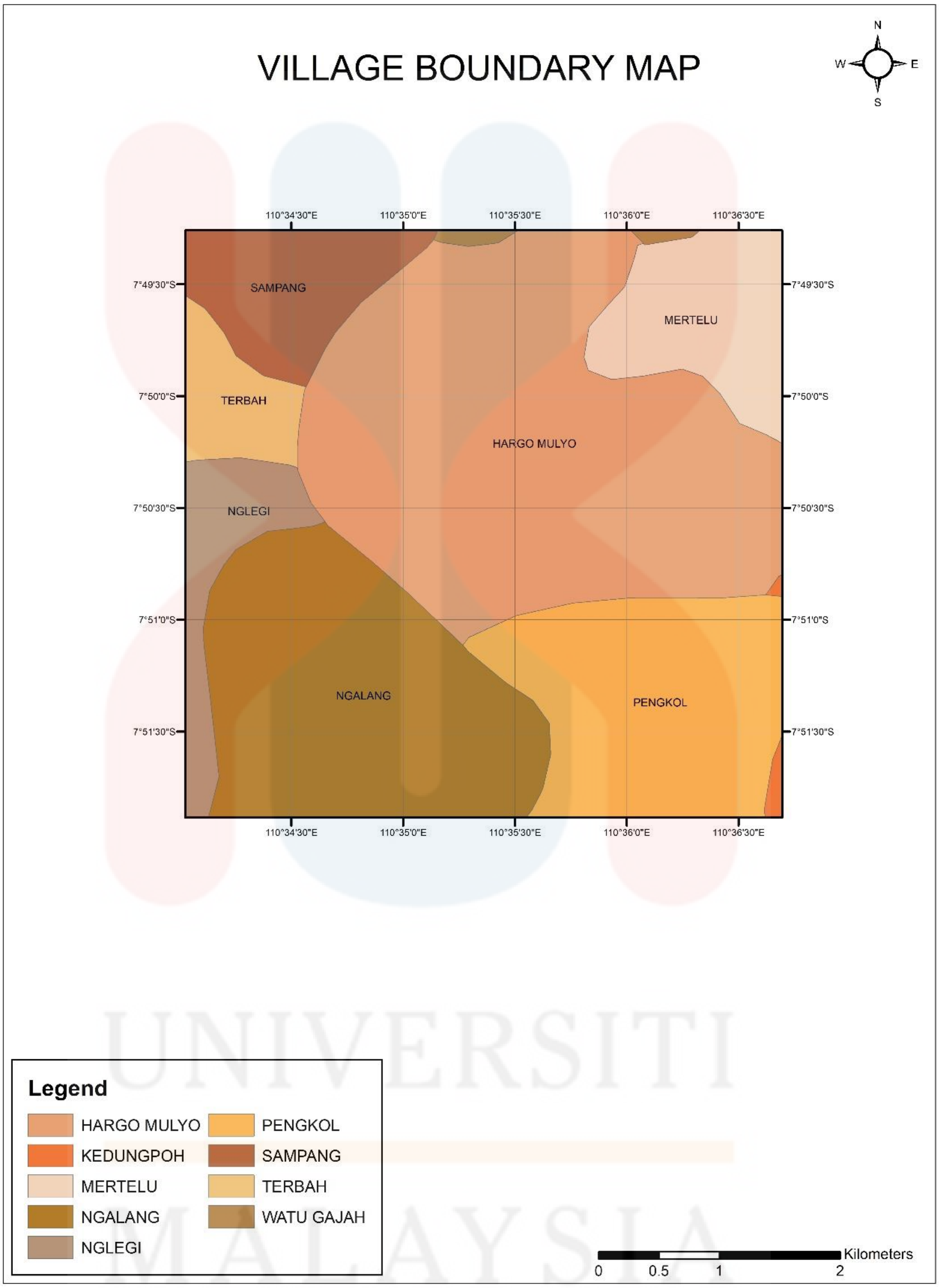

Figure 1. 1: Village Boundary Map

Table 1. 2: The statistic of five village in the study area.
(Source: Badan Pusat Statistik Kabupaten Gunung Kidul Tahun 2019)

Village / Desa	Gender		
	Male	Female	Total
Hargomulyo	3309	3556	6865
Kedungpoh	2882	3073	5995
Mertelu	1858	1956	3814
Ngalang	3929	4227	8156
Nglegi	1421	1548	2969
Pengkol	2742	2883	5625
Sampang	1436	1492	2928
Terbah	1188	1232	2420
Watugajah	1944	2051	3995
Total	20709	22018	42767

1.7.2 Land use

Yogyakarta has about 32.5 km^2 of city. The city is spread toward all path from the craton or known to be Sultan's place. The Yogyakarta is the center of present-day city toward the north, revolve around building and the business area. Yogyakarta is having principal creation of yields, for example, rice paddy, corn, sweet potato, ground nuts, peanuts and yams. The Yogyakarta land are one of primarily place of interest as this is on the grounds that there were numerous sanctuaries, for example, Prambanan and Borobudur sanctuary. Mount Merapi likewise one of the places of interest in Yogyakarta.

1.7.3 Social Economy

The center Yogyakarta is craftsmanship culture, a city with numerous societies and customs as rich as they follow the customary Sultanate systems which is not quite the same as the rest of Indonesia urban areas. The Yogyakarta gives significance predominantly for training, economy and the travel industry. Gadjah Mada University is one of the Indonesia most noticeable colleges and other distinctive nearby college. Yogyakarta economy is generally on entire, transportation and warehousing, land and other corporate service.

Gunung Kidul's capital region, Wonosari, is going through fast turn of development while other districts are lagging behind due to underdeveloped and low financial contribution. In the Gunung Kidul area, the tourism sector is the main source of economic development. Tourism increases the number of tourists over the years and at the same time expands the socio-economic status of the community there. Moreover, Gunung Kidul Regency consists of different economic potential from agriculture, livestock, industry, mining, and tourism.

CHAPTER 2

LITERATURE REVIEW

2.1 Regional Geology and Tectonic Setting

Indonesia is very complex as it is the meeting point of some tectonic plates and lies on the Ring of Fire Pacific which the Pacific plate and the continent plate of Indo-Australia pushed down below the Eurasian continental plate as shown in Figure 2.1. A complex geological setting formed as the tectonic plates in the Indonesian region move actively against each other.

Java Island, Indonesia is located in the southern part of the Sunda land linked to the Sunda Shelf Sea. Geologically, Java is an essential part of the tertiary mountain system around the Sunda Land pre-Paleogene. The rock assemblages formed Java land and were associated with the tectonic setting of the active plate convergence margin. The Indonesian Archipelago is temporarily subdivided into 13 terranes based on palaeontology, palaeomagnetics and stratigraphy (Hartono & Tjokrosapoetro, 1986).

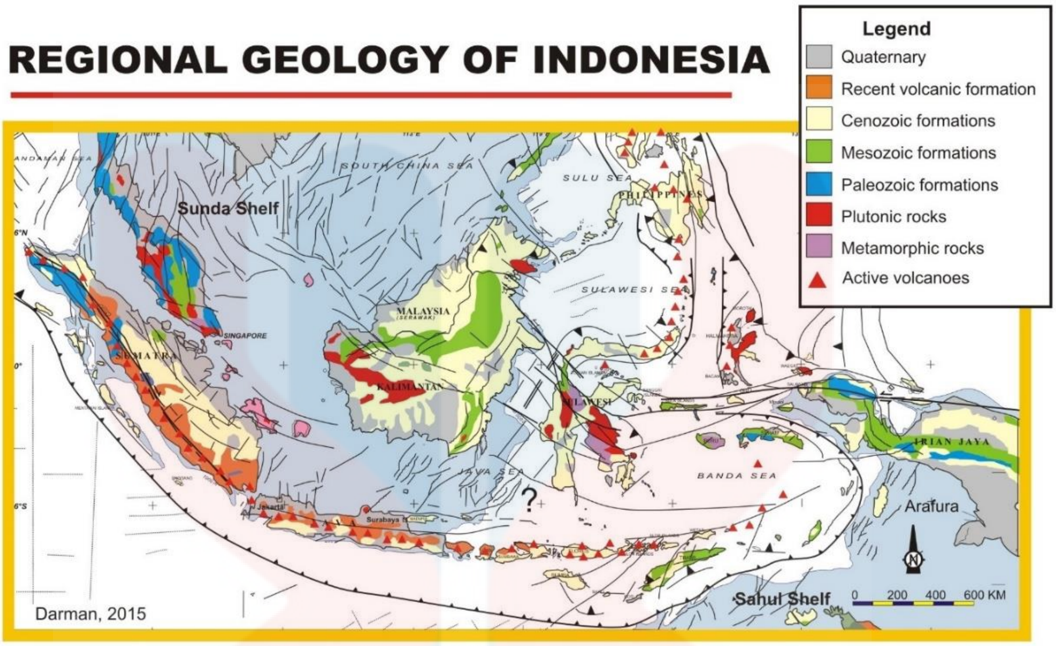

Figure 2. 1: Regional geology of Indonesia (Darman, 2015)

The plate movement of Australian to the Java Island in perpendicular direction formed subduction zone that cause earthquake (Palupi *et al*., 2016). Subduction curved from Ciletuh continues to Karangsambung and turn to Meratus. According to Hamilton (1979), subduction from Java formed particularly in Cretaceous which curved from Ciletuh to northeast in Meratus (East Kalimantan).

The subduction resulted in Java Island as shown in Figure 2.1 is due to the melting process of the Australian-Indian plate under the Eurasian plate along the Java Trench. The crust melted and created volcanoes and sedimentation in Java along with the subsequent. As a result, the surface lithologies consist of Cenozoic volcanic rocks, clastic sediments and uplifted corallin limestones.

2.2 Stratigraphy

The lithostratigraphy of the Southern Mountain generally formed by clastic sediments and carbonates mixed rock with aged tertiary rock. Surono, (2009). The sedimentary rock in Southern Mountain Arc in East Java were deposited on the basement which is overlain by poorly dated poorly dated regional unconformity (Robert Hall et al., 2008). The unconformity separated the Upper Cretaceous basement rock and the Cenozoic succession rock during the uplift and erosion occurred.

The stratigraphy can be divided into three unconformity-boundary. The first unconformity recorded during the initial of arc volcanism and early stage of development which happen middle Eocene to early Oligocene. It is believed that the oldest sedimentary rock overlain on the basement in angular conformity. The lithologies stands from conglomerate and interbedded sandstone. This are the only exposure rock onshore that does not contain any volcanic material.

They are dominated by quartz grain and metamorphic and igneous clasts including vein and metamorphic quartz, chert, phyllite, schist, metasedimentary rock and basalt. The rock is nearly similar to basement rock in Cretaceous basement. During the age of middle Eocene to early Oligocene, the southern mountain presenting transgressive succession where it has coal, conglomerate, sandstone, siltstone and mudstone form the top to the bottom.

The second conformity recorded the growth until the termination of volcanism in the Southern Mountain which happen at late Oligocene to the early Miocene. At this time the unconformity deposited primary by volcanic rock and epiclastic rock. These rocks spread widely in Southern mountain and also within thrust-fold belt of the Kendeng Basin.

The oldest rock of this event is bioclastic tuffaceous mudstone. There are many explosive and acidic composition in Southern mountain and has the deposit range from andesite to rhyolite according to the composition of SiO2 (Smyth, 2005).

The lithologies of on this period is thick mantling of tuffs, crystal-rich tuff, block and ash flows, pumice-lithic breccia, andesite breccia, silicic lava domes and lava flows. Thus, this is under Semilir formation and there was major eruption at the end period and have the accumulation of pyroclastic surge, flow breccia. The deposits show the end of volcanism.

The third unconformity where the abundance of carbonate rock growth and there were erosion and redeposition of rock from the earlier unconformity in middle Miocene until no volcanic activities. In this period bioturbation and there are several tuffs can be found at the top of turbidite. The limestone are thick bed and the carbonate source within volcanogenic turbidites.

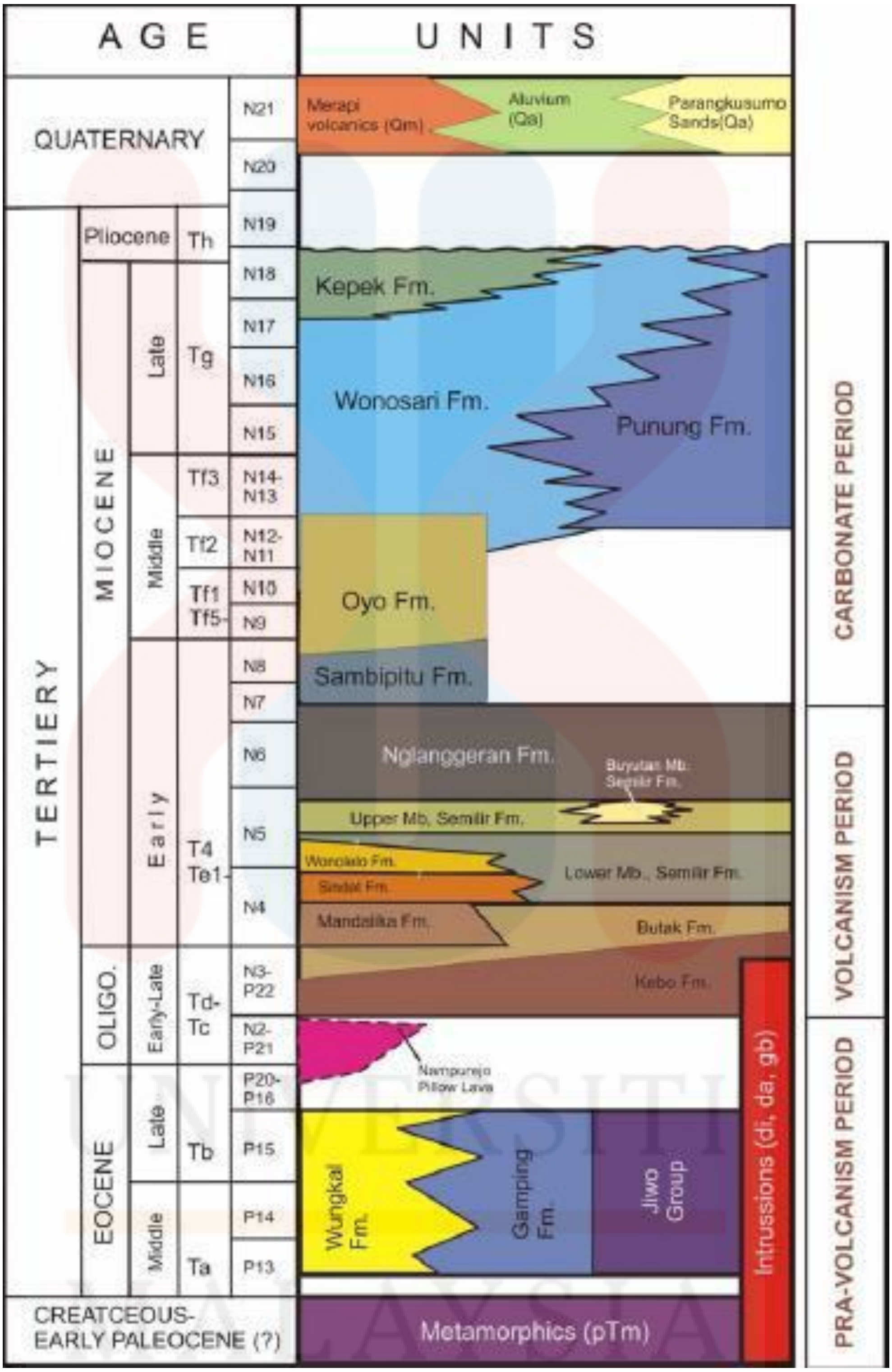

Figure 2. 2: Stratigraphy of Southern Mountain Indonesia (Surono, 2008)

The rock unit formed during this period are igneous rock that are totally opposite with Jiwo group. Period of volcanism, take place during volcanic eruption. The rock unit form is Kebo-Butak group which sequentially overlap by the Semilir Formation and Nglanggran Formation. At post-volcanic period which takes place after the volcanic eruption end, the carbonate organism grows in fertile. This period known to be carbonate period. At this period the rock unit are form such as Oyo Formation, Wonosari Formation, Punung Formation and Kepek Formation From the regional geological map sheet Surakarta-Giritontro, Java, the research area comprises Semilir Formation, Nglanggran Formation and Kebo-Butak Formation. All the formation in the research area under volcanism period (Figure 2.2).

2.2.1 Semilir Formation

Surono (2009) says that the bottom stratigraphy of Southern Mountain is formed during the period of volcanism are Kebo-Butak formation. This formation overlaps uncertain with Wungkal and Gamping in the pre-volcanic period stratigraphy Bothe (1929, in Surono, Toha B and Sudrano 1992). Kebo Beds is bottom and its top are Butak Beds. Both beds can be seen at foot of Baturagung mountain south of Klaten thus it known to be Kebo-Butak Formation.

The Kebo Butak Formation consists of sandstone, claystone, shale, tuff and agglomerate. The sandstone has tuff characteristics. Andesite and basalt are found in the middle of the formation and overlain by andesite breccia. Fossil such as foraminifera are found in late Oligocene to early Miocene. The deposition environment of this formation is generally open sea influenced by turbidity current.

2.2.2 Semilir Formation

Surono et al., (1992) state that Semilir Formation mainly consists of tuff, breccia pumice, tuffaceous sandstone and shale. Lapilli tuff and clay interbedded tuff, breccia is found at the bottom of this formation. It come from marine sediment and has under sea landslide structure.

Semilir formation has very little fossil. The range of age for the fossil are from early Miocene to middle Miocene. It has shallow to deep sea depositional environment. This is because at bottom and middle of formation it has shallow marine and deep marine due to turbidity current which at the top of formation.

2.2.3 Nglanggran Formation

Surono et al., (1992) state most of Nglanggran Formation composed of volcanic breccia, agglomerate, and tuff and andesite basalt lava. Volcanic breccia and agglomerated dominate this formation. Volcanic breccia is found coral limestone which form lens in the middle of formation. The surrounding area has sandstone epiclastic sandstone. This formation aged from early Miocene until middle Miocene. The Nglanggran Formation were experienced underwater landslide and it reflect marine depositional environment.

2.3 Structural Geology

Structural geology is the study of three-dimensional distributions of rock units that cause the widespread of the deformation. There are many factors contributed to the formation of structural geology such as tectonic process, deposition of sediment and the stress by the energy Earth.

By understanding the dynamics of stress field, the important events in geologic past can be correlated. It also concerned with its physical and mechanical properties of rock nature as the structural deformation such as faulting, folding, foliation and joins can be identified.

The major structural can harm the humans which can lead to natural disaster such as earthquake. Earthquake risk for example, can only be inspecting with a combination of structural geology and geomorphology. In addition, in geotechnical risk, the areas of steep slopes which are potential to face the landslide or collapse can be identified through geological mapping. Through geological mapping, the orientation of the structures can be analysed as well as its measurement and distribution.

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Structural geology of Gedangsari area and its surrounding is dominated by fault. In regional scale, the fault that occurred on the western part is higher compared to eastern side. The study by Barianto et al., (2009) shows the lineaments that was control by faulting and joint. Compared to the southern part, the lineament in the western part is controlled by frequent tectonic activities. Opak fault can be found on the eastern margin on the edge of the parallel fault, but there is no fault in Yogyakarta on the western side.

The NE-SW fault in the western margin and E-W fault which is buried in the northern margin can be observed as in Figure 2.3 and Figure 2.4. The western margin is controlled by NE-SW, N-S and E-W faults from the south to the north Yogyakarta. The E-W fault from the western part of the Menoreh Mountains to the eastern part of the Kebo-Butak Mountains can be observed. It is known as sinistral fault. Jonggrangan Formation, Sentolo Formation, Oyo Formation and Wonosari Formation have similar sedimentary depositional environment with different elevation. A major uplift occurred after the Kepek Formation and Sentolo Formation were created.

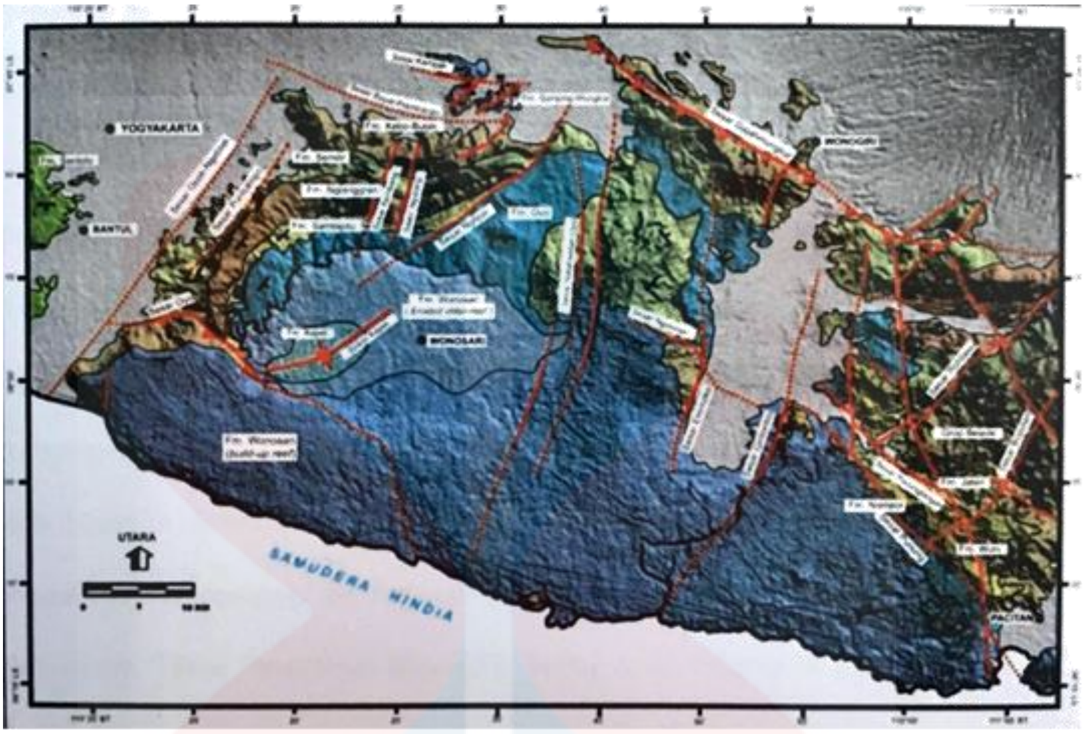


Figure 2. 3 : The interpretation of remote sensing imaginary of the regional geological map of Wonosari, Indonesia (Sources: Prasetyadi, et. al., 2011)

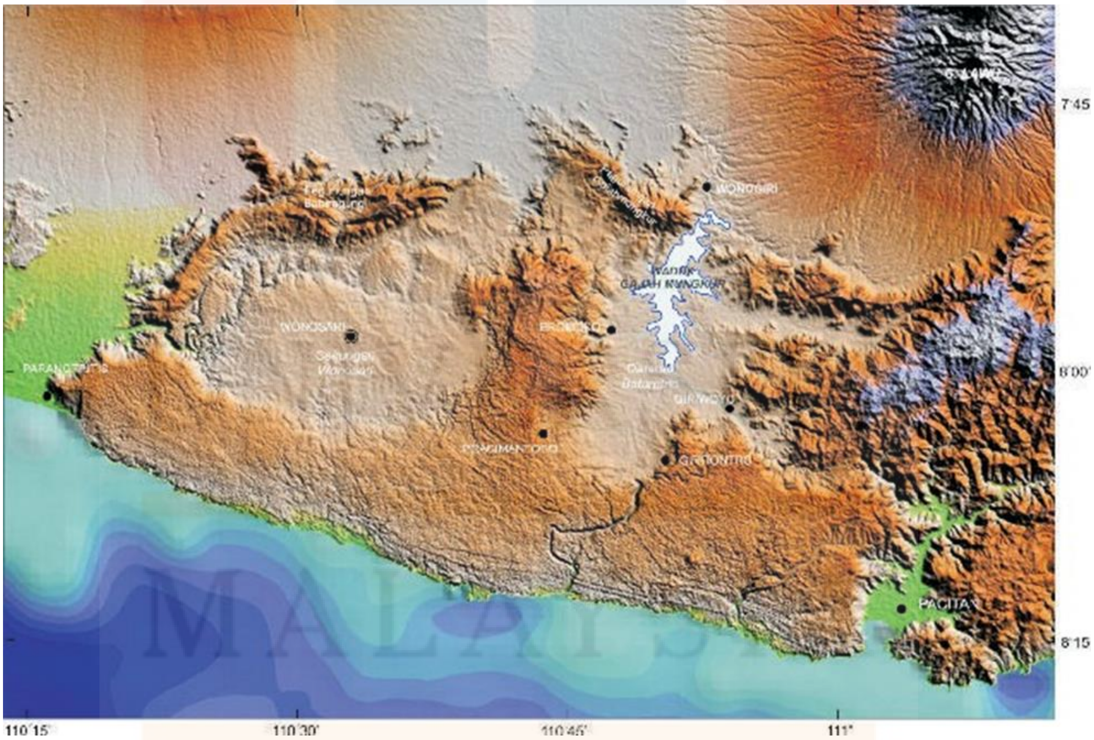


Figure 2. 4: The interpretation of remote sensing imaginary of the regional geological map of Wonosari, Indonesia (Sources: Surono, 2009)

2.4 Historical Geology

Indonesia is a geologically complex region located on the Eurasian continent's south-eastern edge. It is bordered by tectonically active areas characterized by seismicity and volcanism of intense subduction. Most active distortion occurs in Sumatra between the trench and the Sumatran fault. In contrast, in a complex suture zone up to 2000 km wide, active deformation occurs, including several small plates and multiple subduction zones ; boundaries of plates.

Over the past 300 million years, Indonesia was formed by reassembling fragments ripped from the supercontinent of Gondwana, which reached the Eurasian subduction margin. The Yogyakarta area's geological history is known as the pull-apart basin. The features associated with Yogyakarta's pull-apart basin are described as Opak-Muria Faults, while the Principal Displacement Zone (PDZ) of Java Island is also identified.

The release band and the response of sinistral strike-slip movement trans-tension deformations characterize the depression of Yogyakarta. The Opak-Muria Fault's geological past is recognised as Cretaceous-Paleocene Meratus Suture's oldest formation. The suture regulates the pull-apart basin of Yogyakarta.

2.5 Landslide

2.5.1 Landslide Definition

Landslide is catastrophic event which happens much of the time in the precipitous area of the world and causes misfortune and life property. Landslide positioned fifth as far as number of passing is among the best ten most significant debacles 2010. The event of landslide might be because of great territory conditions, which is additionally activated by outrageous precipitation, human movement and seismic tremors (Bonaventura, 2010).

It can cause a great deal of harm and misfortune. Almost 600 individuals are assessed to be murdered worldwide consistently because of incline disappointment (Aleotti and Chowdhury, 1999).

There are several types of landslides based in the Varnes Classification of Slope Movement (Varnes, 1978). Landslide can be classified into two which include the material type and type of movement. The material type can be classified into rock, earth, soil mud and debris as in Table 2.1. There are five kinematically distinct type of movement of the slope which include falling, toppling, sliding, spreading and flowing as shown in Table 2.2. Table 2.3 shows the distinct types of landslide movement according to Varnes' Classification of Slope Movement. There are 6 types of movement of rocks or boulder which triggered landslide to occur.

Table 2. 1: Varnes Classification of Slope Movement.

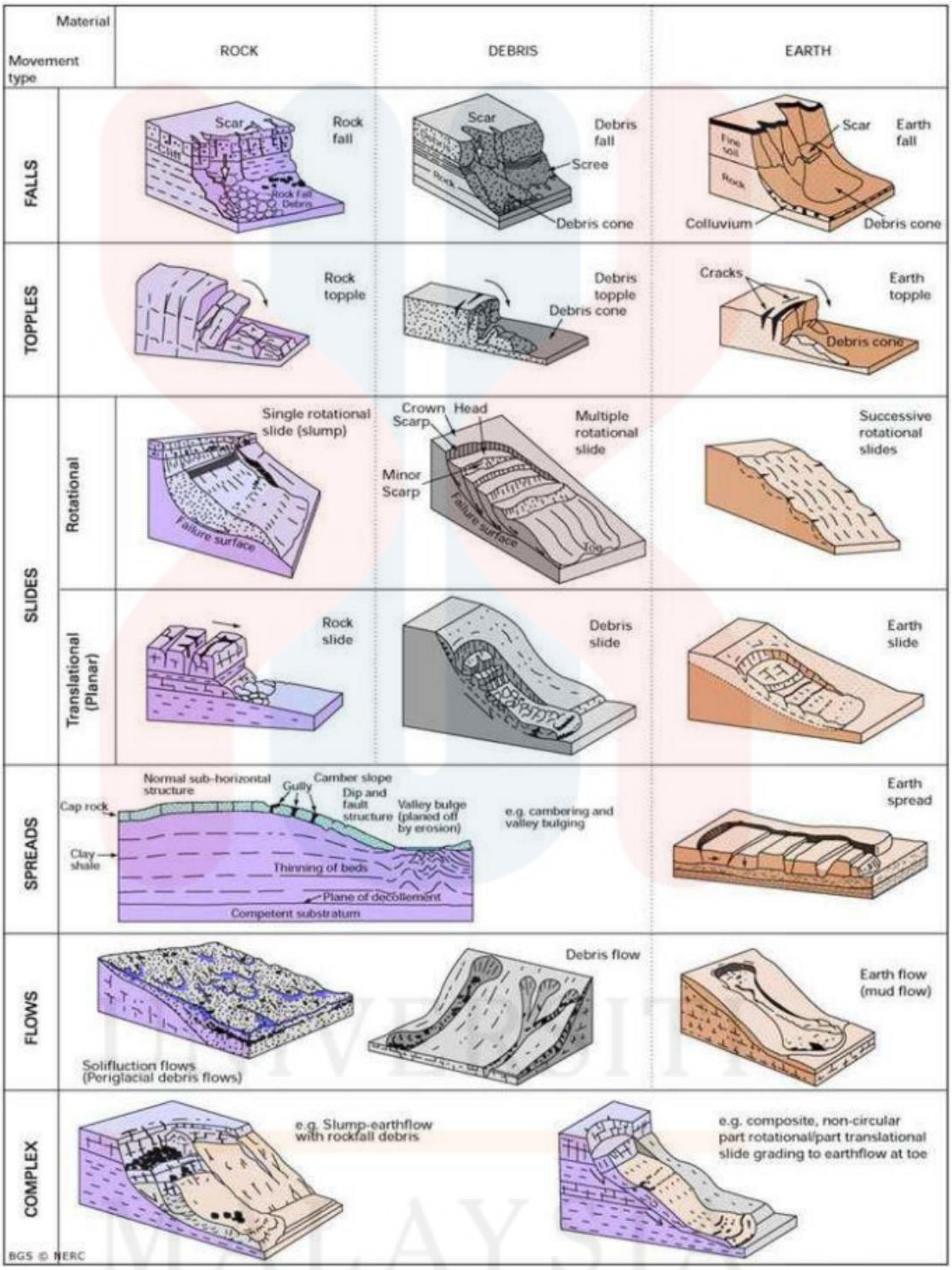
(Sources: Varnes, 1978)

Type of Material	Description
Rock	Hard or firm mass that was intact and in its natural position before any movement occur.
Soil	Aggregate of solid particles, which generally of minerals and rocks. It can be transported or formed by weathering of rock.
Earth	Materials in which 80% or more of the particles are less than 2mm, the upper limit of sand sized particles.
Mud	Materials in which 80% or more of the particles are less than 0.06mm in sized which the upper limit of silt sized particles.
Debris	Containing significant proportion of course materials, 20 to 80% of particles are larger than 2mm.

Table 2. 2: Varnes Classification of Slope Movement.
(Sources: Varnes, 1978)

Type of movement		**Type of Materials**		
		Bedrock	Engineering Soils	
			Predominantly course	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	Debris flow	Earth flow
Complex		Combination of two or more principal types of movement		

Table 2. 3: Distinct types of landslide movement



2.5.2 Past Landslide in Indonesia

A landslide in Banjarnegara Central Java, Indonesia, killed 93 people with 23 missing in December 2014. The disaster happened around 3 p.m. in Jemblung Village in Banjarnegara when the mountain fell to the entire village. That landslide has been one of Indonesia's worst and most deadly landslides since 2006. Recently, 30 houses in Sirnaresmi village in West Java’s Sukabumi district facing landslide that plunged down surrounding hills just before sunset. According to Maulana E. (2017), the landslide that occurs on the hill which located behind the house is a stone quarry site of Jentir, Sambirejo, Ngawen, Gunungkidul. That landslide cause two fatalities because of both of them stayed in the landslide hillside.

Gunung Kidul Regency is district with land condition relatively prone and unstable to movements oil or rock mass. According to the BNPBD Gunung Kidul (2001), disaster incident landslides have often occurred in several districts, no exception Gedangsari District, which is one of the districts in Gunung Kidul which is prone to landslides. Remember condition of the area of Gedangsari District, Gunung Kidul which is geomorphological located at a height of 120 - 800 masl (meter above sea level) with a flat slope slope – very steep which allows it to occur landslide disaster (Sulistyani, 2016). Gedangsari District consists of nearly seven villages entirely frequent land disasters landslides resulting in casualties and material loss. Several ground events landslides in Gedangsari District in five the last year is as follows in Table 2.4.

Table 2. 4: Landslide incident in the District Gedangsari Year 2011 - Year 2015
(Source*: Badan Pusat Statistik Gunungkidul Tahun 2015*)

No	Year	Numbers of Events	Location
1.	2011	2	Watugajah, Mertelu
2.	2012	11	Watugajah, Mertelu, Tegalrejo
3.	2013	81	Hargomulyo, Mertelu, Ngalang, Serut, Watugajah
4.	2014	29	Hargomulyo, Mertelu, Sampang
5.	2015	13	Watugajah

2.5.3 Landslide Hazard

As indicated by Nandi (2007) many impacts that occur due to landslides that will adversely affect the lives of humans, animals, and plants. The occurrence of a landslide disaster has a tremendous impact on life, especially humans. When landslides occur in areas with high population density, there will be heavy casualties, and will have a major impact, especially landslides that occur suddenly without any signs of landslides.

The impact caused by the occurrence of landslides on life is landslide claimed many victims, damage to public infrastructure such as roads and bridges, damage to buildings such as office buildings and housing and religious facilities, and inhibiting the process of human activity and harming both the community which is around the disaster and the government.

2.6 Geographic Information System (GIS)

A Geographical Information System (GIS) is a PC framework utilized for mapping and breaking down things that exist and occasions that happen on earth surface. The geographical implies the areas of the information things which is as coordinates systems.

The word information itself refers to the information or attribute of the data. The data can be shown in either coloured maps, graphics, tables, model or many more. System refers to how the data being manage and organized. How the segment that made up GIS play out their works (Xie, 2014)

Many approaches can be used in GIS methods in generating landslide hazard map. From the previous study, the spatial data were organized in GIS SPRING software (Câmara et al., 1996) and calculations related to the computation of probabilistic methods performed using MATLAB software (MATLAB, 2016). By performing both methods, it is possible to determine the slope failure by producing a study area slope inclination map.

Shahabi & Hashim (2015) used the GIS-based statistical model for generation of landslide hazard mapping using GIS and remote sensing data, at their study area. Their study area located at Cameron Highlands and use parameter such as fault, SPOT 5, WorldView-1image and distance between roads that was extracted using SAR data. After calculation and determination, the maps are then constructed between factors identified using multiple models including analytical hierarchy process (AHP), weighted linear combination (WLC) and multi-criteria spatial evaluation (SMCE) models.

Rodeano et al., (2017) used Weightage Overlay Method (WOM) and Landslide Hazard Level (LSL) map to produce a landslide hazard zoning map along Genting Sempah to Bentong area, Pahang. The study weightage the most causative factor such as land use, drainage, distance from lineament, soil lithology and geomorphology.

Those parameters were retrieved from the topographic database and were classes into landslide hazard level from very low to high which reflects the possible occurrence of landslide in the study area. Heavy rainfall triggered the landslide by changing the land and soil intensity. From all the data, layering method by raster input was weighted.

CHAPTER 3

MATERIALS AND METHOD

3.1 Introduction

This part will be discussed about several materials and methodologies that were used to conduct this research. It will give scientists a guideline to follow the materials and techniques used in this exploration. In addition, it will also give the other parties the ability to continue with this analysis by using the specified law. Materials and methodologies originally agreed to carry out the exploration. It would enable the examination to collect information as well as to examine information.

3.2 Material

To create the landslide zonation map, the secondary data collection of land information, Digital Elevation Model (DEM), and satellite pictures are fundamental. The maps of causative factor, for example, lithology map, soil map, drainage map, land use map, aspect map, slope map and NDVI map are extracted from secondary data gain from agencies and geographical mapping. The secondary data can be collected from United State Geological Service (USGS).

The Global Positioning System (GPS) is very important to identify the coordinates and to mark the location. The position will be identified and a GPS box will be produced to let the researcher know the precise location of the study area. During the sample collection, the position coordinate required to be labelled and recorded for further reference in the field note book. The GPS system is one of the best with high sensitivity and has obtained faster input from the satellites and will make it easy for the researcher to know the location during the traverse.

The program that used to create maps is ArcGIS software. This is a program that has been used to develop, update and interpret the data collected and to construct a perfect map. By using ARCGIS, all maps are generated before and after the program.

The maps that the researcher wants to create include a base map, a contour map, a drainage map, a watershed map, a lineament map, a tin map, a rock boundary map, a landform map and a land use map. In addition, Google Earth Pro apps can also incorporate maps with ArcGIS in order to achieve a more reliable and correct location of the study area. These maps provide extensive details on the area itself, including the satellite image that occurs between objects, structures and more.

In order to generate a landslide zonation map, secondary data collection of topographical data, the Digital Elevation Model (DEM) and satellite images are necessary. Maps of causative variables such as lithology map, soil map, drainage map, land use map, slope map, aspect map and NDVI map are derived from secondary data gathered from agencies and geological mapping.

3.3 Methodology

The DEM map, slope map, aspect map and drainage density map were produced using ArcGIS software to determine the distribution from the parameter used. As for the final product, landslide hazard area was produced and assessment was done. A Weighted Overlay Method was used from secondary data collection and be converted into a raster using reclassify tool in ArcMap. The raster then weighted. The evaluation was then made on the scale 1 to 5 to places with high and low potential of landslide. Figure 3.1 shows the overall research flowchart.

3.3.1 Preliminary Study

All information about the way to do the research was obtained and fully understands by preliminary study before starting the research. An article review of previous research was done in the study area or research related to the landslide susceptibility in order to gain extra information throughout the research. It is important and crucial as it involves in brainstorming and surface knowledge of what should be done. Because of that, the structural, history, lithology and formation of the study area are known.

The research question and the development of a research problem are the most critical ones to complete this research. This is because the research is split into two analyses of general geology and landslide susceptibility. Once the issue and the study topic have been established, continue with the literature review collection. It may come from a journal, a book or a previous academic thesis. Observation of the topographic map and the satellite image was also carried out.

a) Lithology map

The lithologies of the study area were identify by satellite images, previous research, and previous existing maps. By observing the rocks and its boundaries, the lithology was identified. As the observation was done, the data that was recorded in the field are mapped out and formed lithology map.

b) Slope map

By put the DEM from the satellite imaginary data and then do the conversion of slope, the slope degree can be identified. It shows the distributions of the slope based on its angle .The slope are classified using Zuidam classification, 1985.

c) Aspect map

An aspect maps is a map that shows direction and degree of steepness of the slope for a terrain. It was generated in ArcGIS from the USGS website as well (Abuckley, 2008).

d) Land use map

Land use of the study area can be mapped out from geological mapping and derived from DEM satellite image. The data is derived from Indonesia GeoSpatial Portal or *'Rupa Bumi Indonesia'*

e) Drainage density map

The drainage density map was design from the USGS satellite image from the USGS websites. It is very important as the drainage density is proportional to the mean erosion rate. Hill slope transported the sediment affect the process of runoff erosion. To create the drainage density map, DEM satellite image produced in ArcGIS using Hydrology toolset from the Spatial Analyst Toolbox.

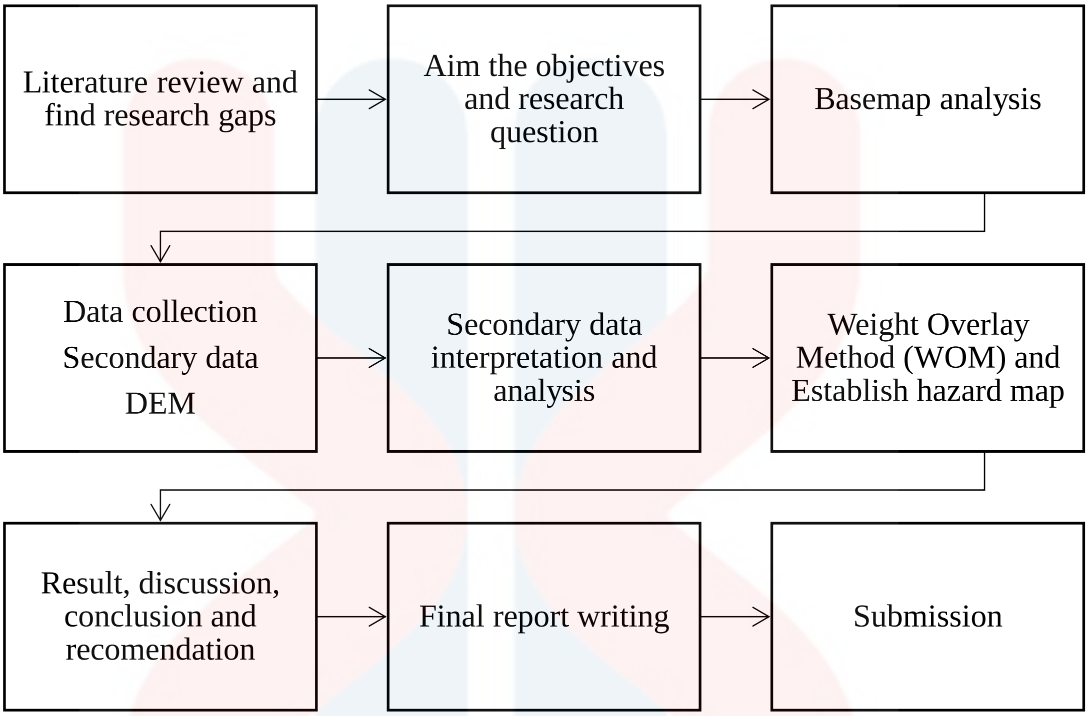


Figure 3. 1: Research flow chart.

3.3.2 Data Processing

a) Evaluation of causative factors that triggered landslide to occur

In the assessment of causative factors that cause landslides to occur, six parameters such as lithology, slope, drainage density, land use, aspect and vegetation were considered. The occurrence of landslides usually occurs because of these variables, so all kinds of data in the study area such as dimension and past landslides were collected during the geological mapping.

b) Landslide susceptibility map

The Weighting Overlay Method was used for landslide susceptibility map production. Satellite data and data collection from geological mapping as well as the parameter involved have been mapped. It was then converted to raster-based data.

Raster was weighted and rated using the rating scheme, in which all these factors and their classes were set as numerical values. The landslide was assessed with a scale of 1 to 5.

Scale 1 is the least prone to landslides, while Scale 5 is the very high potential landslides, as shown in Table 3.1. All raster-based data were weighted as a percentage based on their importance. The total influence of the raster must be 100 %.

3.3.3 Analysis and Interpretation

For geological mapping, information on the study area needs to be generated by the researcher from the data obtained. The geological map should be updated to display the evidence of the project. The research on laboratory results, drainage patterns, geomorphology, lithology and stratigraphy of the research region should be concluded. Geospatial Information System (GIS) is used to conduct a geological map including a traverse, a geological map and a stratigraphic column. The researcher should be in a position to use GIS to complete the study.

For the development of the Landslide Susceptibility Inventory, the specific parameters determined during the interpretation, such as the slope, the drainage density analysis, the lineament analysis, the watershed analysis and also the topographic analysis. All of these parameters were important in determining the landslide susceptibility weighted in the study area.

Raster layer of parameters used, such as slope, vegetation, drainage density and aspect map, was created by the use of the DEM. From all the data, the layering techniques were weighted by the input of the raster. The weight assessment was carried out using the reclassification method in ArcMap based on the reclassified weight. As a result, a landslide hazard map was created.

Results from weighted overlay methods indicate the most susceptible region to landslides with a scale of 1 to 5 and susceptibility classes. The landslide assessment was conducted to demonstrate that the distribution of high potential to low landslide potential was most likely to occur. The landslide hazard map can be used as an indication to prevent any construction of infrastructure or houses near a high susceptibility region.

CHAPTER 4

GENERAL GEOLOGY

4.1 Introduction

In this chapter, geology, will be discussed about the details of geological information of Hargomulyo area in terms of geomorphology, lithostratigraphy, structural geology and historical geology based on interpretation. Few maps namely topography, drainage pattern, lithology map is created in order to understand the characteristics of study area. Furthermore, the data which collected in the field used for to create a geological map of the study area with scale of 1:25 000.

4.2 Geomorphology

Geomorphology is the landform analysis which emphasis the origin, evolution, form and distribution that were created by physical and chemical processes at the Earth surface. The study of topographic map and the ground observation from peak can determine the type of landform, drainage and contour pattern. Mountains, hills, plateau and plains are the example of major landform. Endogenic and exogenic process made up the different type of landform.

The geomorphology of southern mountain of Central Java was classified as in the physiographic zonation of western part of Southern Mountains as stated by Husein *et al.* (2007); after Van Bemmelen (1949) as in Figure 4.1. The geomorphology of Gedangsari Area is divided into two main landscape, hilly landscape at the North Zone called Baturagung region and flat landscape at the central zone called Wonosari Plateau.

Baturagung Range is range of mountains that separate the east of Bantul Regency and the north side of Gunungkidul Regency and was dominated by volcanic rocks. Other than that, Wonosari Plateau is the low-land area that was dominated by sedimentary rock.

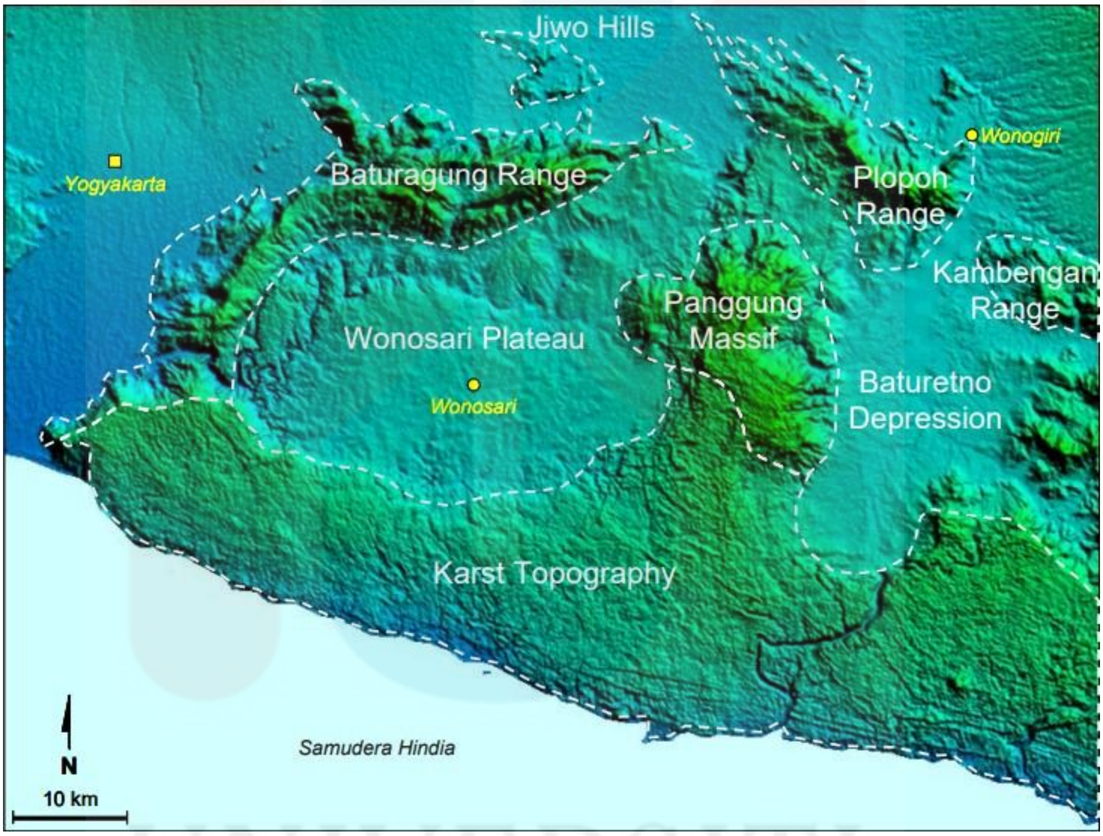


Figure 4. 1: Physiographic Zonation of Western Part of Southern Mountains (Source: Husein *et al.*, 2007; after van Bemmelen 1949)

4.2.1 Landform

Generally, in the study area, the landform is divided into two types of landform which is hilly and mountainous area. Different types of landform indicate different in lithology. The northern part of the study area, consist of volcanic unit and the southern part was dominated by sedimentary rock. The volcanic unit in the study area include the andesite lava, epiclastic and pyroclastic breccia while the sedimentary rocks include the sandstone carbonate, sandstone, claystone and limestone. The landform classification can be classified by the elevation above sea level in meter as shown in Table 4.1. The observation of the landform can also be made by studying the landform map as shown in Figure 4.2. The landform can be divided into two which is low hill and hilly according to Van Zuidam (1985) classification.

Table 4. 1: The landform classification

Relief / Landform	Elevation (m)
Low Hill	100-200
Hill	200-500
High Hill	500-150

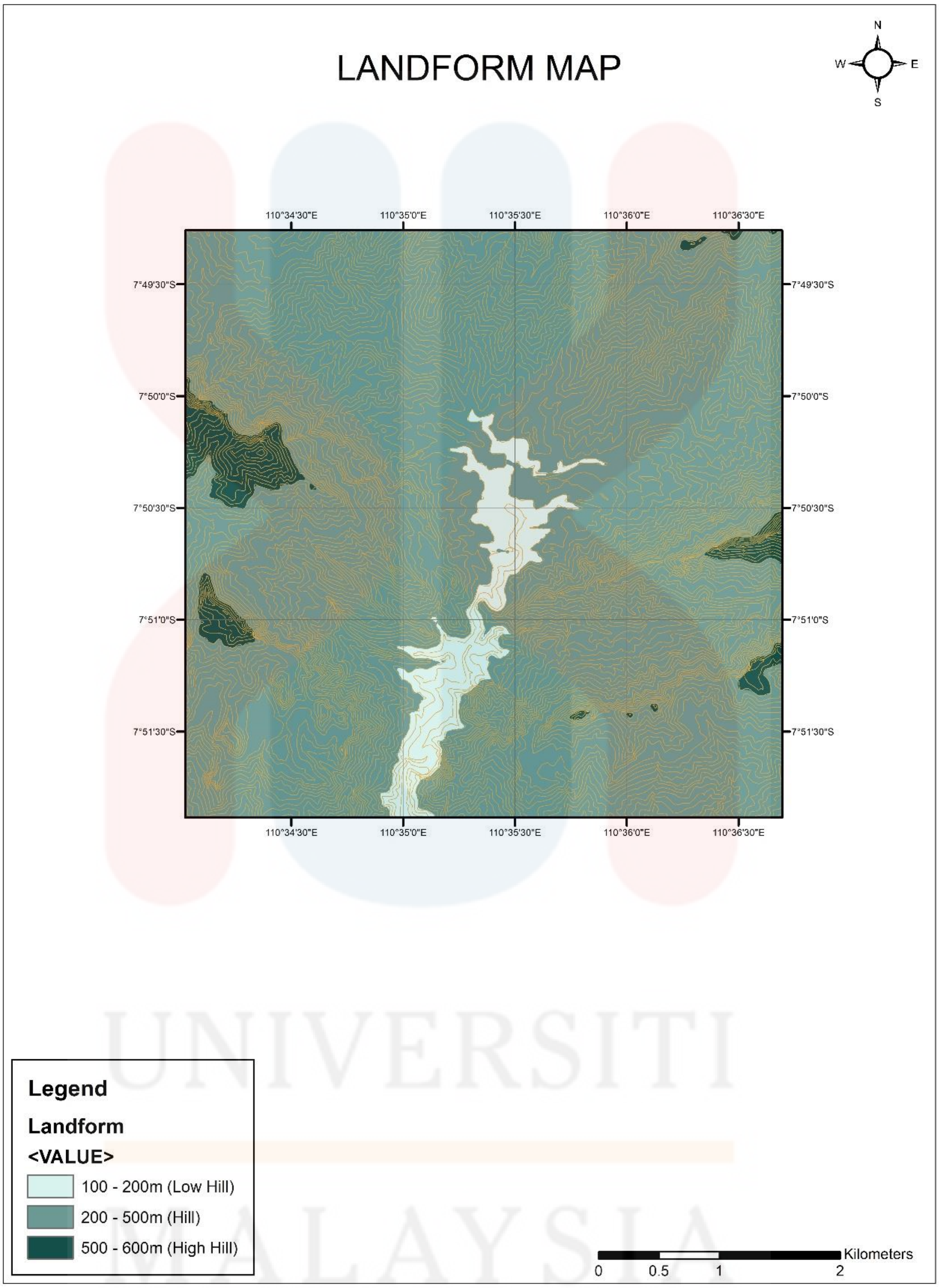


Figure 4. 2: Landform maps of the study area

4.2.2 Drainage Pattern

Drainage pattern formed by streams, lakes and rivers in a particular drainage basin. The drainage pattern depended on the topography and geology of the particular region whether the region dominated by hard or soft rock. The gradient of the land also able to determine. The tributaries that flow to some location along the stream within basin describe the characteristics of the parent rock and the structure within that rock such as fold, fracture and fault.

The study area consists of three type of drainage pattern namely dendritic, parallel and rectangular shown in Figure 4.3. Dendritic pattern is most common pattern which occur in many areas. This pattern develops where unconsolidated material located at beneath the stream and has no particular structure. This pattern eroded equally easily in all directions. The pattern like tree branching shape and characteristics by flat or homogenous rock.

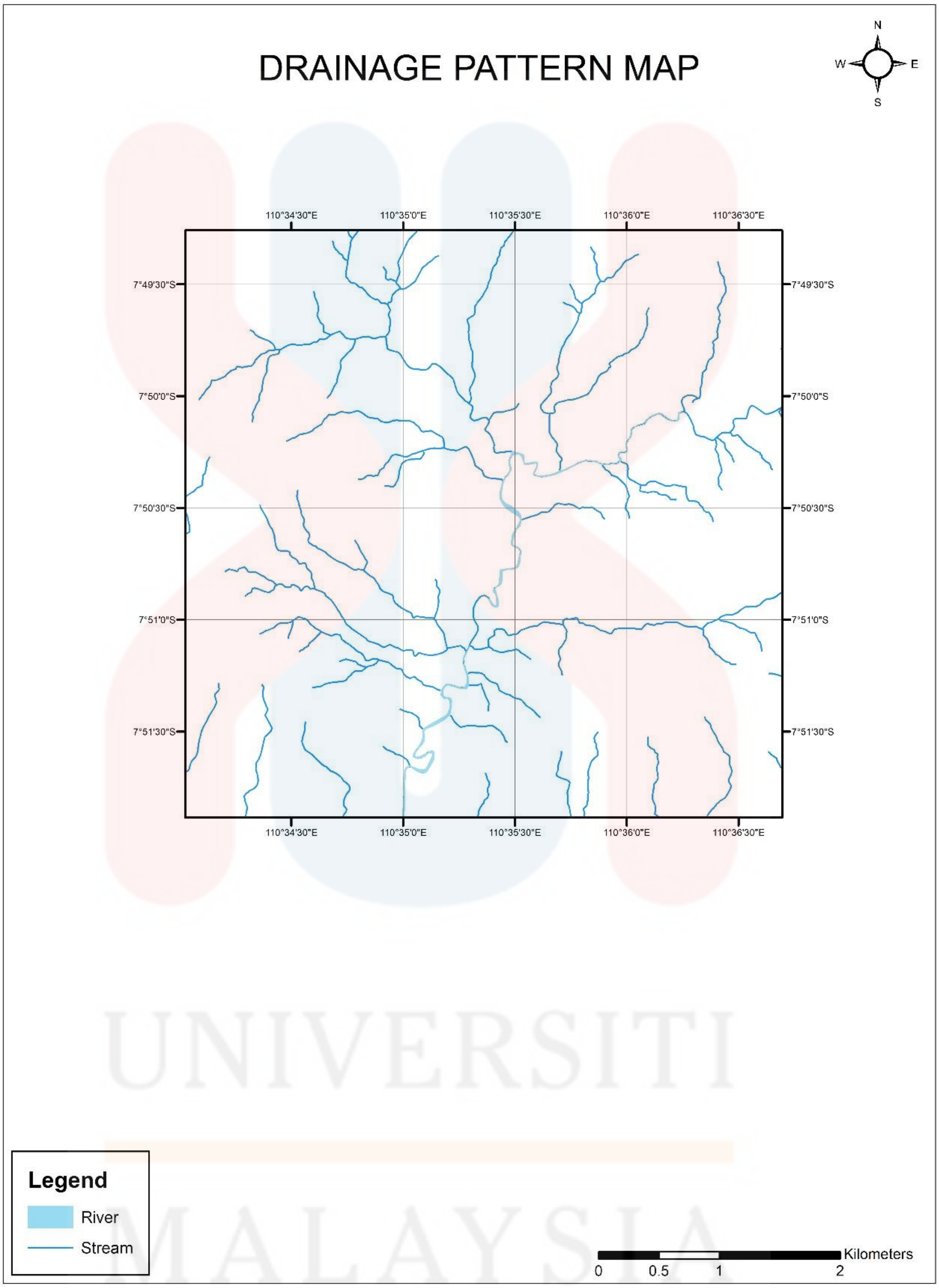


Figure 4. 3: Dendritic drainage pattern map

4.3 Stratigraphy

Stratigraphy is an observation of rock strata and its layering. The characteristics of layered rocks and the relationship between the layered rocks and age of formation were study and identified. One of the sub-disciplines of stratigraphy is lithostratigraphy. It concerns on the study of rock layer and describe the relationship between the formation of igneous and sedimentary rocks.

4.3.1 Lithostratigraphy

Lithostratigraphy in is the study of sequence of rock in layers and the relative stratigraphic position in geological time scale. The relative stratigraphic position of rock unit can be determined by considering geometric and physical characteristics of rock that indicate the older and the younger rock. There are 6 lithological unit in study area. Each unit are named according on the dominant lithology formation which shown in Figure 4.4 name tuff, tuffaceous sandstone, green tuff, tuff breccia, lapilli tuff and volcanic unit.

Lithology refers to the analysis and explanation of the physical characteristics of rocks, especially in hand specimens and outcrops (Bates and Jackson, 1980). Characteristic of the lithology, including colour, size of grain, rock form and mineral content. There are 6 main lithologies in the study area which is referred to *Peta Geologi Lembar Wonosari* 2017 are andesite unit, volcanic breccia unit, tuff unit, pumice breccia unit, tuff unit and tuffaceous sandstone unit. The lithologies can be divided into formations such as Nglanggran Formation that include andesite and volcanic breccia unit, Semilir Formation with tuff and pumice breccia unit, and Kebobutak Formation with tuff and breccia tuffaceous sandstone.

The oldest unit in study area is Kebo-Butak formation it is located at the northest part of study area. Where it has tuff unit is the oldest, followed by tuffaceous sandstone and green tuff unit from oldest to youngest. The rock unit in Kebo-Butak formation is age late Oligocene.

Semilir formation is younger than Kebo-Butak formation which age early Miocene. Semilir has two unit of rock tuff pumice at upper and lower lapilli unit. These two-rock unit believed interfinger each other. Semilir formation is comprising middles of the study area. The youngest rock unit in study area is volcanic unit which has pyroclastic, epiclastic andesite breccia and it is under Nglanggran formation which age early Miocene.

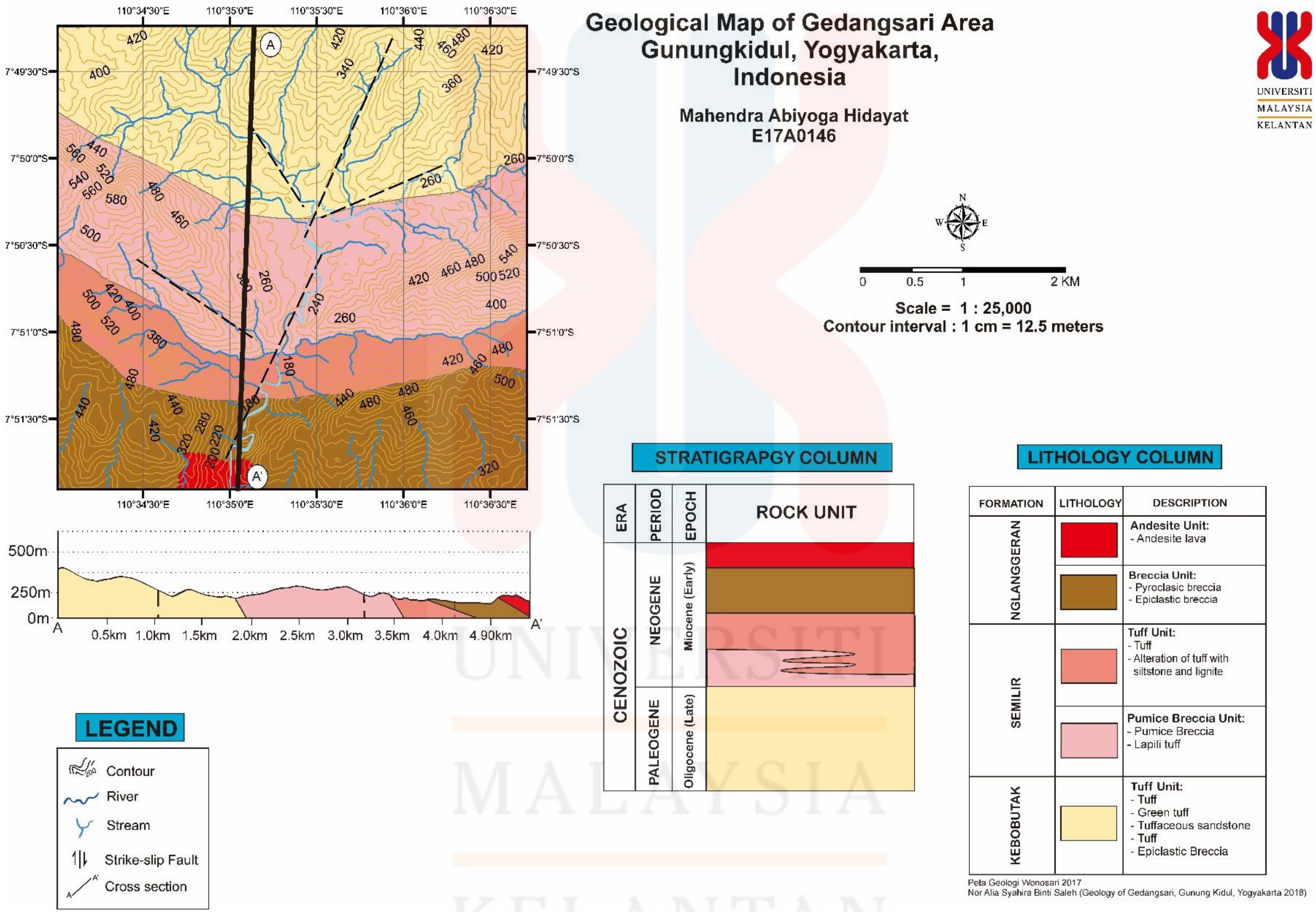


Figure 4. 4: Geological Map of Gedangsari with lithology unit

4.4 Structural Geology

Structural geology concern on the geological features formed due to tectonic movement that cause deformation to occur. It is important to analyse the geometries and investigate the Earth tectonic activities as well as the stress and strain of the rock. By knowing the structural geology, the history of the Earth can be revealed. Deformation cause fault, fold, joint, bedding and veins to occurred. The deformation of Earth can be detected through geological mapping and lineament analysis using terrain map.

4.4.1 Lineament Analysis

Lineaments provide information about the geological structure lying on the Earth though linear or straight line. By using satellite image or aerial photograph, the terrain surface expresses the faulting and other structure in large scale.

Lineament were divided into two categorize which is positive and negative lineament. Positive lineament was presented by ridge and range while negative lineament showing streams, faults and valleys. Figure 4.5 shows the lineament maps of the study area.

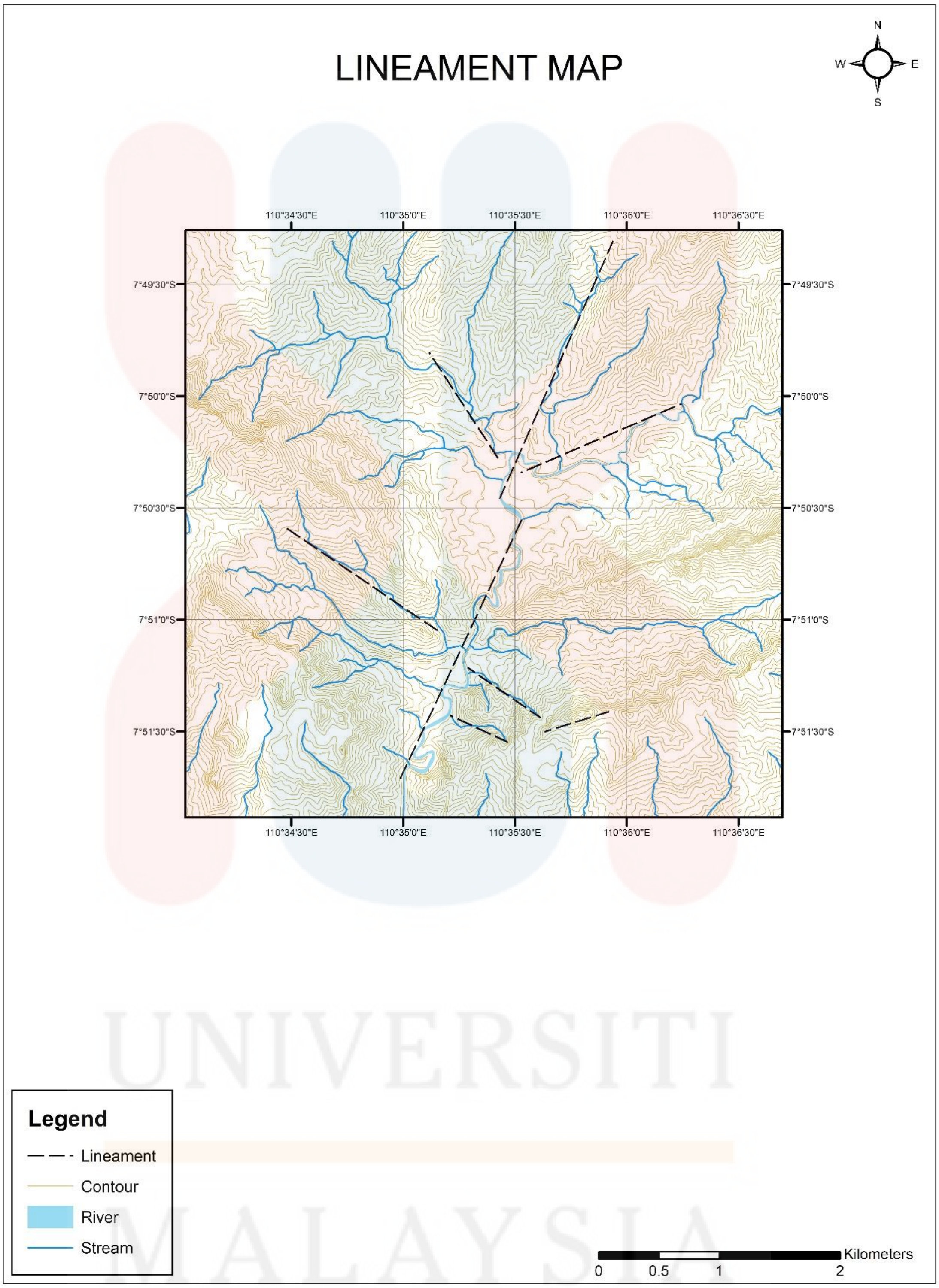


Figure 4. 5: Lineament map of the study area

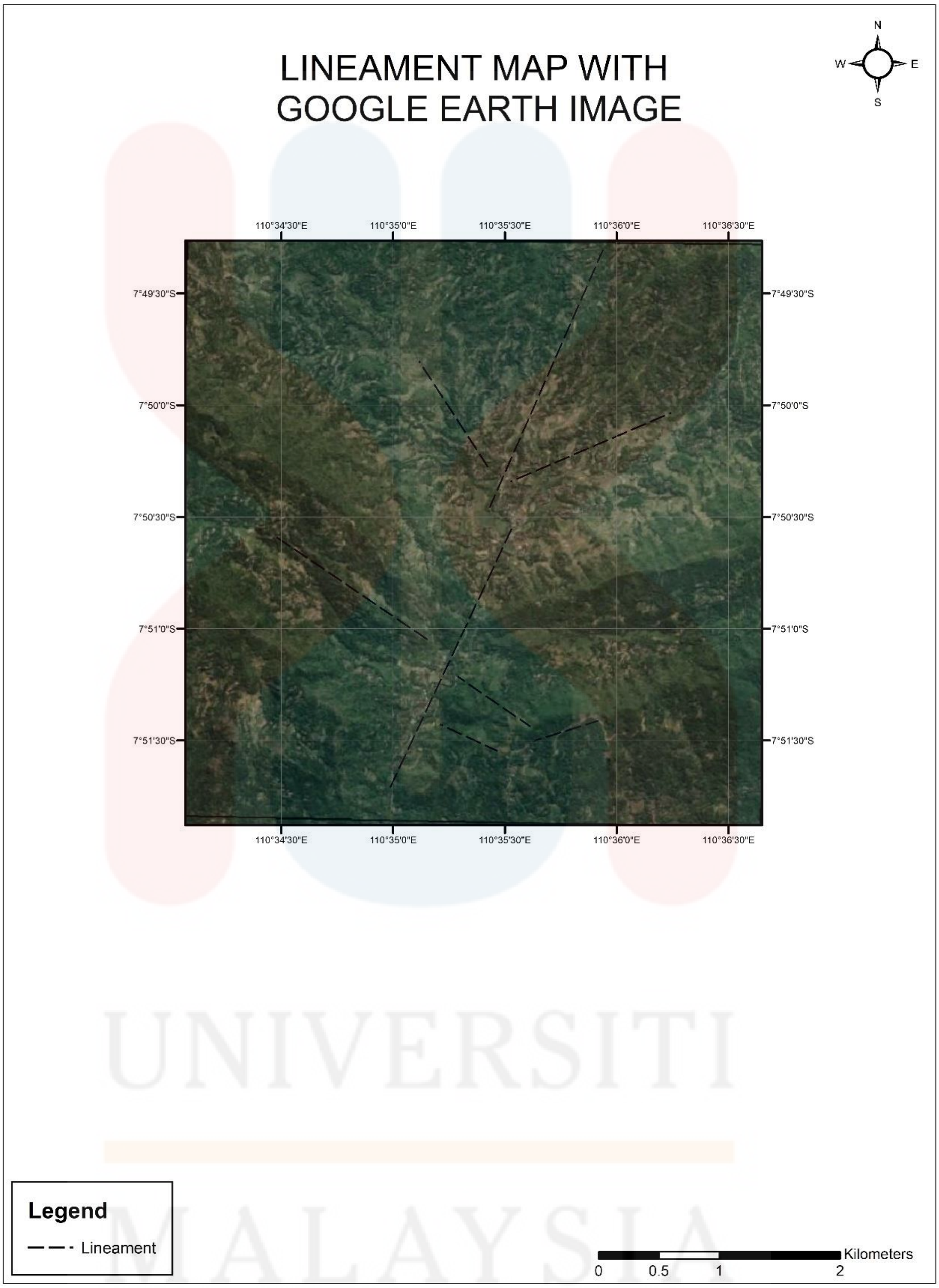


Figure 4. 6: Lineament map with google earth image of the study area

4.4.2 Fault

Fault is a fracture or crack between the rocks. Usually, faults were formed between Earth's tectonic plates. The piece of the Earth's crust along a fault move over time occurs in active fault while in non-active faults, the Earth's crust is no longer move. When the fault moves, it formed earthquakes. There are three general type of faults which is normal fault, reverse fault and transform fault. Strike slip fault, oblique fault, and dip-strike slip fault is a sub division of faulting.

Normal faults occur when the hanging wall is moved down relative to the footwall. It occurs when a tension applied and pulls apart the rock. Reverse fault is happened when the rock was pushed together because of compression forces leaving the hanging wall moving upward in 45^{o} angle and above. Thrust fault is a sub-division of reverse fault but with less than 45^{o} angle.

The third fault is transformed fault which include strike-slip fault. Strike-slip fault is divided into two which is dextral strike-slip fault and sinistral strike-slip fault. Dextral strike-slip fault is when the side opposite move to the right while sinistral is when the side opposite is move to the left.

Strike-slip fault is the vertical fractures where most of the blocks have moved horizontally. There are two types of strike-slip fault that is called sinistral and dextral. Sinistral strike-slip fault is when the far sides of the blocks move to the left while dextral strike-slip fault is when the far sides of the blocks moves to the right. In the study area, the type of the strike-slip fault is the sinistral strike-slip fault as the as the far sides of the blocks move to the left.

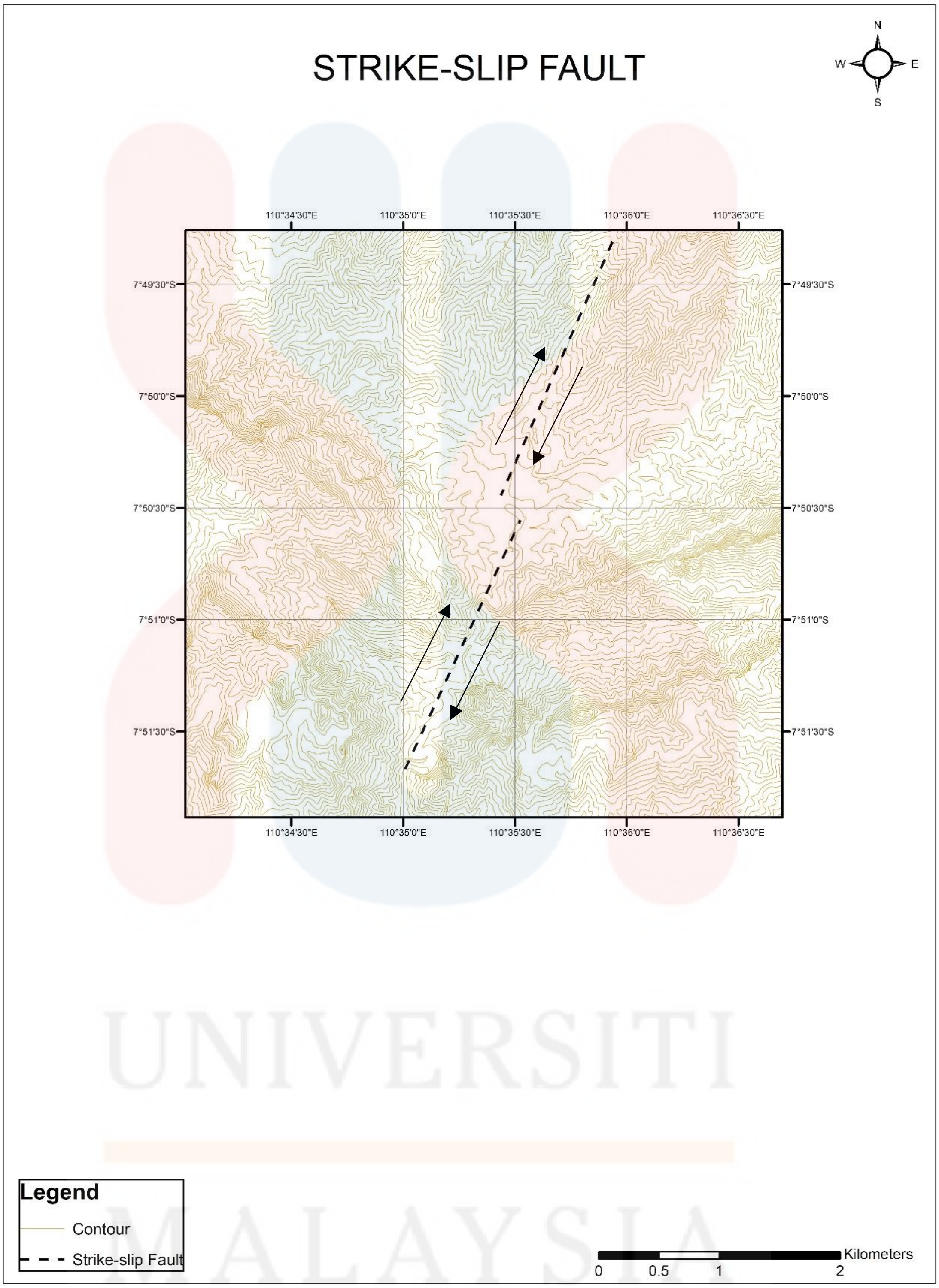


Figure 4. 7: Strike-slip Fault.

CHAPTER 5

LANDSLIDE ZONATION

5.1 Introduction

In this chapter, the landslide susceptibility assessment was analysed and determined. Based on the study area of Gedangsari, Gunungkidul Regency, six parameters were used in determining the landslide causative factor such as lithology, slope, aspect, vegetation, land use and drainage density. The parameters were generated from DEM data of year 2018. The average weightage score of each parameter were selected to determine the landslide hazard area.

5.2 Parameter of Landslide Hazard

The weightage of the parameter selected in determining the landslide susceptibility is shown in Table 5.1.

Table 5. 1: Weightage of parameter of landslide causative factor
(Source: Surat Keputusan Menteri Pertanian Nomor: 837/Kpts/Um/11/1980)

No	Parameter	Weightage (Wi)
1	Lithology	7
2	Slope	10
3	Aspect	8
4	Vegetation & Land use	6
5	Drainage density	9

5.3 Lithology

Lithology map were the parameter used in determining the susceptibility of landslide occurrence in the study area. The differences in lithology played an important role where the area is prone or low vulnerability to landslide. The higher the grade one factor score, the greater the influence of these factors on the sensitivity of the region to erosion or landslide.

The lithologic condition and formation differentiate the characteristics of rock and soil. The three formation which is Nglanggran, Semilir and Kebobutak formation in the study area dividing the lithology unit into few categories as shown in Table 5.2. The lithology weighting was marks as 7 because the lithology condition affected the vulnerability to landslides.

Figure 5.1 shows the lithology of the study area showing that the distribution of lithology is from oldest to youngest from the northern to southern area. The rocks formed during Early to Middle Miocene.

Table 5. 2: Weightage and score for lithology

No	Lithology Class	Weightage (Wi)	Score (Sij)	Weightage x Score (Wi x Sij)
1	Andesite Lava	7	1	7
2	Pyroclastic Breccia, Epiclastic Breccia	7	1	7
3	Alteration of Tuff with Siltstone and Lignite	7	1	7
4	Pumice Breccia and Lapilli Tuff	7	1	7
5	Tuff, Green Tuff, Tuffaceous Sandstone	7	1	7

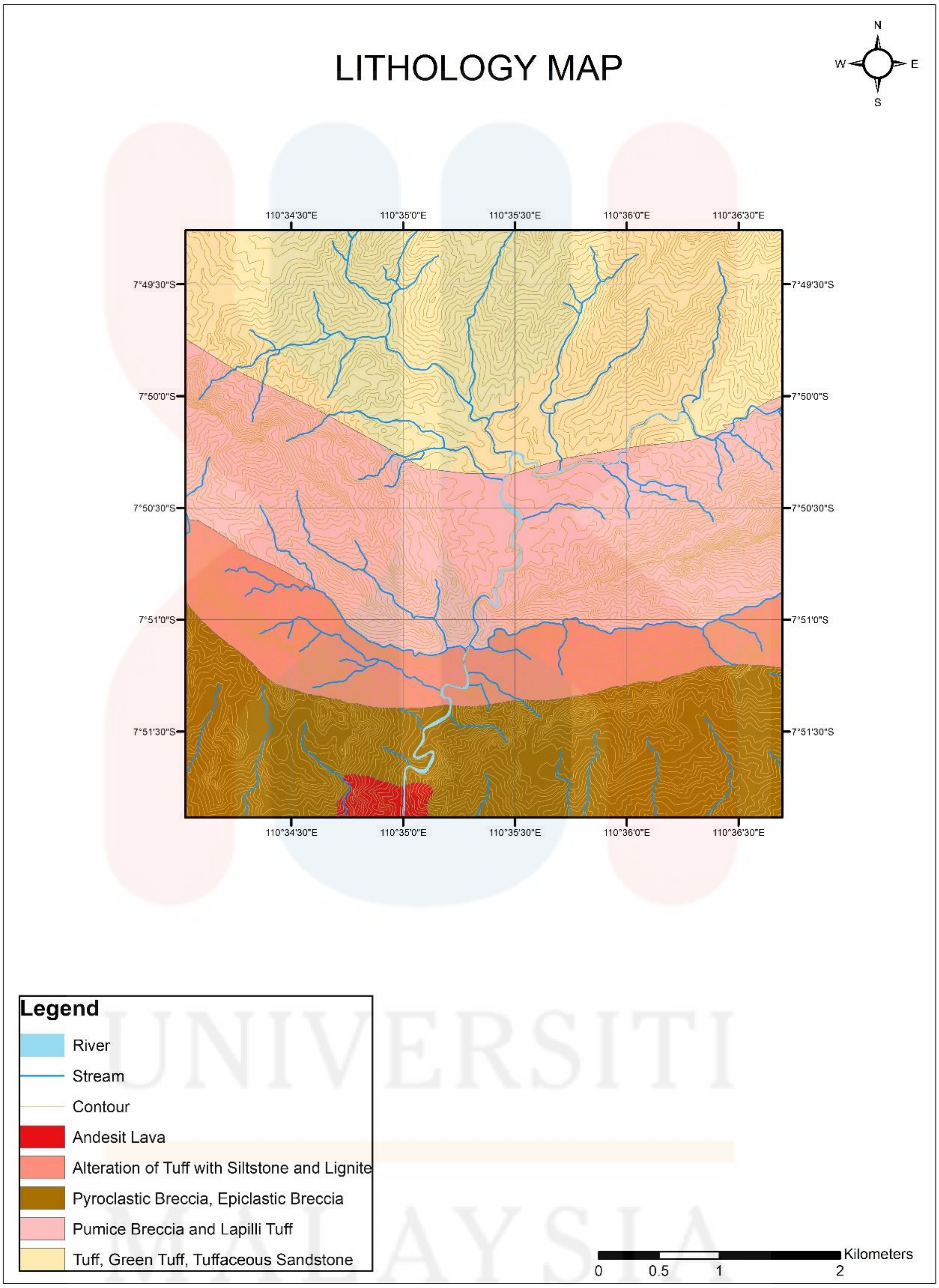


Figure 5. 1: Lithology maps of the study area.

5.4 Slope

Landslide is the movement of mass of rock, debris or earth down a slope. The soil and rock down-slope movement were influenced by gravity. The effect of down-slope forces contributes to low or reduce strength. Slope is an important parameter in determining the landslide susceptibility in the study area. The study area was divided into two mountainous area on the north named Baturagung and flat area on the middle to the south of the Wonosari Plateau. The slope was classified into six categories according to Surat Keputusan Menteri Pertanian Nomor : 837/Kpts/Um/11/1980 as shown in Table 5.3. The Northern side of the study area were dominated with steep to very steep slope with 25 – 35º and 35º and more, while the southern part is moderate to gentle slope.

Table 5. 3: Slope Classification
(Sources: Surat Keputusan Menteri Pertanian Nomor : 837/Kpts/Um/11/1980)

No	Class	Description
1.	0– 8º	Very gentle
2.	8– 15º	Gentle
3.	15 – 25º	Moderate
4.	25 – 45º	Steep
5.	> 45º	Very Steep

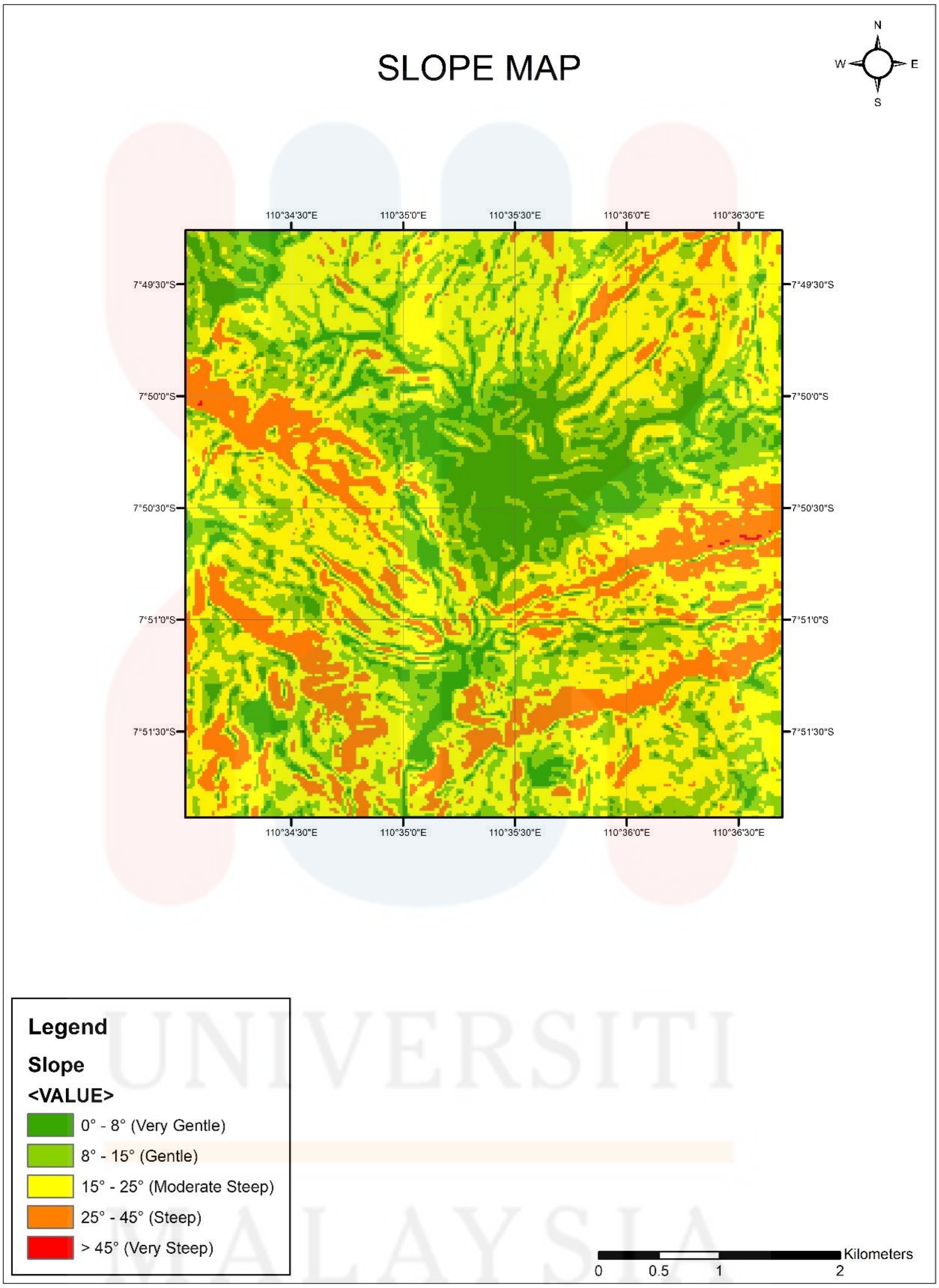


Figure 5. 2: Slope map of the study area.

The weightage and score for the slope is divided into five using the slope classification by Surat Keputusan Menteri Pertanian Nomor: 837/Kpts/Um/11/1980 with 10 scores for weightage. This is because, the slope factor gives high influence to landslide occurrence. The scores increase with the increasing of degree of slope.

Table 5. 4: Weightage and score for slope

No	Class	Weightage (Wi)	Score (Sij)	Weightage x Score (Wi x Sij)
1	0– 8º	10	1	10
2	8–15º	10	2	20
3	15– 25º	10	3	30
4	25– 45º	10	4	40
5	> 45º	10	5	50

5.5 Aspect

Aspect map were generated from DEM data. The aspect map was divided into 8 classification of slope direction that due to the North. The parameter was used to observe the direction of slope which resulting the differences in gravitational force. The instability and orientation of slope can be identified. It is measured counter clockwise in degrees from 0 (North) to 360 degree (due to North). Table 5.5 shows the slope direction of aspect and Figure 5.6 shows the aspect map of the study area.

Table 5. 5: Weightage and score for aspect

Slope direction	Weightage (Wi)	Score (Sij)	Weightage x Score (Wi x Sij)
North-Facing (0 – 22.5)	8	1	8
North-East (22.5 – 67.5)	8	3	24
East-facing (67.5 – 112.5)	8	5	40
South-East (112.5 – 157.5)	8	6	48
South-facing (157.5 – 202.5)	8	9	72
Southwest-facing (202.5 – 247.5)	8	6	48
West-facing (247.5 – 292.5)	8	5	40
North-West (292.5 – 337.5)	8	2	16
North (337.5 – 360)	8	1	8

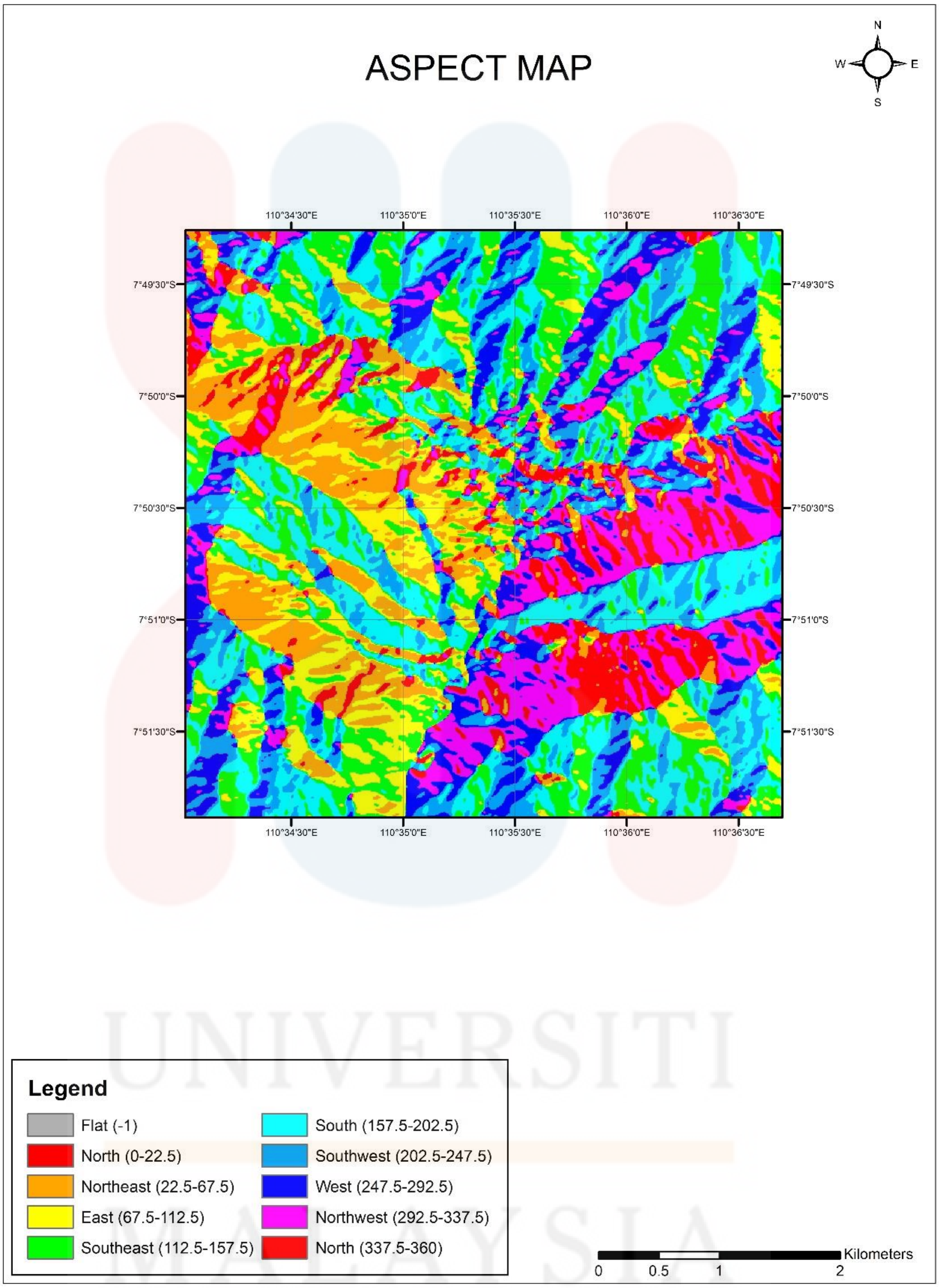


Figure 5. 3: The aspect map

5.6 Vegetation and Land Use

Land use map were produced from the secondary data collected from Indonesia Geospatial Portal (2006). Most of the land were used for plantation such as field, bushes, garden and some of them were covered by rice field. Land cover indicates the stability of the slopes. Human activities can accelerate and have strong influence in the occurrence of landslides. Table 5.6 shows the weightage and score for land use and vegetation while Figure 5.7 shows the land use map of the study area.

Table 5. 6: Weightage and score for land use and vegetation

No	Class	Weightage (Wi)	Score (Sij)	Weightage x Score (Wi x Sij)
1	Lakes	6	2	12
2	Reeds	6	3	18
3	Rice field	6	3	18
4	Garden	6	3	18
5	Housing area	6	4	24
6	Bush	6	3	18
7	Field	6	3	18

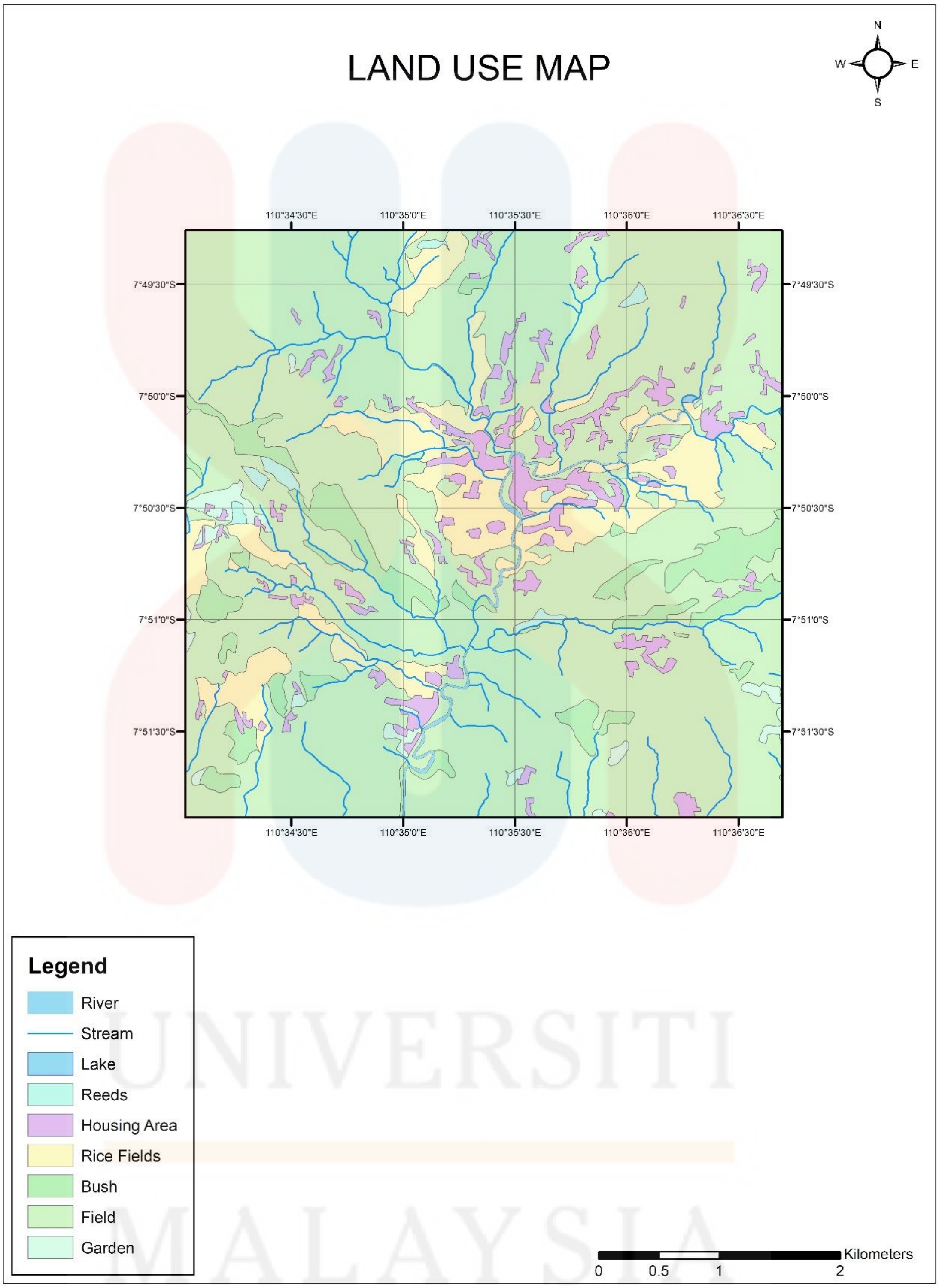


Figure 5. 4: The land use map

5.7 Drainage Density

Drainage density refers to total length of the streams and river in a drainage basin divided by the total area of the drainage basin. Drainage variation was influenced by climate, topography, soil infiltration, vegetation, and flux density. It is essential in determining the fluvial network in the study area. The vulnerable area of landslide to occur can be determined in extent of debris flow and seepage due to rainfall infiltration.

Drainage density map were extracted from DEM data in ArcGIS. Drainage density is the stream length divided by area. The drainage density was classified into three categories which is low, moderate and high. High drainage density indicates the high possibilities of the landslide occurrence. This is because, the surface runoff is high. Table 5.7 shows the weightage and score for drainage density, while the Figure 5.5 shows the drainage density map of the study area.

$$Drainage\ Density = \frac{Li\ (Stream\ Length)}{A\ (Area)} \qquad \text{(Equation 5.1)}$$

Table 5. 7: Weightage and score for drainage density

No.	**Drainage Density**		**Weightage (Wi)**	**Score (Sii)**	**Weightage × Score (Wi × Si)**
1.	Low	0-455	9	4	36
2.	Moderate	455-911	9	6	54
3.	High	911-1367	9	8	72

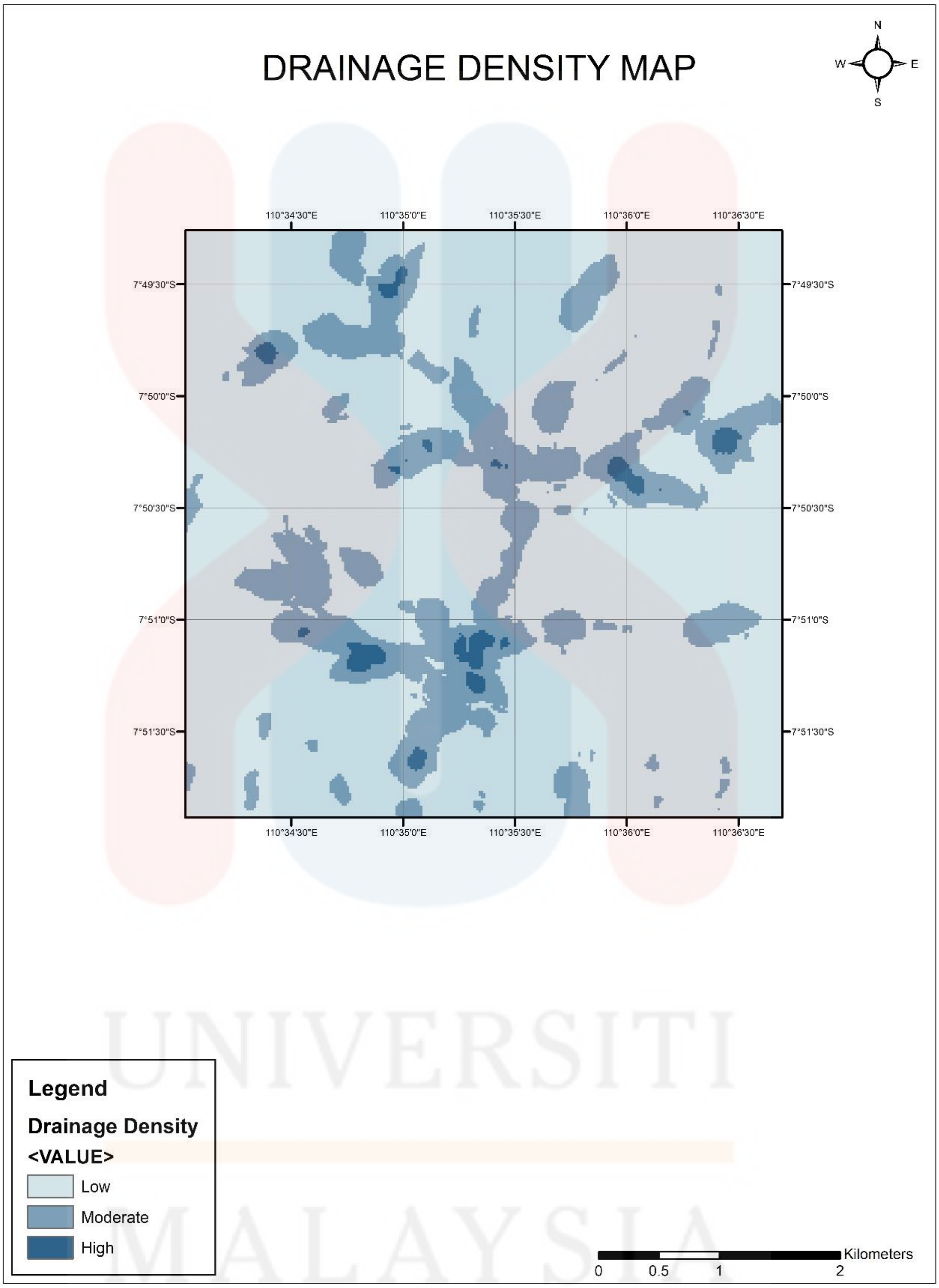


Figure 5. 5: Drainage density map

5.8 Factors Triggers Landslide

Several things can be a factor that triggered landslide. In the study area, rainfall intensity and earthquake were identified as the main factor that triggered landslide to occur every year. Excessive rainfall can trigger landslide especially in an area with thick and weathered soil. When rainfall poured intensely and filled the porosity and void in the soil, it leaves the excessive amount of water that slides through the bedrocks, causing landslide. Clay with high plasticity leading to high pore pressure in the soil with small shear angle will cause a landslide (Arifianti *et al.*, 2015)

Earthquake can trigger the mass movement of soil. The earthquake and landslide cause destructive natural disaster where the rapid shaking of the earth breaks the rocks at underground and steep slope. The study area is near to major fault such as Hargomulyo fault, Watugajah fault, and Ngalang fault.

5.9 Rainfall Intensity

The climate graph of rainfall distribution of Yogyakarta of year 2018 showed in Figure 5.6. Yogyakarta is tropical region. Significant rainfall marks most months of the year. There is little impact on the short dry season. Yogyakarta's average annual temperature is 26.4°C with an average of 2157 mm of precipitation. Yogyakarta's driest month in 2018 is August, where precipitation occurs at 16 mm. The highest amount of precipitation with an average of 392 mm occurs in January. Figure 5.6 refers to the precipitation that varies 376 mm between the driest month and the wettest month. The variation in temperatures throughout the year is 1.7°C.

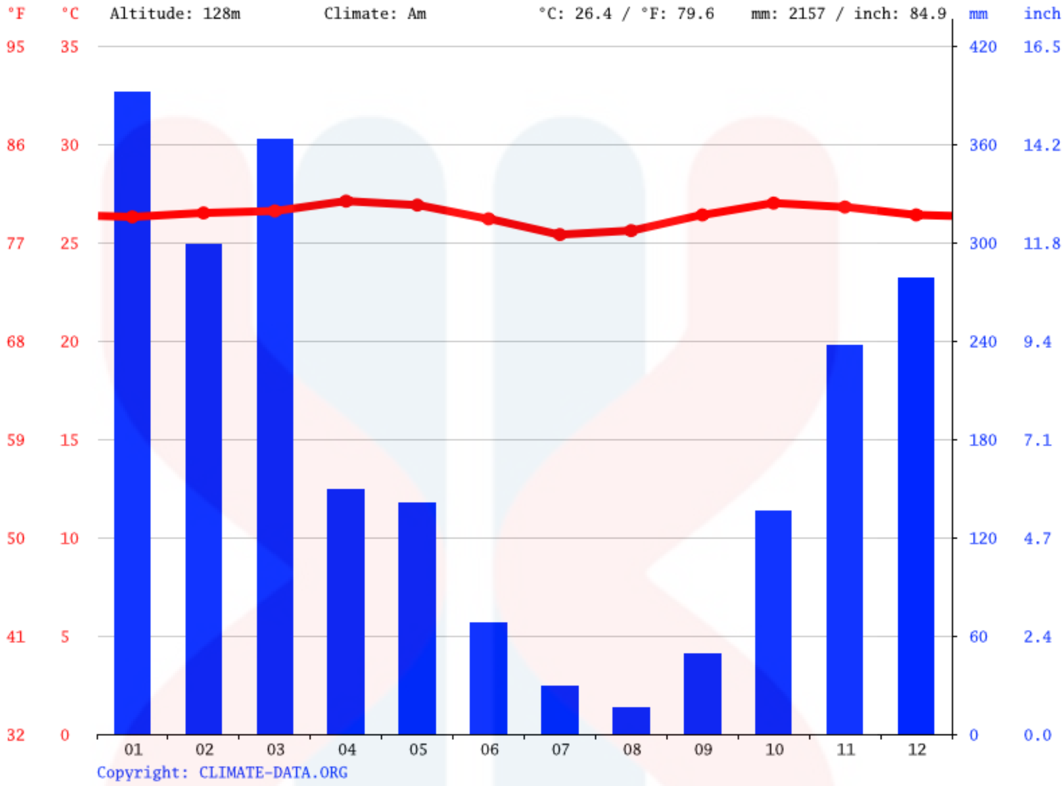


Figure 5. 6: Climate graph by month of Yogyakarta
(source: https://en.climate-data.org, **2018)**

Table 5.9 shows the rainfall distribution data collected from *Badan Pusat Statistik Kabupaten Gunung Kidul Tahun 2016.* It can be observed that in five years, the rainfall distribution is higher in November to May annually. In June – September will be drought season where all the water sources becoming dry and frequent shortage of water. Landslide may occur because Indonesia has tropical climate, so weathering processes may occur rapidly, and rainwater can reach the pores of the rock or soil, raising the mass of the rock or soil (Prihutama *et.al.*, 2018).

Table 5. 8: Rainfall distribution in Gunung Kidul Regency from 2010 - 2016
(Sources: *Badan Pusat Statistik Kabupaten Gunung Kidul Tahun 2016*)

Month	Rainfall Distribution (mm)						
	2010	2011	2012	2013	2014	2015	2016
January	226.17	357.06	442.78	499.78	387.94	6364	4386
February	265.11	408.33	322.39	296.11	332.78	4450	6695
March	125.17	325.81	397.50	168.83	108.22	6620	4628
April	126.67	241.24	158.50	198.78	179.89	5695	4391
May	109.67	134.20	73.11	172.78	63.89	1423	2282
June	36.67	-	0.92	334.17	56.50	193	3597
July	1.72	-	-	131.67	59.56	11	1172
August	0.50	-	-	0.06	0.83	-	1478
September	0	-	-	0.06	-	-	3795
October	56.19	43.17	78.44	245.28	220.11	1642	6510
November	101.38	256.78	227.35	245.28	220.11	1642	6510
December	126.31	389.39	399.25	374.17	471.78	3222	5471

5.11 Landslide Hazard Analysis

All parameters were converted into raster data set before the landslide susceptibility map can be produced. These raster data then were reclassified its weightage. The landslide susceptibility map was prepared using weightage overlay method using GIS application. The parameters of landslide causative factor that were chosen are lithology, slope, aspect, vegetation & land use and drainage density. The parameters were assigned with weightage respectively and the sum of all factor were equal to 100% and using the formula as shown in Equation 5.2:

$$S = \frac{\sum wisi}{wi} \qquad \text{Equation 5.2}$$

It is important to reclassify the data in order to generate the landslide susceptibility map using the weightage overlay method. Table 5.10 shows the reclassify data sets.

Table 5. 9: Reclassify data with influence

No	Raster Datasets	Influence (%)
1	**Lithology :** Andesite Lava Pyroclastic Breccia Epiclastic Breccia Alteration of Tuff with Siltstone and Lignite Pumice Breccia and Lapilli Tuff Tuff, Green Tuff, Tuffaceous Sandstone	25
2	**Slope :** 0-8° 8-15° 15-25° 25-45° > 45°	25
3	**Aspect :** North Facing (337.5-22.5) North-East (22.5-67.5) East Facing (67.5-112.5) South-East (112.5-157.5) South Facing (157.5-202.5) Southwest Facing (202.5-247.5) West Facing (247.5-292.5) North-West (292.5-337.5)	10
4	**Vegetation and Land use :** Reeds Rice fields Garden Housing area Bush Fields	15
5	**Drainage Density :** Low (0-455) Moderate (455-911) High (911-1367)	25
TOTAL		100

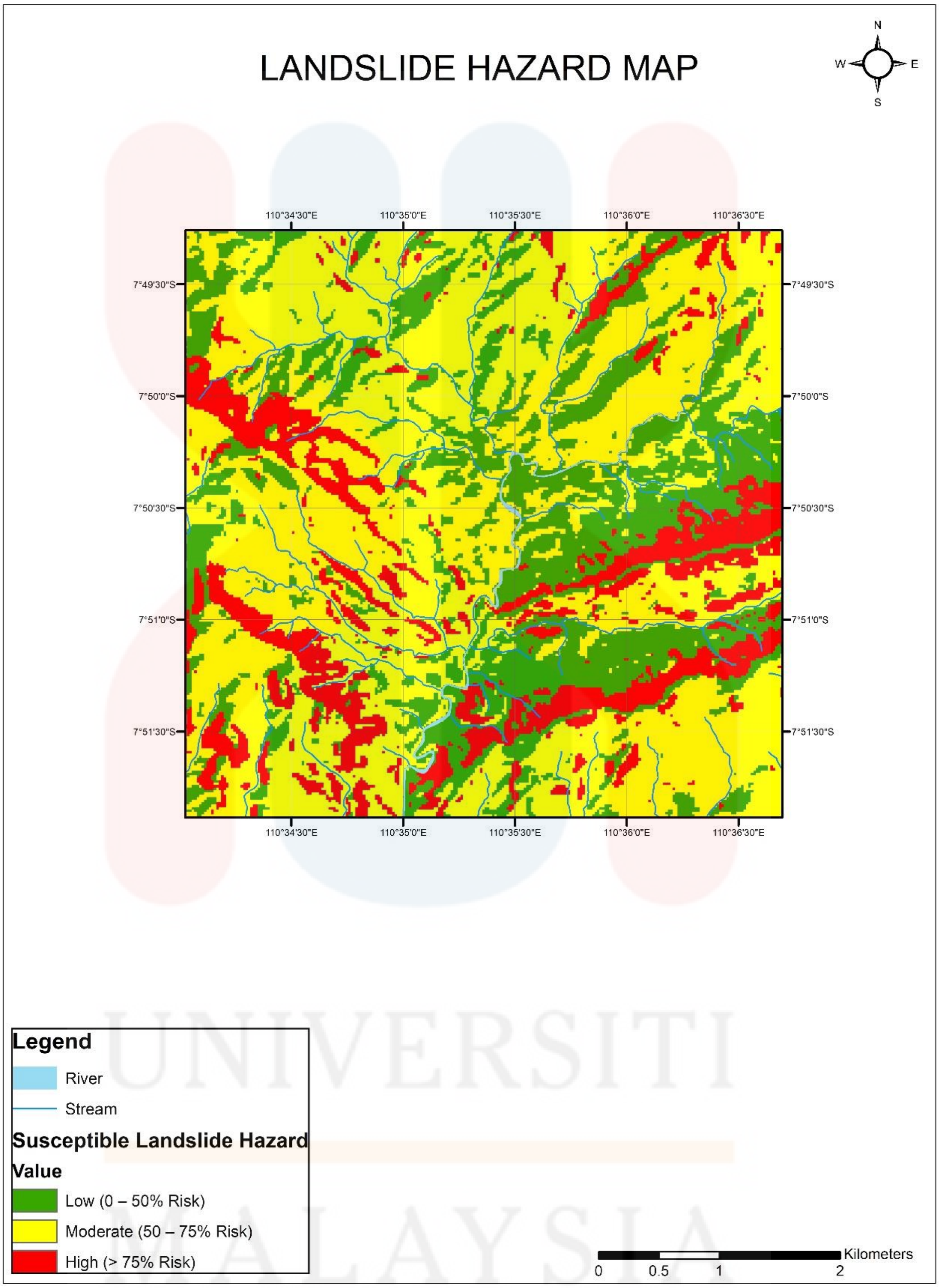


Figure 5. 7: Landslide Hazard Map of Gedangsari Area

Slope, lithology and drainage density play a key role and becoming the parameters that have a high effect on landslide hazard study. Slope with a steeper rate has a greater tendency for landslides to occur. Lithology also impacts the landslide, since the rock and soil produced in the region have varying porosity and void. The strength of the drainage density indicates that the hydrological factor will cause landslides when much of the high inclination to landslides happens along the river and stream.

Vegetation, land use and appearance have a mild effect on the phenomenon of landslides. However, with respect to other parameters and the triggered factor, also at the same time important for landslide analysis in the research area. Table 5.11 indicates the landslide hazard class in the research area.

Table 5. 10: Susceptible landslide hazard in study area

Susceptibility Class	**Risk**	**Area Percentage (%)**
Low	0 – 50%	15
Moderate	50 – 75%	70
High	> 75%	15

When heavy rainfall occurred in the study area, the porosity between the soils was filled. When the bottom layer of the interflow is bedrock, excessive water flows and landslides are triggered. The failure of the land system caused the earth's mass to slide. Heavy rainfall and earthquake caused a landslide, particularly in the southern part with a high altitude and steep slope. As the earthquake happens, the earth shakes and the structure becomes unstable.

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

In conclusion, A geological map of Gedangsari area, Gunungkidul was updated with more details in scale of 1:25000. With respect to the lithostratigraphy, the lithology of the study area was divided into six unit which is Nglanggran Formation that include andesite and volcanic breccia unit, Semilir Formation with tuff and pumice breccia unit, and Kebobutak Formation with tuff and breccia tuffaceous sandstone.

The oldest unit in study area is Kebo-Butak formation it is located at the northest part of study area. Where it has tuff unit is the oldest, followed by tuffaceous sandstone and green tuff unit from oldest to youngest. The rock unit in Kebo-Butak formation is age late Oligocene.

Semilir formation is younger than Kebo-Butak formation which age early Miocene. Semilir has two unit of rock tuff pumice at upper and lower lapilli unit. These two-rock unit believed interfinger each other. Semilir formation is comprising middles of the study area. The youngest rock unit in study area is volcanic unit which has pyroclastic, epiclastic andesite breccia and it is under Nglanggran formation which age early Miocene.

The landslide susceptibility map of the study area was created using five parameters, such as lithology, slope, aspect, vegetation, land use and drainage density. Using the weighted overlay method in ArcGIS, susceptibility maps have been developed and reclassified into three classifications of low, medium and high landslide susceptibility potential. The research areas were typically vulnerable to landslides with 70% of medium, 15% of high and 15% of low susceptibility.

The parameter and the causative factor of landslide were addressed, while the factor that caused the landslide to occur was analysed. From the study, rainfall rate and earthquake were established as the key factors causing a landslide in Gunungkidul.

6.2 Recommendation

Based on current studies, the suggestions for the next research are that the geological mapping itself should be initiated earlier so that concerns such as the lack of data collection can be avoided. It is also important to develop the general knowledge of mapping, both in mapping knowledge and in another field of geological knowledge, such as structural geology and also in the lithologies of the study area.

In the specification part, various types of parameters, such as the form of vegetation, the slope aspect and also the geomorphology of the research area, are recommended for use in the next study. The explanation is that the different type of parameters used which provide different outcomes than the outcome can be compared to know which parameters most affected the landslide susceptibility to the research area.

Landslide hazard research was proposed to be carried out using the ArcGIS program since it is an easy software that can assess the susceptibility of landslides in the study region. As far as landslide susceptibility is important, it is advisable for construction in the research area to be carried out properly as the area has a high probability of occurring of landslide hazards. It is for the safety of the people and also to avoid the loss of life and property.

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