GENERAL GEOLOGY AND LAND USE DEVELOPMENT OF TARAGONG AREA, GARUT, INDONESIA USING REMOTE SENSING ANAYSIS

by

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

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DECLARATION

I declare that this thesis entitled General Geology and Land Use Development of Taragong Area, Garut, Indonesia using Remote Sensing Analysis 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.

Signature : ___________________________________

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General Geology and Land Use Development of Taragong Area, Garut, Indonesia using Remote Sensing Analysis

ABSTRACT

The study area is located in Taragong area, Garut, Indonesia and has two different areas coverage. For the general geology, the area covers 25 km^2 while for the specification part, specifically on the land use development the area covers 225 km^2. The difference in the study area coverage is because Landsat has a low spatial resolution of 30 m. The change in land use can be understood with the aid of satellite imagery. In this research, two generations of Landsat namely Landsat 7 (ETM+) and Landsat 8 (OLI and TIRS) are used to acquire the satellite imageries for two different time periods that is 2005 and 2015 respectively. The research shows the land use dynamics of Taragong area of Garut District in West Java, Indonesia over a period of 10 years from 2005 to 2015. The objectives of this research are to update the geological map of Taragong area, Garut, Indonesia and to identify the land use development hence generating a land use map. Based on the updated geological map, basalt and andesite are two types of lithology found and can be divided into 11 rock units. In this study area, the elevation ranges between 700 m – 1 450 m and thus, is classified under mountainous area. Parallel, deranged, dendritic and rectangular are four types of drainage patterns found the study area. Faulting is also present as the geologic structure. Supervised classification technique of the Maximum Likelihood Classification (MLC) method in ENVI 5.1 is used to identify the five classes of land use. The results indicate the built up area, vegetation area and water body area have increased by 7.827% (17.646 km^2), 20.468% (46.143 km^2) and 21.816% (9.677 km^2) respectively while agriculture area and barren area have decreased by -22.766% (51.206 km^2) and -15.206% (34.281 km^2) respectively.

Geologi Umum and Perkembangan Penggunaan Tanah di Kawasan Taragong, Garut, Indonesia dengan Menggunakan Analisis Penderiaan Jarak Jauh

ABSTRAK

Kawasan kajian terletak di kawasan Taragong, Garut, Indonesia dan mempunyai dua liputan kawasan yang berbeza. Bagi bahagian geologi umum, kawasan kajian meliputi keluasan 25 km^2 manakala bagi bahagian spesifikasi khususnya pembangunan penggunaan tanah, kawasan tersebut meliputi keluasan 225 km^2. Perbezaan dalam liputan kawasan kajian ini adalah disebabkan ciri-ciri Landsat yang mempunyai resolusi ruang yang rendah iaitu 30 m. Pembangunan dalam penggunaan tanah dapat difahami dengan bantuan imej satelit. Dalam kajian ini, dua generasi Landsat iaitu Landsat7 (ETM+) dan Landsat 8 (OLI & TIRS) telah digunakan untuk memperoleh imej satelit untuk dua period masa yang berbeza bagi tahun 2005 dan 2015. Kajian ini menunjukkan penggunaan tanah yang dinamik di kawasan Taragong yang terletak di Daerah Garut di Barat Jawa, Indonesia dalam tempoh 10 tahun dari tahun 2005 hingga tahun 2015. Objektif kajian ini adalah untuk mengemaskini peta geologi kawasan Taragong, Garut, Indonesia dan untuk mengenal pasti pembangunan penggunaan tanah seterusnya menghasilkan peta penggunaan tanah. Berdasarkan peta geologi yang telah dikemaskini, basal dan andesit adalah dua jenis lithologi yang dijumpai dan boleh dibahagikan kepada 11 unit batuan. Kawasan kajian ini mempunyai ketinggian di antara 700 m - 1 450 m dan dapat dikelaskan di bawah kawasan pergunungan. Selari, terganggu, dendritik dan segi empat tepat merupakan empat jenis pola saliran yang terdapat di kawasan kajian. Sesar juga hadir sebagai struktur geologi. Teknik klasifikasi terselia iaitu kaedah “Maximum Likelihood Classification (MLC)” dalam ENVI 5.1 digunakan untuk mengenal pasti lima kelas penggunaan tanah. Hasil kajian mendapati bahawa kawasan pembangunan, kawasan tumbuhan dan kawsan air telah meningkat sebanyak7.827% (17.646 km^2), 20.468% (46.143 km^2) dan 21.816% (9.677 km^2) manakala kawasan pertanian dan kawasan tanah kosong teleh menurun sebanyak -22.766% (-51.206 km^2) dan -15.206% (34.281 km^2).

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LIST OF ABBREVIATION

km^2	kilometre per square
km	kilometre
mm	millimetre
m	metre
ETM+	Enhanced Thematic Mapper Plus
OLI	Operational Land Imager
TIRS	Thermal Infrared Sensors
Lh	Lahar
G_{fall}	Guntur Pyroclastic Fall
G_{lava} C	Guntur Lava C
G_{lava} B	Guntur Lava B
G_{flow}	Guntur Pyroclastic Flow
G_{lava} A	Guntur Lava A
P_V	Volcanic Product of Picung
C_V	Volcanic Product of Cileungsing
$P\text{-}K_V$	Volcanic Product of Putri – Katomas
$G_{a\ D.A}$	Volcanic Avalanche of Gandapura
K_V	Volcanic Product of Kamojang
CPL	Cross Polarized Light
PPL	Plain Polarized Light
3D	3 Dimensional

LIST OF SYMBOLS

°C	celcius
%	percentage
σ	sigma

CHAPTER 1

INTRODUCTION

1.1 General Background

The research of this project involves two different aspects of study which are the general geology of Taragong area and the change in land use development of Taragong area by using remote sensing analysis. The study was focusing on Guntur Complex specifically in Tarogong area of Garut District that is located in Southern Bandung. The Java Island is divided into two major provinces namely West Java and East Java (Herman & Sidi, 2000). The study area, Taragong area is located at West Java, Indonesia (Figure 1.1). An alluvial lowland plain and a mountainous belt in the North and South respectively formed the West Java (Bemmelen, 1949). It is bounded by the Java Sea to the north, the Central Java's province to the east, the Indian Ocean to the south and the Banten's province to the west. The capital of West Java Province is Bandung (Badan Pusat Statistik, 2014).

A study on the general geology of Taragong area has been carried out in order to understand the geology of the study area. This general geology includes geomorphology, stratigraphy and structural geology. The data and information obtained from the geological mapping and laboratory are important in producing an updated geological map of a scale of 1:25000. The processed data and information contained data on geomorphology, structural geology, road connections and other geological features.

On the other hand, the research was also focussing on the land use development of Taragong area in the District of Garut. Over years, the city is becoming congested due to urbanization, development of buildings like housing areas and shopping complexes as well as development of roads. This is important so that an effective plan on the land use development of Taragong area can be implemented for future use.

1.2 Problem Statements

The current geological information has been used as general references by students and researchers for learnings and researches purposes. However, the geomorphology of Taragong area and its surroundings have experienced a lot of changes over the past few years due to vast developments and constructions. The geological map of Garut was published in 1998. This caused the provided geological information of the study area to be less accurate. General geology like geomorphology has certainly changed. Thus, through this research, the geological map of Taragong area has been updated and gave more accurate information for future uses.

Besides that, rapid development has taken place in Taragong area during this period. Lands which used to be vacant before are now occupied by buildings and roads. Therefore, by conducting this research, the development usages on the land use were studied. Hence, a land use change in development map has been generated as well. Both of these justifications were be done by using remote sensing analysis.

1.3 Research Objectives

The objectives of this research are:

1. To produce a geological map of Tarogong area with 1:25000 scale

2. To identify the land use development of Tarogong area using remote sensing analysis

3. To generate a land use map of Tarogong area

1.4 Study Area

The study area is focussing at Tarogong area which is located in West Java of Java Island, Indonesia, particularly in the District of Garut. The study area can be divided into two parts. For the general geology part, the study area has a total of 25 km^2. It lies at longitude of 107°51’30.09” E to 107°54’13.45” E and latitude of 7°9’12.52” S to 7°11’54.55” S. The base map of the study area is shown in Figure 1.2. For the land use development part, the study area has a total of 225 km^2. It lies at longitude of 107°49’10.50” E to 107°57’17.20” E and latitude of 7°6’28.08” S to 7°14’33.72” S. This difference is due to the low spatial resolution of satellite which is 30 m. However, the latter study area is only applicable in Chapter 5.

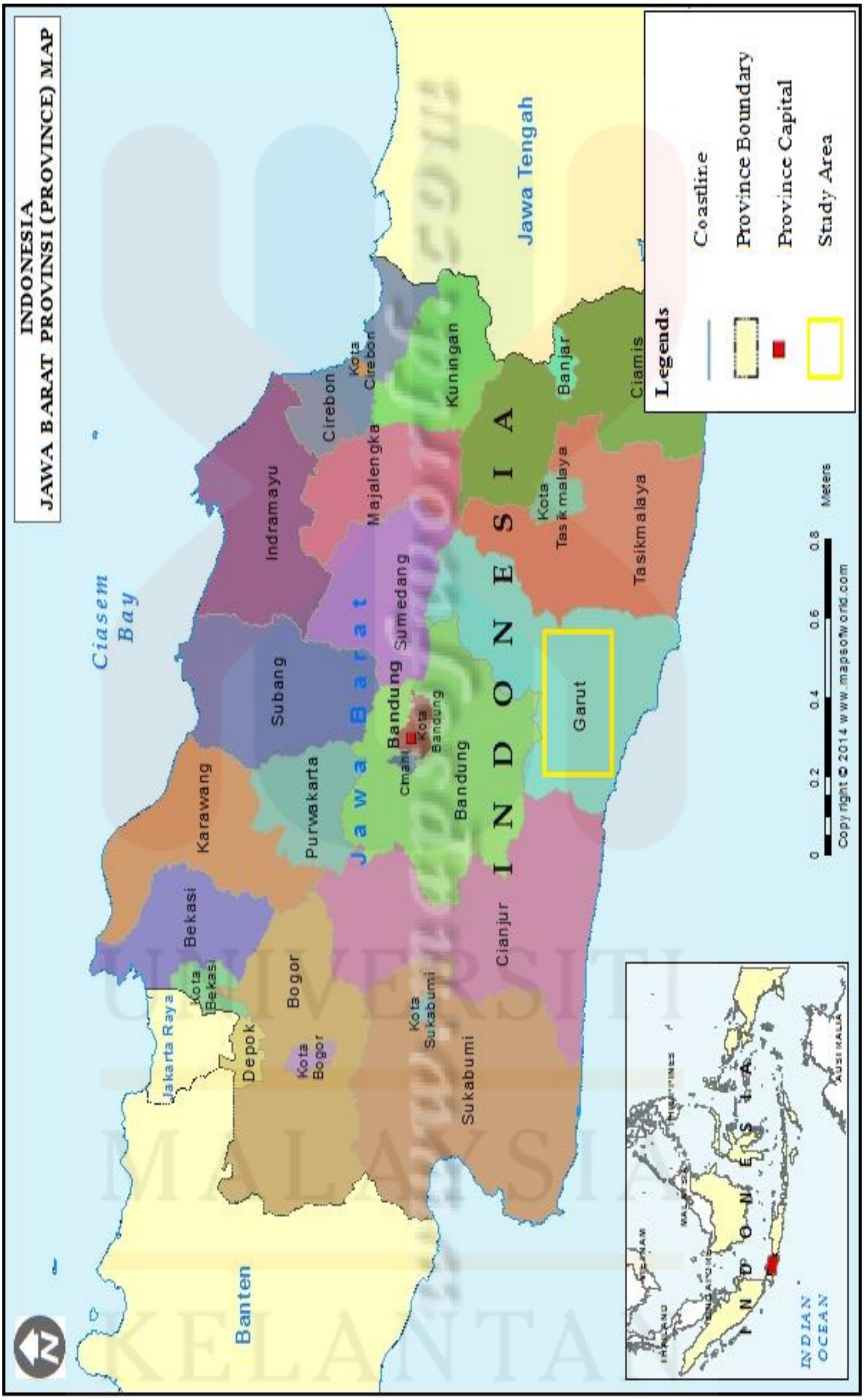

Figure 1.1 West Java, Indonesia (Source: Compare Infobase Ltd., 2014)

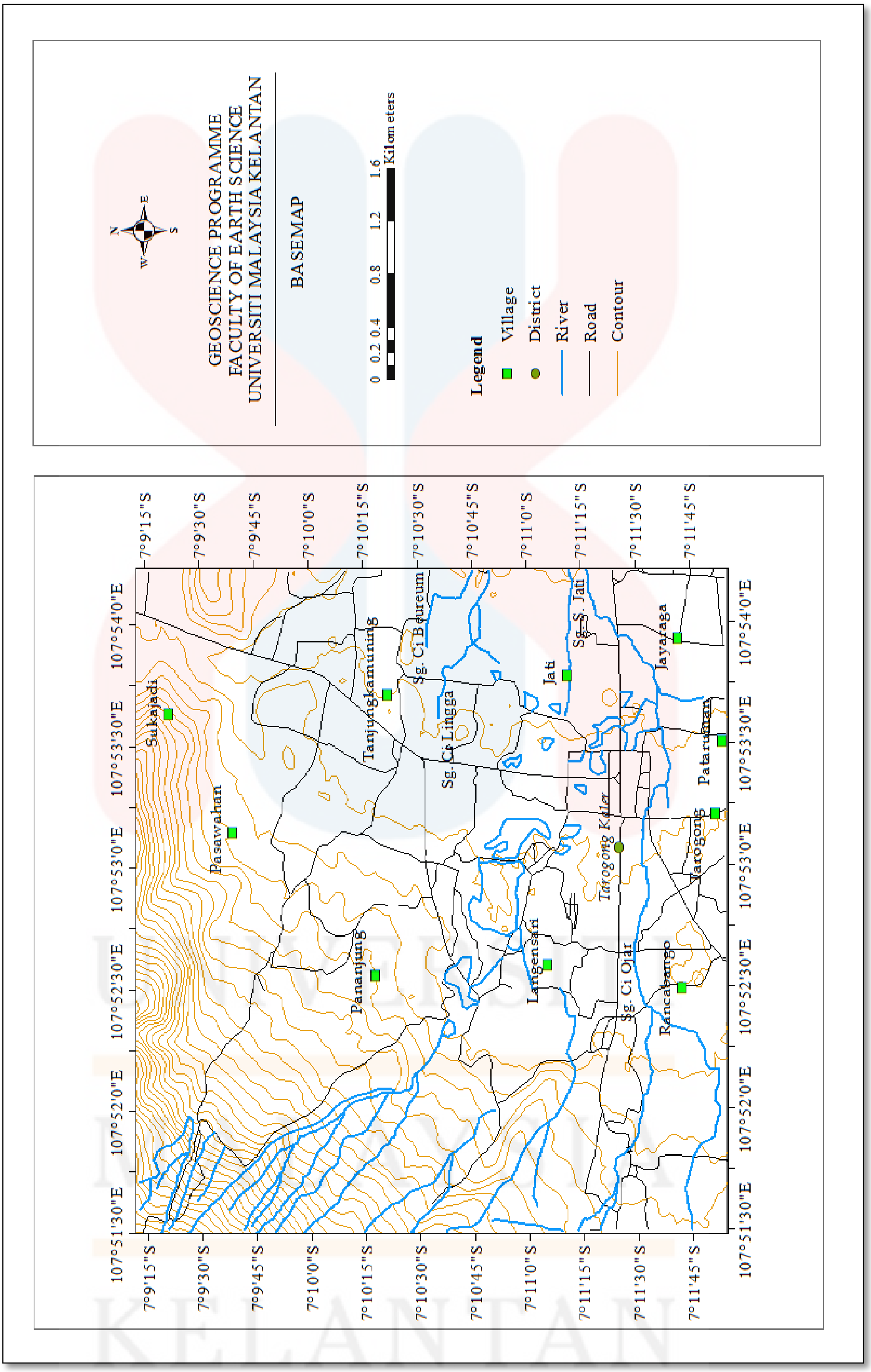

Figure 1.2 Base map of study area

1.4.1 Location

Administratively, Garut District is made up of 42 sub-districts and 421 villages. Tarogong area is one of the sub-districts. The District of Garut which has a total area of 306 519 km^2 is bounded by Bandung District and Sumedang District to the north, Tasikmalaya District to the east, Indonesia Ocean to the south as well as Bandung District and Cianjur District to the west. Geographically, it is located at 107° 25’ 08” E to 108° 07’ 30” E and 6° 56’ 49 ” S to 7° 45’ 00” S (Pemerintah Provinsi Jawa Barat, 2015).

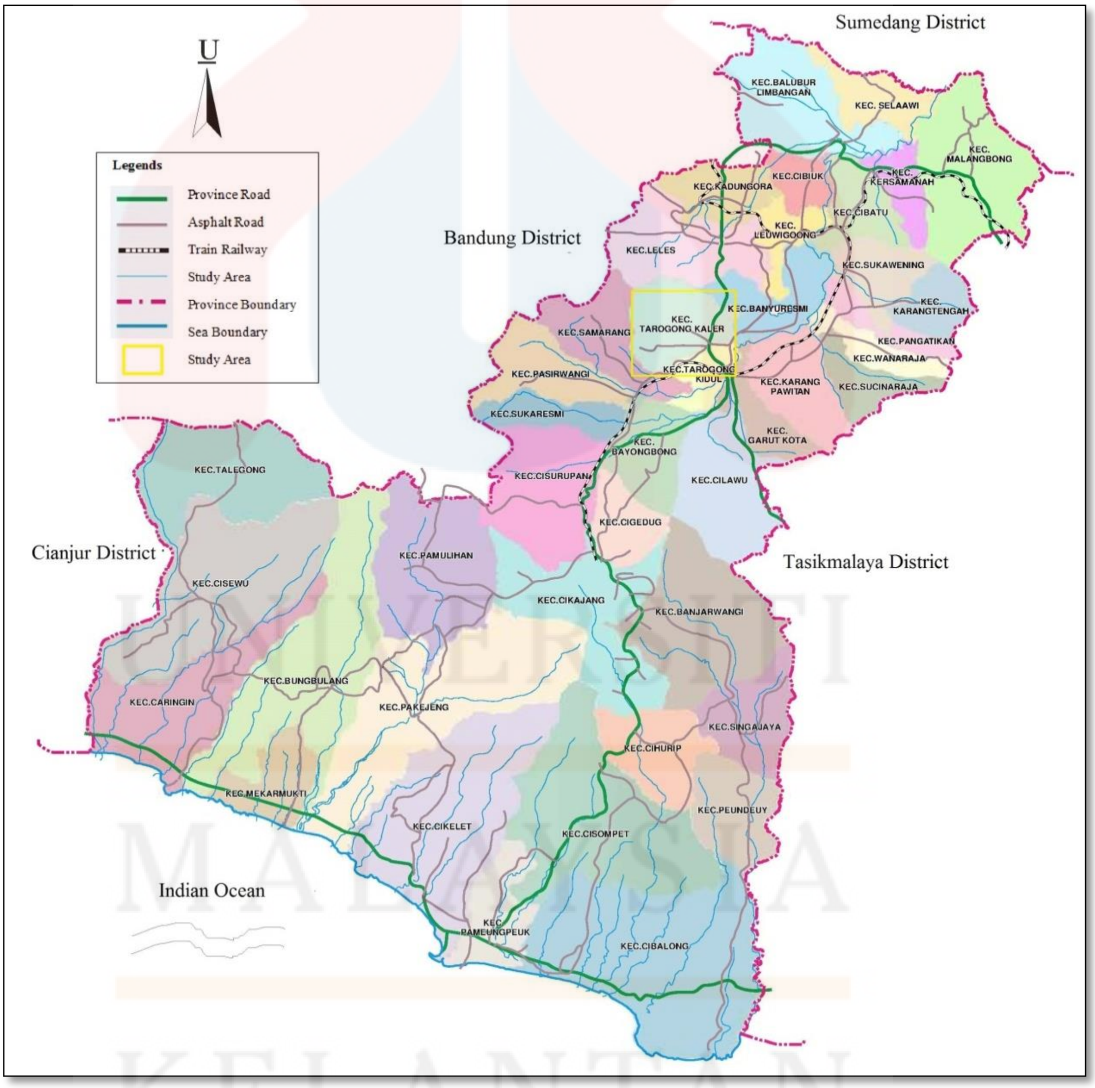

Figure 1.3 Administration map of Garut District (Source:Dinas Komunikasi Dan Informatika — Kabupaten Garut, 2015)

1.4.2 Demography

As of 2015, the District of Garut has a total population of 2 548 723 people occupying an area of 306 519 km^2. Table 1.1 is showing the people distribution in Garut District according to sex. The population consisted of men with a total of 1 284 817 people and women with a total of 1 263 906 people. Generally speaking, the total number of men is more as compared to women. Garut District has a population density of 832 people / km^2. The people distribution is showing increasing trend.

Table 1.1 People distribution in Garut District according to sex **(**Source**:** Badan Pusat Statistik Kabupaten Garut, 2016)

Year	**Population of men**	**Population of women**	**Total**	**Population density (People / km^2)**
2013	1 262 697	1 239 713	2 502 410	816
2014	1 274 098	1 252 088	2 526 186	824
2015	1 284 817	1 263 906	2 548 723	832

1.4.3 Rainfall

The climate in the District of Garut can be classified as wet tropical climate (humid tropical climate). The seasonal wind circulation patterns (monsoonal circulation pattern), the topography mountainous region in the central part of West Java and the elevation topography in Bandung are the three main factors influencing the climate and weather in Garut District (Pemerintah Provinsi Jawa Barat, 2015).

During rainy season, the moist air from the South China Sea and the western part of the Java Sea is carried by the constantly blowing wind from the Northwest.

On the other hand, during dry season, a relatively high temperature of dry winds is blowing from Australia on the South East (Pemerintah Provinsi Jawa Barat, 2015).

As of 2015, the highest precipitation is 100 mm in October while the highest average rainfall days are 15 days from October to December. The lowest average temperature is 22°C during the February and the highest average temperature is 32°C for five consecutive months from April to August.

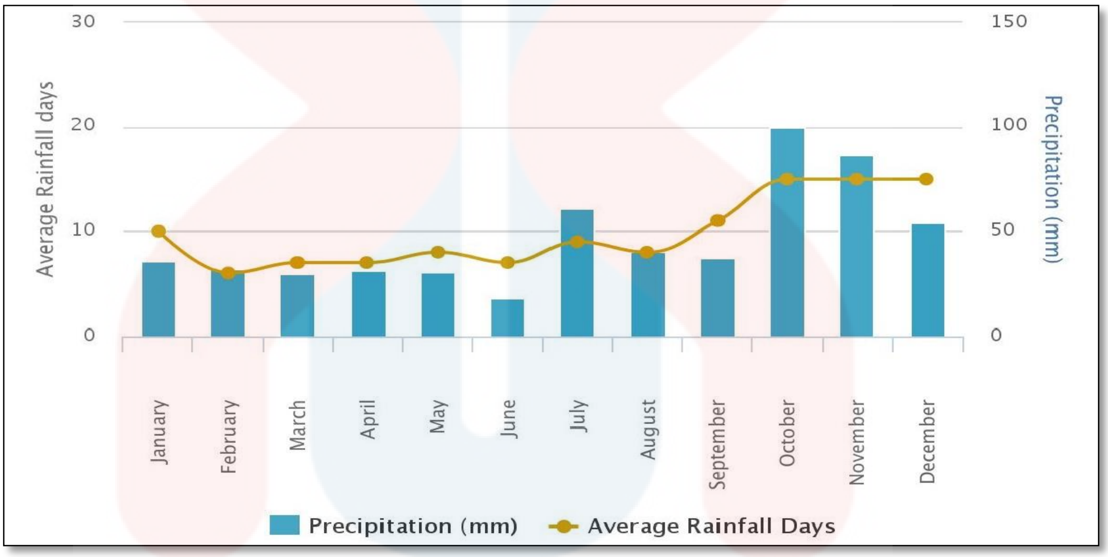

Figure 1.4 Average rainfall graph of Garut District

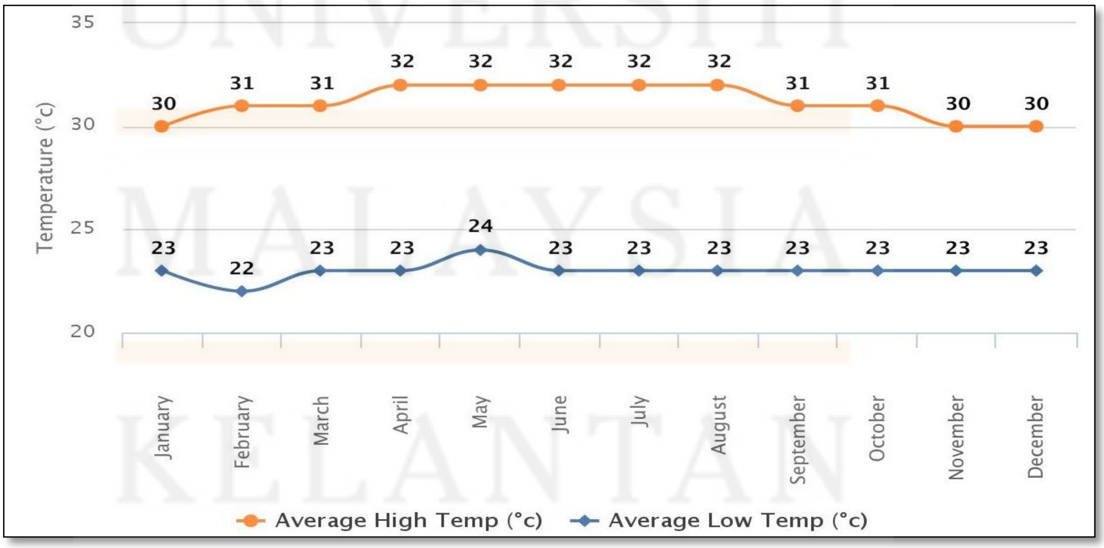

Figure 1.5 Average temperature graph of Garut District

1.4.4 Land Use

Garut District experienced significant growth especially during the third period in the year of 1940 to 1960's in the physical city development. This development can be seen in housing and population growth (Pemerintah Provinsi Jawa Barat, 2015). The latter affected the land use vastly in terms of vegetation with 22.02% and paddy field for irrigation and rain fed purposes with 13.06% and 3.20% respectively. The land is largely covered by woods with 26.76% of both forests and mangrove forests. The remaining percentage of land uses are in forms of estate, bushes, villages, buildings and others (Gunawan, 2015).

The main sources of vegetation in the District of Garut are rubber plantations and tobacco plantations as well as banana plantations (Badan Pusat Statistik Kabupaten Garut, 2016). The land use will be discussed further in Chapter 5.

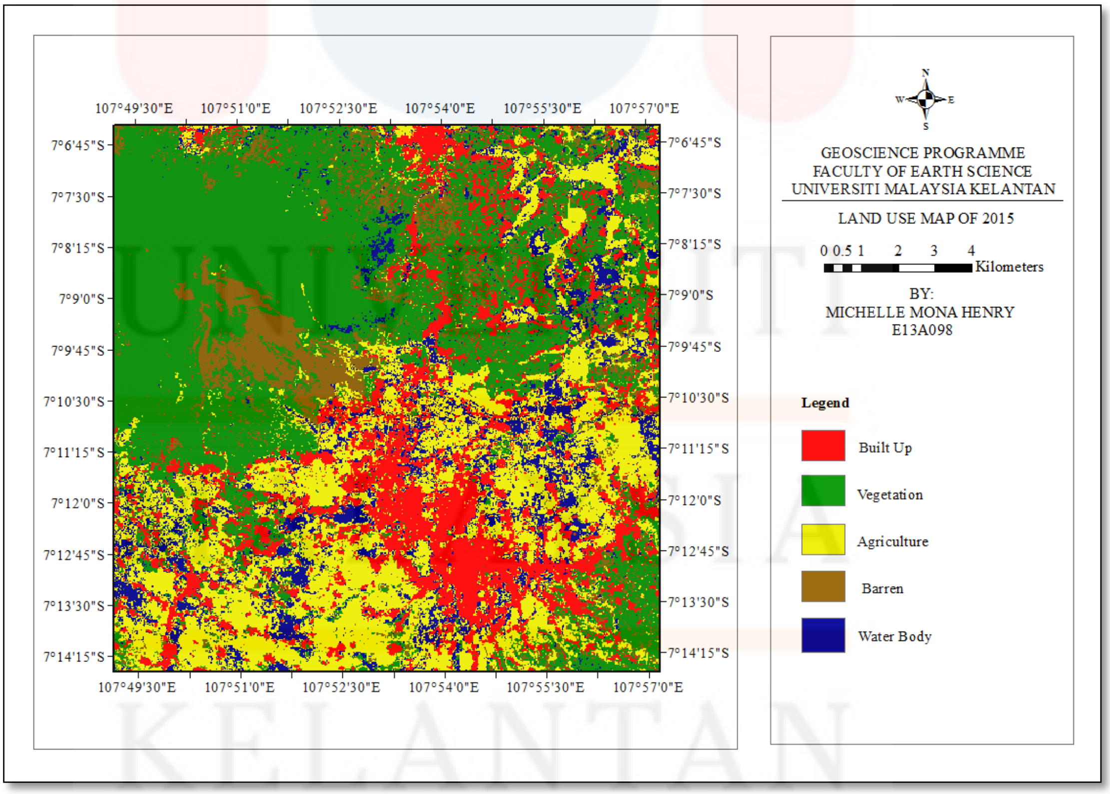

Figure 1.6 Map of land use

Figure 1.7 Building in Taragong area

Coordinate: 107°52'55.13" E 7°11'13.06" S

Figure 1.8 Paddy field in Taragong area

Coordinate: 107°51'48.42" E 7°11'38.22" S

1.4.5 Social Economic

As of 2013, the agricultural sector is still the prime mover in moving the economy of Garut District with a contribution of 44.04% in the gross regional domestic product which had a decrease of 1.92% as compared to 2009. The important role of agricultural sector is affected by comparative advantages such as relatively more fertile and suitable soil conditions for agriculture commodity and large population (Badan Pusat Statistik Kabupaten Garut , 2016).

With 26.62%, trading sector is one of the sectors that have a dominant contribution to the gross regional domestic product. It has a decrease of 0.04% in comparison of the year 2009. This is an indication from the rising volume of services and goods offered in Garut District. The trading sector is dominated by subsectors of wholesale and retail trading as well as hotel and restaurant (Badan Pusat Statistik Kabupaten Garut , 2016).

Figure 1.9 Trading market in Taragong area

Coordinate: 107°53'37.03" E 7°11'4.31" S

1.4.6 Road Connection/Accessibility

For land transport, road infrastructure and facilities is the key that influenced the speeding up of economic activities in Garut District. Further enhancement in the road quality and the road condition facilitate the mobility in expediting its activities so that the economic development of the society can be accelerated.

The total length of the road in the District of Garut is 402 292 km with 31 104 km of national road, 27 294 km of provincial road and 82 876 km of district road as well as 2 883 km of village road. A total of 4 254 687 m is made up of asphalt, 70 m is made up of concrete, 14 040 m is made up of gravel and 160 m is made up of soil (Pemerintah Provinsi Jawa Barat, 2015).

Figure 1.10 Road connection in Taragong area

Coordinate: 107°53’11.90” E 7°11’44.48” S

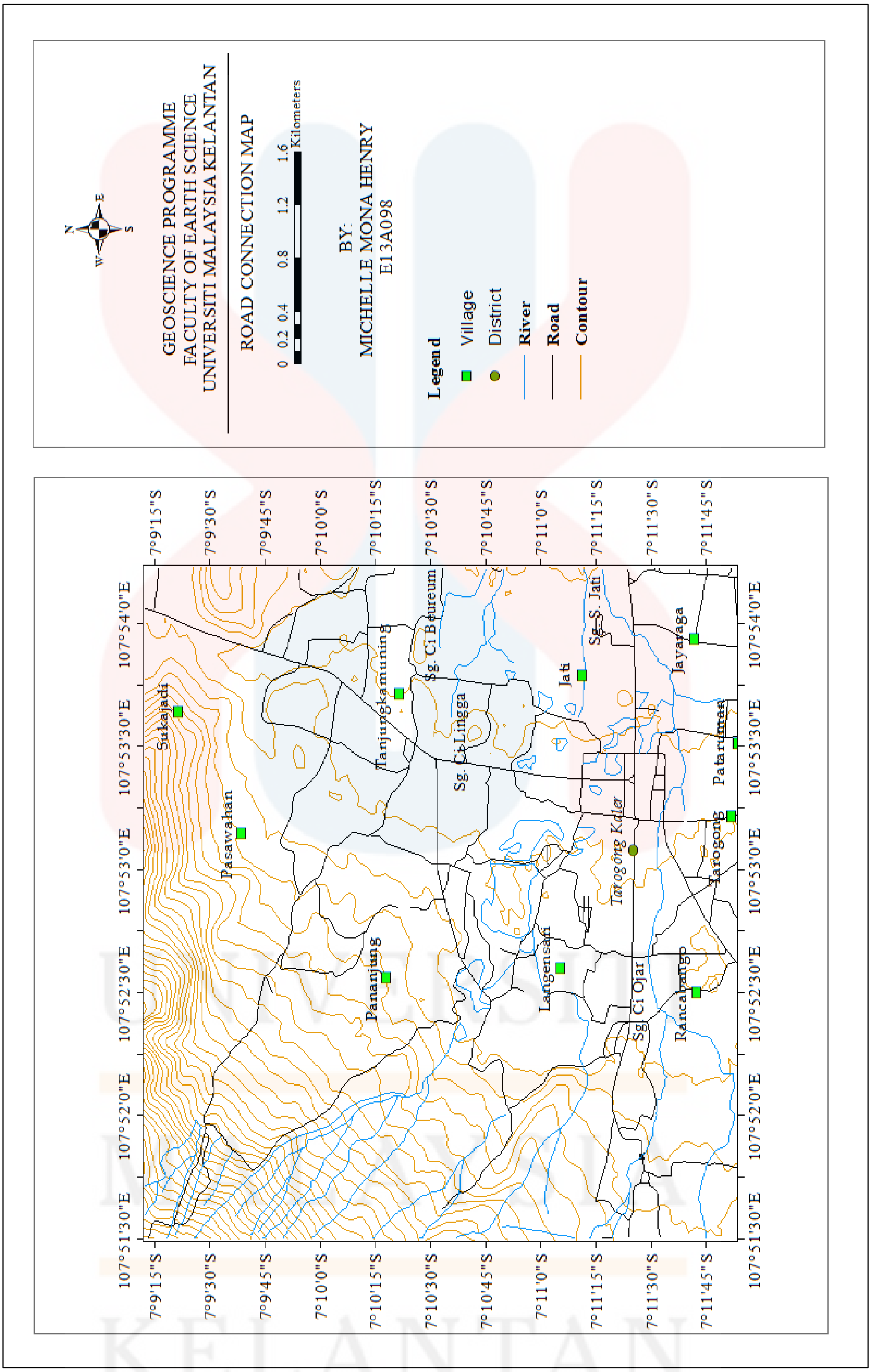

Figure 1.11 Road connection map of Tarogong area

1.5 Scope of the Study

Generally, this research covered a study area of 25 km^2. The study area is situated in Tarogong area in the District of Garut. This research was studying the general geology and focussing on the land use development of Tarogong area.

For the study of general geology, a geological mapping has been carried out in the mentioned study area. The general geology that was being study is geomorphology, stratigraphy, structural geology and petrography. This geological mapping was done with the aids of geological devices such as Garmin Global Positioning System (GPS) 62S, Brunton & Suunto compasses and geological hammer.

Furthermore, the research was focussing on land use development of Tarogong area using remote sensing analysis. The satellite image of Tarogong area was taken using Landsat 7 and Landsat 8. From there, the image was then processed using ER Mapper software to identify the geomorphology of Tarogong area.

1.6 Research Importance

By conducting this research which involved the basic geological mapping, a detailed and accurate general geological information such as geomorphology, stratigraphy and structural geology of Taragong area are provided not only to the local communities of the particular study area but also to future researchers. Moreover, an updated geological map on geography information such as land use and road connection is produced at the end of this research.

The land use development of Tarogong area is also be identified. This was done by using remote sensing analysis. A satellite image on Tarogong area was taken using Landsat 7 and Landsat 8. This then led to the production of the land use change in development map of Tarogong area. This research also a heads up for the future researchers who wish to do further study or research about the land use development on the study area and geological settings of the particular area.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter discussed about the literature review of the previous study that had been done before as well as other topics which are related to this research. The purpose of doing the literature review is to justify the proposed methodologies which serve as guidance within wider disciplinary aspects. Therefore, this chapter is covering the Geological Review which can be further divided in four sub-topics namely Regional Geology and Tectonic Setting, Historical Geology and Regional Stratigraphy as well as Structural Geology. The research specification of the study are covered too.

2.2 Regional Geology and Tectonic Setting

The structural configuration of Indonesian archipelago consists of highly complex pattern of continental blocks, active and extinct volcanic arcs, old and young ocean basins and subduction complexes Meanwhile, the backbone of West Java archipelago is a chain of subduction-induced volcano-plutonic arc in which most of them have a height of 3000 m high and interval about 80 km apart. Since West Java is situated at the southern part of Sunda Land of Eurasian plate, the oceanic American-Indian plate is overridden by this Eurasian plate at the north direction at N20°E and at the rate of 6 - 7 cm/yr in West Java area (Fauzi *et. al*, 2015).

As of today, the intrusion and deposited ‘Old Andesite’ volcanic arc that occurred since latest Oligocene – earliest Miocene along the Sunda Arc is following the South Coast (Southern Mountains). These activities of intrusions and depositions are caused by the plate tectonics movement of the active plate convergence. As a result, there are two subduction zones namely oblique subduction (western part of convergence) and frontal subduction (eastern part of convergence) on Sumatra and its adjacent area. The oblique subduction is on the side of Sumatra and its adjacent areas whereas the frontal subduction leads to the production of Java, Bali and Sumbawa Islands (Fauzi *et. al*, 2015) as shown in Figure 2.1. Generally, West Java region is at the transition between oblique subduction in Sumatra and frontal subduction at the eastern part.

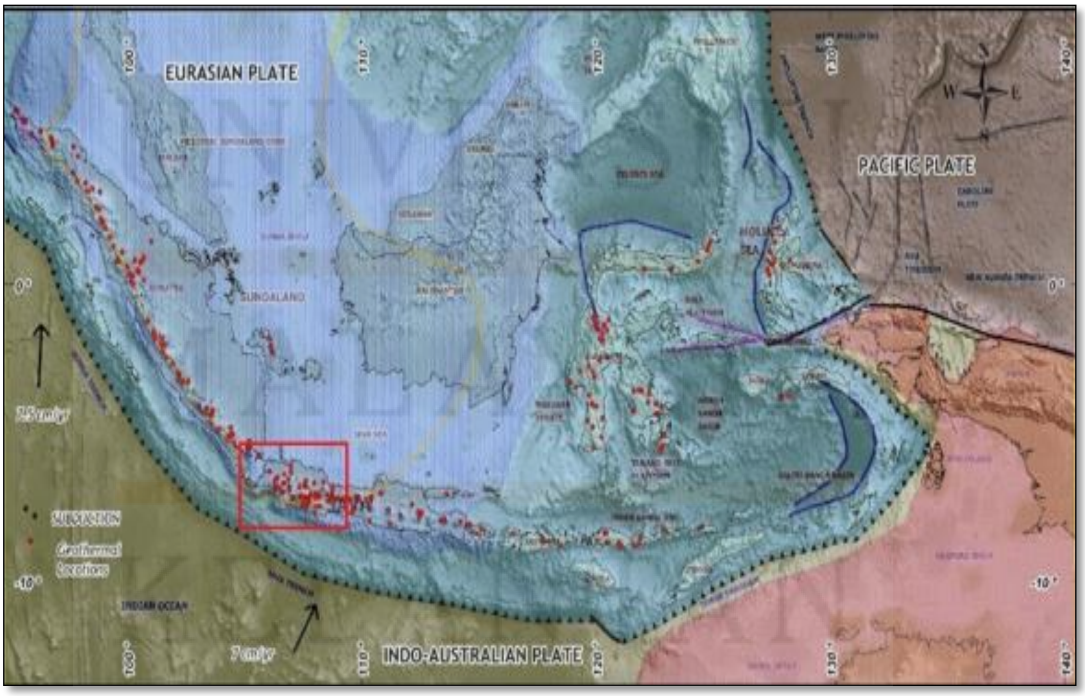

Figure 2.1 Present day tectonic setting of Indonesia (Fauzi *et. al*, 2015)

In general, the tectonic provinces of West Java can be subdivided into five tectonic provinces as follows: 1) Northern Basinal Area: A relatively stable platform area filled Eocene – Oligocene non-marine clastic and covered by Miocene and younger shallow sedimentary in North - South trending rift basins offshore and adjacent onshore. 2) Bogor Trough: Foreland basins composed of Tertiary deep water sediment gravity flow facies. Miocene and younger sediments mostly deeper water sediment gravity flow facies. Young East -West anticlines take place because of the recent northwardly compression. 3) Modern Volcanic Arc: Active andesitic volcanism affiliated to the process of Indian Oceanic Plate subduction of Indian Oceanic Plate underneath Sundaland Continent 4) Southern Slope Regional Uplift: Mainly made up of Eocene-Miocene sedimentary rocks including the Old Andesite Formation (OAF), structurally complex, North -South trending block faults, East - West trending thrust faults and anticlines and possible wrench tectonism. 5) Banten Block: In the most western part of Java can be split into three which are at the North area is the Seribu Carbonate Platform, Rangkas Bitung sedimentary sub-basin and at the South area is the Bayah High. Meanwhile, Ujung Kulon and Honje High as well as Ujung Kulon and West Malingping Low are located in the west part (Keetley, *et al*., 1997).

2.2.1 Stratigraphy

Based on the Regional Geological Map of Western Bandung with a scale of 1:500000 (Gafoer & Ratman, 1998), the geology of the western part of Java can be differentiated into four belts namely North Java Belt, Bogor Belt and Central Volcano Belt as well as South Mountainous Belt. The North Java Belt is formed by deposition of alluvium (river and sea sediment), limestone reef deposit and alluvium fan of Quaternary age. Besides that, the Bogor Belt is formed by sediments of

Tertiary age. The Central Volcano Belt is formed by volcanic rocks of Quaternary and Tertiary age. On the other hand, the South Mountainous Belt is formed by rocks of Quaternary, Tertiary and Pre-tertiary age.

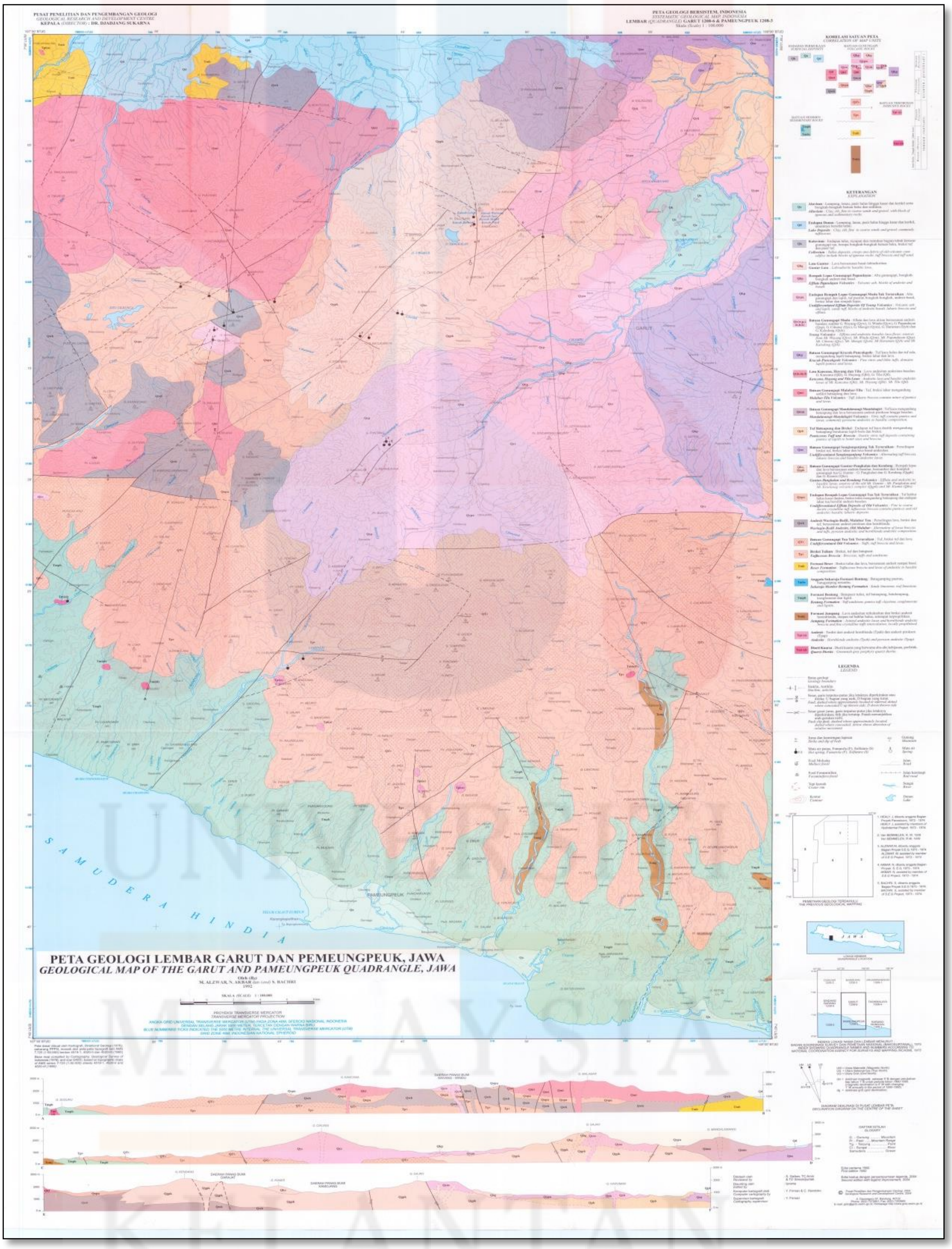

Figure 2.2 Geological map of Garut District (Scale 1:25 000) (Source: Alzwar, Akbar, & Bachri, 2004)

2.2.2 Structural Geology

Structural geology is the study of the three-dimensional distribution of rock units with respect to their deformational histories. The main goal of structural geology is to use measurements of present-day rock geometries to uncover information about the history of deformation (strain) in the rocks, and ultimately to understand the stress field that resulted in the observed strain and geometries.

The main geological structures of Java Island are the geanticline of South Java and the geosyncline of North Java. To the South of West Java, there is an extension of a complex belt of hills and mountains from the Djasinga area near the boundary of Bantam to the Permali River and Bumiaju in Central Java. The belt which is known as Bogor Belt is an anticlinorium of strongly folded Neogene strata with hypabyssal volcanic necks, stocks and bosses intrusions. Its western part extends West to East. Meanwhile, its eastern part extends West Northwest – East Southeast with a convex to the North and is crowned by young volcanoes like the Sunda Complex, North of Bandung (highest summit – Bukittunggul, 2 209 m), the Tampomas (1 684 m) and the Tijiremai (3 078 m) (Bemmelen, 1949) .

Based on a geological map prepared by (Mirzam & Masatsugu, 2012), folds, faults and joints are the geological structures that can be found in Garut District. The folds formed are trending in NW – ESE direction of Bentang Formation and NNW – SSE of Jampang Formation. The difference in the direction is caused by the different stages as well as the intensity of the tectonics. The faults found are of normal fault and shear fault which are trending in SW – NE. The faults are of young faults because there is rocks involvement from Tertiary and Quaternary age. Based on the pattern, the tectonic style originated from the distribution of North – South and are assumed to occur at least during Late Oligocene – Early Miocene period. Therefore, it can be presumed that those faults may be a part of reactivation of older faults. Generally, joints occur on older rocks such as the rocks and quartz diorite of Jampang Formation (Pemerintah Provinsi Jawa Barat, 2015) .

2.2.3 Historical Geology

A depressed zone called Bandung Zone is a longitudinal belt of intermontane depression. With a width of 20 – 40 km, this belt extends from the Wijnkoops Bay in the East, via the Tjimandiri Valley (with Sukabumi, 600 m), the upland plains of Tjiandjur (459 m), Bandung (715 m) and Garut (711 m) to the Tjitanduj Valley (with Tasikmalaja, 351 m) in the West and ends in the Segara Anakan of Central Java South coast. The Bandung Zone comprises the top part and North flank of the geanticline of Java (Bemmelen, 1949).

The subduction of Indian Ocean plate to the bottom of Southeast Asia plate has greatly influenced the tectonic processes in the District of Garut. The subduction which occurred during Late Oligocene – Early/Middle Miocene has generated andesite volcanic activities together with carbonate sedimentation in shallow marine environment. The sedimentation ended the magmatic activities with intrusion of quartz diorite during late Middle Miocene and hence, causing the alteration on the Jampang Formation (Pemerintah Provinsi Jawa Barat, 2015).

After the process of folding and removal as long as erosion, volcanoes are created in accordance with the magmatic activities. During Plio Pleistocene period, volcanoes' activities continued and followed by a chain of volcanic activities of Early Quaternary. These volcanic activities are widely spread in central and northern part of Garut District (Pemerintah Provinsi Jawa Barat, 2015).

2.3 Research Specification Review

Raharjo, Gunawan, & Hadi (2016) had conducted a research on the knowledge-based analysis on medium resolution images of remote sensing to extraction information land use type SCS-CN. The research was conducted in the Grompol watershed located in Karanganyar, Central Java. Various types of data such as Landsat-5 (1994), Landsat-8 (2013), RBI map, scale 1:25000 (2000), geological maps, scale 1:100000 (1992), soil map, scale 1:250000 (1966) and data analysis laboratory tests had been used in this study. Remote sensing imagery Landsat-8 has good temporal resolutions and can be used to identify the type of land cover as well as it is easy to retrieve data. Landsat-8 (2013) has been georeferenced well which corrects L1T. By using the control points for the accuracy of Digital Elevation Model (DEM) topography, the correction is showing the radiometric correction and geometric correction systematically.

Furthermore, according to the research done by Rawat & Manish (2015) on monitoring land use/cover change using remote sensing and GIS techniques in Hawalbagh block, district Almora, Uttarakhand, India, the landscape dynamics can be understood by using multi-temporal satellite imagery. The changes in the Hawalbagh block over a period of 20 years using Landsat satellite were acquired by Global Land Cover Facility Site (GLCF) and earth explorer site. Supervised classification methodology has been employed using maximum likelihood algorithm (MLC) technique in ERDAS 9.3 Software with remote sensing image data. A post-classification detection method was conducted to perform land use/cover change detection. A pixel-based comparison was used to produce change information on pixel basis.

Cross-tabulation of two different decade data were compared to determine qualitative and quantitative aspects of the changes from 1990 – 2000.

Other than that, application of GIS and remote sensing technique had been used by Adewumi, *et al*. (2016) to change detection in land use/cover mapping of Igbokoda, Ondo State, Nigeria. Three satellite images for three different periods 1986, 1999 and 2013 were used to produce a land use/cover map classification. The Landsat images were analysed using change detection technique (NDVI differencing) along with SRTM 90 m DEM to generate the extent of the changes that have occurred. In this study, Landsat 5 (TM), Landsat 7 (ETM+) and Landsat 8 (LC) imageries are used. Landsat 5 with Thematic Mapper (TM) feature has better spatial and spectral resolutions that enable the satellite to capture image from a wider view. Landsat 7 with Enhanced Thematic Mapper plus (ETM+) has an additional eight band known as panchromatic band with 15 m spatial resolution and responds spectrally from the green through the near infra-red region of the wavelength of the electromagnetic spectrum.

Lastly, a research on the geology of Mt. Guntur, Garut District was conducted by Saepuloh, Sumintadireja, & Suryantini (2004) employed the analysis and interpretation of ASTER image (Advance Spaceborne Thermal Emission and Reflection Radiometer). The flow impression on ASTER image was used to characterize the Guntur products and was distinguished by outer Guntur products that show sculpture impression. Near the crater, the bright tone in TIR (Thermal Infrared Radiometer) band which associated with thermal activities is caused by fumaroles. On the other hand, the bright TIR tone found in pyroclastic flow is caused by the emittance from silica rich materials. Gunung Putri fault appears as bright red hue lineament trending in NW – SE direction in ASTER band 3-2-1.

CHAPTER 3

MATERIALS AND METHODOLOGY

3.1 Introduction

Materials are the things used in order to conduct the basic geological mapping and to perform thin section as well as to carry out the remote sensing analysis for analyzation of data whereas methodology is the techniques which were carried out to obtain the data and result for the research project.

This chapter discussed about the workflow of the study comprising the preliminary research, field study, laboratory investigations as well as data analysis and interpretation. Lastly, report writing was the last step in which all the findings, data and results were obtained and discussed. This final year project is divided into two general sets namely the geological mapping of the study area and the remote sensing analysis of land use development. For geological mapping, the general geology mapping was done during site visit where interpretations of the outcrops were done to study geology of the area.

3.2 Materials

The materials that were using in this project can be divided into two which are materials for basic mapping and materials for thin section.

For basic geological mapping, the materials used are base map, global positioning system (GPS), compass, hand lens, hydrochloric acid (HCl), geological hammer, measuring tape, sample bags, camera and field notebook. For thin section, the materials used are polarizing microscope, glass sides, grinder and thermoplastic cement.

Table 3.1 Materials for basic geological mapping

No.	Materials	Uses
1.	Base map	It is a spatial model that is developed from Geographic Information System (GIS) characterized by large-scale detail and quantitative representation of relief.
2.	Global positioning system (GPS)	It is a space-based navigation system that provides location and time information in all weather conditions, anywhere on or near the Earth where there is an unobstructed line of sight to four or more GPS satellites. This equipment is used in geological field mapping for marking ones position, mapping lithology, traversing and others.
3.	Compass	It is an instrument used for navigation and orientation that shows direction relative to the geographic cardinal directions or "points".
4.	Hand lens	It is a tool used to closely examine rocks, sediments, soils, sand, minerals and other materials with tiny features during field by magnifying them before further analysis is performed in the laboratories.
5.	Geological hammer	It used for splitting and breaking rocks. In field geology, they are used to obtain a fresh surface of a rock to determine its composition, nature, mineralogy, history and field estimate of rock strength.
6.	Sample bags	It is usually a water-proof zipper-lock bag. In geological field mapping, sample bags are used to place the collected rock samples inside it.
7.	Camera	Camera is an electronic device used in geological field mapping to photograph the images of the outcrops and other features of the surrounding areas in the locality.

10.	Field notebook	Field notebook is used to jot down all the information and data obtained from the field. All important observations must be written down in a concise, orderly and legible manner.

Table 3.2 Materials for thin section

No.	Materials	Uses
1.	Polarizing microscope	Polarizing microscope which is also known as polarized light microscopy is used to determine the optical properties of the minerals.
2.	Glass slides	It is a long thin piece of glass in which specimens are placed or secured (“mounted”) on for observation under a microscope in laboratories. The glass slides are held in.
3.	Grinder	Any of various power tools or machine tools used for grinding that uses an abrasive wheel as the cutting tool. Each grain of abrasive on the wheel's surface cuts a small chip from the work piece via shear deformation.
4.	Epoxy	Epoxy is best known as a type of durable glue that provides a high level of bonding properties that are far superior to most ordinary paste style glues. It is used to securely bind a various kinds of materials, metals and woods.

3.3 Methodology

The methodology used in this research can be divided into preliminary research, field studies, laboratory works as well as data processing and data analysis and interpretation.

3.3.1 Preliminary Studies

Preliminary research is an early study and serves as an important connection between pre-writing and preparing a thesis. It is often done before going to site visit by studying related data and information from previous thesis, journal, article and other resources. The goal of the preliminary research is to narrow things down on a relevant scope for the title of the research project. Furthermore, preliminary research also permits the writer to change his mind about the intended topic before too much time and effort are committed to the process.

3.3.2 Field Studies

Field study was conducted for collecting primary data using suitable method to fulfil the research objectives. The geological mapping was carried out in the field of study area. The geological mapping involved looking for outcrops and geological structures. All relevant information and data about the lithology, structural geology and geomorphology of the study area were collected. All the data was collected and analysed before the geological map about the area can be produced.

The lithology is the types of rock units existed in the study area. The rock samples were taken to perform thin section in order to check the lithology of rock units present in the study area.

Besides that, structural geology is the study of the three-dimensional distribution of rock units with respect to their deformational histories. Some typical examples of structural geology are fracture, bedding, fault and such.

Lastly, geomorphology is defined as the study of landform and the processes that create the landforms. The geomorphology of the particular area enables us to know the regional geologic past history.

a) Sampling

The aim of sampling is to identify the bedrock underneath the study area. The rock samples were taken using the geological hammer upon the discovery of any outcrops either from the outcrop, sub-crops or floats that can be found in the area of study. They were then labelled according to the locations where the samples were found by using Global Positioning System (GPS). The samples must be of fresh rocks as weathered rock samples will give invalid data. It is very important to do sampling to differentiate one bedrock from other bedrocks. Although the types of rocks found in different locality are the same, they might be varying in terms of mineral composition. The rock samples were analysed using hand lens before being sent to the laboratory for further analyzation.

3.3.3 Laboratory Work

After the site visit and field work was done, laboratory investigations which consisting of sample preparation and sample analysing were conducted. The collected rock samples were sent to the laboratory for sample preparation and further analyzation. For the sample preparation, the thin section of the rock samples was produced. For sample analyzation, the produced thin section was analysed under the polarizing microscope.

a) Thin Section

Mineralogy is the study of physical properties, chemistry and crystal structure of mineral. Classification of mineral, geographical distribution, utilization process of mineral origin and formation are the examples of detailed studies in mineralogy.

The thin section of the rock samples were used to identify the minerals and rocks under an optical polarizing microscope. Therefore, the thin section slides are required to study the properties of the rock samples. Polarizing microscope was used to determine the optical properties of the minerals. The steps in the preparation of thin section include sectioning, vacuum impregnation, girding, cementing, re-sectioning, grinding and polishing.

Firstly, cutting. A small section of chip-sized from the rock sample was cut by using the diamond saw of Petro-cut machine. Secondly, grinding. The rock chip was mounted on a grinder to smoothen the surface on the rock chip's side. Thirdly, lapping. The rock chip was lapped on a piece of glass (75 mm x 25 mm) with the aid of carborundum powder to smoothen the surface perfectly of flat surface. Carborumdum powder is an abrasive composed of silicon carbide crystals. Next, mounting. The rock chip was mounted onto a thin glass slide using Canada Balsam on a hot-plate with the temperature approximately of 120°C. This was done after the surface had been polished. After that, trimming. The rock chip was trimmed down to get a thin rock slide using Petrothin machine. Moving on, grinding. Second grinding is required to minimize the thickness of the rock sample to obtain a very think rock slide. Second lapping was done until it is only 50µm in order to get a thickness between 20µm to 30µm with a final polish. Last but not least, a cover glass was cemented on top of the rock sample slide by ensuring there is no air bubbles trapped in between of those two glass slide.

3.3.4 Data Processing

A number of software has been used in order to achieve the research objectives mentioned earlier in Chapter 1.

a) MapInfo

MapInfo is a software with a full-featured computer mapping and geographic information system (GIS) that provides a rich set of tools and advanced options for processing geography and topology data and creating detailed graphical representations, maps and reports. It is used for mapping and location analysis by allowing users to visualize, analyse, edit, interpret, understand and output data to reveal relationships, patterns, and trends. MapInfo also allows users to explore spatial data within a dataset, symbolize feature and create maps. To name a few, the base map was created using MapInfo.

b) Global Mapper

Global Mapper is a geographic information system (GIS) software that offers access to an unparalleled variety of spatial datasets and provides just the right level of functionality for anyone who works with maps or spatial data. Global Mapper handles vector and raster data as well as elevation data. It provides viewing, conversion and other general GIS features. Global Mapper has built in functionality for distance and area calculations, raster blending, spectral analysis, contrast adjustment, elevation querying as well as advanced capabilities like image rectification, contour generation from surface data and many more. The 3D topography map of Taragong area was projected using this software.

c) ENVI

ENVI which stands for ENvironment for Visualizing Images is a premier software application used to process and analyse geospatial imagery such as multispectral, hyperspectral, LiDAR and SAR. It stacks together a number of scientific algorithms for image processing by combining the latest spectral image processing and image analysis technology to help you get meaningful information from imagery. ENVI offers a robust suite of image processing and analysis tools to support your image exploitation workflows and integrate with GIS software. The datasets from satellite imageries of Landsat 7 and Landsat 8 were imported to ENVI version 5.1 to conduct land use/cover classification under supervised classification by using Maximum Likelihood Classification (MLC) method. Thus, the land use map of 2005 & the land use map of 2015 as well as the built up, agriculture, vegetation, barren and water body maps were generated using this software. Not forgotten, the statistics and data were projected using the same software too.

d) ArcGIS

Arcgis software was used to produce various maps in the study area. By using this software, a digitized base map was produced. A software known as dnrgps was used to transfer the data from Global Positioning System (GPS) to Arcgis in order to produce the map with the available relevant data such as the location data in which the outcrops were found and the attribute data. It is used to present the arrangement of different features and types of lithology as what had been found and observed during the site visit and the done field work. The lithology, geological, drainage and traverse maps were generated using ArcGIS software.

3.3.5 Data Analysis and Interpretation

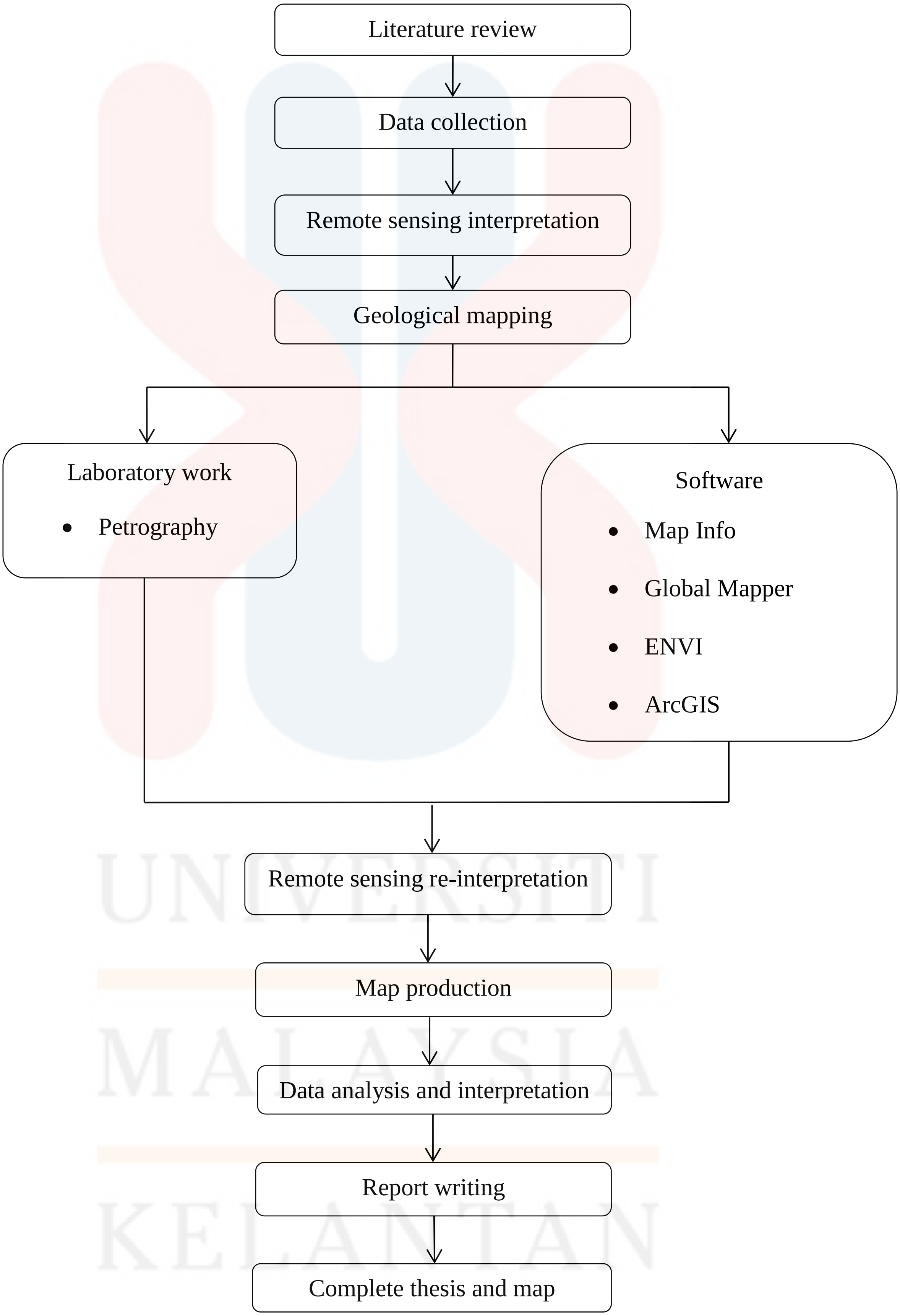

Figure 3.1 Research flowchart

CHAPTER 4

GENERAL GEOLOGY OF TARAGONG AREA

4.1 Introduction

General geology is the study of many parts of the geology in an area. In this chapter, the general geology of Tarogong area, Garut is divided into geomorphology, stratigraphy and structural geology as well historical geology. All of these aspects play important role in helping us to have a better understanding of the events and changes that had happened in the study area.

Tarogong area of Garut is located at longitude of 107°51’30.09” E to 107°54’13.45” E and latitude of 7°9’12.52” S to 7°11’54.55” S. Garut District is made up of 42 sub-districts and 421 villages. This area is accessible by road with a total length is 402 292 km of national road, provincial road, district road and village road. During mapping, both the main road and village road are traversed by using motorcycle and walking.

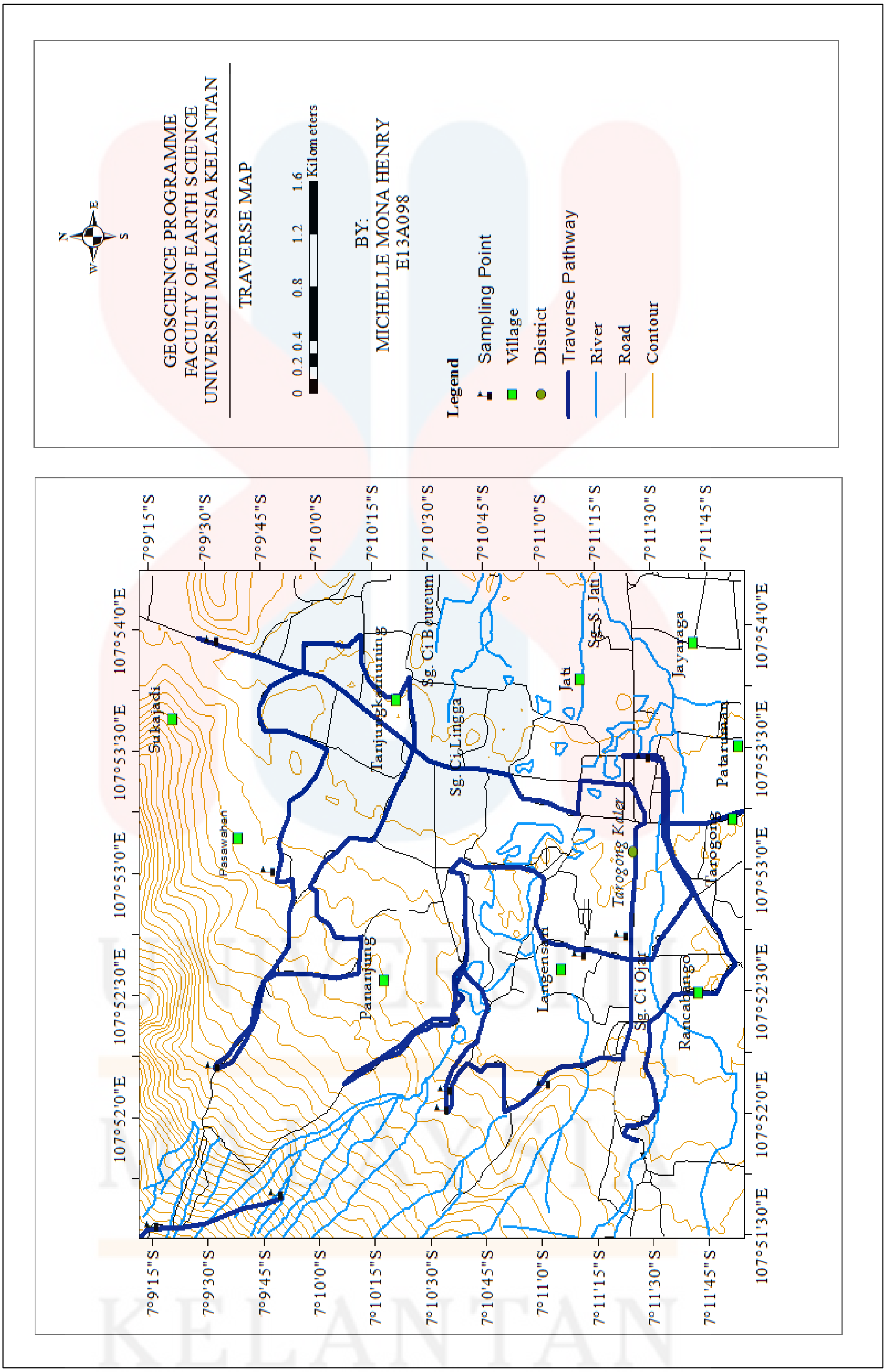

Figure 4.1 Traverse map

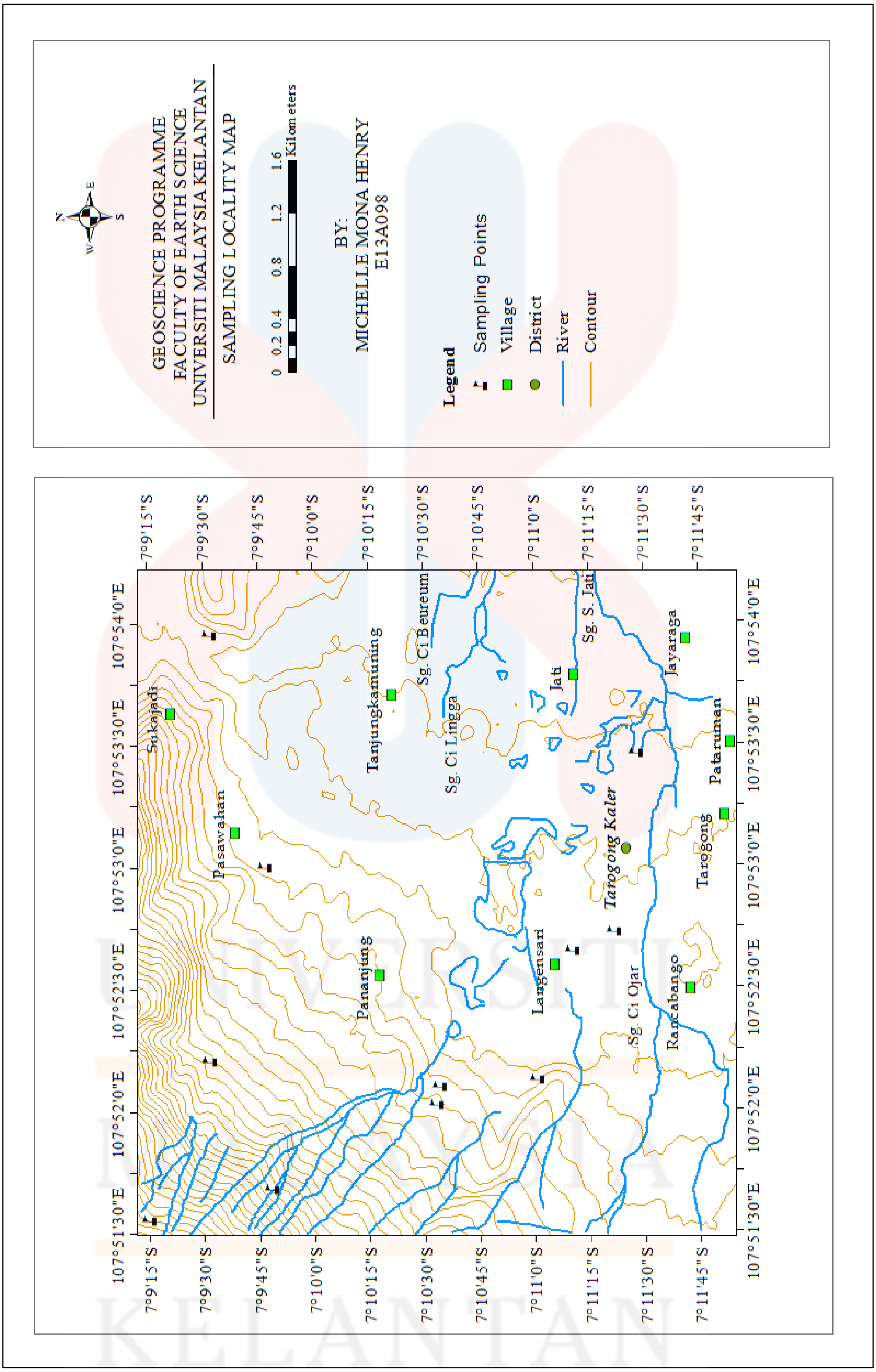

Figure 4.2 Sampling locality map

4.2 Geomorphology

Geomorphology is defined as the study of landforms and its processes related to the origin and revolutions which deals principally with the topographical features of the Earth's surface. It is related with the understanding the form of surface of Earth that have happened at the recent day and the past. The structure, process, slope and drainage system are the basic elements of geomorphology.

The geomorphology of Tarogong Kaler, Garut can be divided into five geomorphologic units which are old volcanic, undulating plains, Gunung Cikakak, Gunung Katomas and Gunung Putri, peak of Gunung Guntur and hillside of Gunung Guntur (Bronto *et al.*, 1982).

The old volcanic zone is made up old volcanic rock particularly lava. The geomorphologic unit comprises of Pasir Beling, Gunung Cakra, Gunung Gandapura, Gunung Gajah and Pasir Malang on the west, Gunung Batususun and Gunung Agung on the north as well as Gunung Picung and Pasir Cileungsing on the east. It has an elevation of 1 000 m – 2 000 m above sea level and a steepness of 25°.

On the other hand, the undulating plain which has been used as the agricultural and settlement area is the largest geomorphology unit occupying the Guntur Complex. The morphology in the west side is bumpier as compared to that of the east side. It consists of old lava, pyroclastic deposits and also sludge of old volcanic lava products. It has an elevation of 600 m - 900 m above sea level and a steepness of 5°.

The southern part is filled with geomorphologic unit of Gunung Cikakak, Gunung Katomas and Gunung Putri and thus creating cones. These cones are said to be of volcanic parasites. The cones have the elevation of 750 m – 1 425 m above sea level and a steepness ranging from 10° - 25°.

Next, the area around the peak of Gunung Guntur is also one of the geomorphology of the study area. Gunung Guntur, Gunung Parukuyan, Gunung Sangiang Buruan, Gunung Geulis and Gunung Masigit occupy the area as the centre of volcanic activities. Among them all, although the other mountains have fumaroles emitting sulphurous gases, only Gunung Guntur has an inactive circular crater of 300 m – 350 m and a depth of 300 m at 84°C - 92°C. These fumaroles caused an alteration of rocks in the surrounding area. The peak of this unit is located at 1 750 m – 2 249 m above sea level.

Lastly, the hillside of Gunung Guntur. This unit is made up of fresh deposits such as lava flows, pyroclastic flows and pyroclastic falls. The dominant lava flows created the hillside. The pyroclastic flows of fan-shaped can be found on the east part of the hillside whereas the pyroclastic falls can only be found in the upper part of the hillside. The elevation of the hillside is of 700 m – 1 750 m above sea level and it has a steepness ranging from 10° - 30°.

4.2.1 Topography

Topography by means of physical featuresis the study about the detailed map of the surface features on the land. It includes the mountain, hills, creeks, and other bumps and lumps on a particular hunk on earth. By elevation means, the topographic unit can be divided into five units (Hutchison & Tan, 2009).

Table 4.1 Topographic unit based on mean elevations (Source: (Hutchison & Tan, 2009))

Class	Topographic Unit	Mean Elevation (m above sea level)
1	Low lying	<15
2	Rolling	16 – 30
3	Undulating	31 – 75
4	Hilly	76 – 300
5	Mountainous	>301

The study area covers 25 km^2 of Tarogong area, Garut. In the study area, the highest elevation is 1 450 m, located at northwest part while the lowest elevation is 700 m, located at the east part. Hence, it can be said that the study area has an elevation ranging from 700 m – 1 450 m. Based on the Table 4.1, the study area falls under mountainous area as the topographic unit as the elevation is >301 m above sea level.

Furthermore, the steepness of the study area is affected by the elevation of the contours. The closer the line between the contours, the steeper the slope is. On contrary, the further the line between the contours, the less steep the slope is. In the northwest part of the study area, steep slopes are formed whereas less steep slope is formed at southeast part of the study area.

In Figure 4.3, the geomorphologic unit of Gunung Cikakak, Gunung Katomas and Gunung Putri are not labelled as they are located outside the box of my area of study.

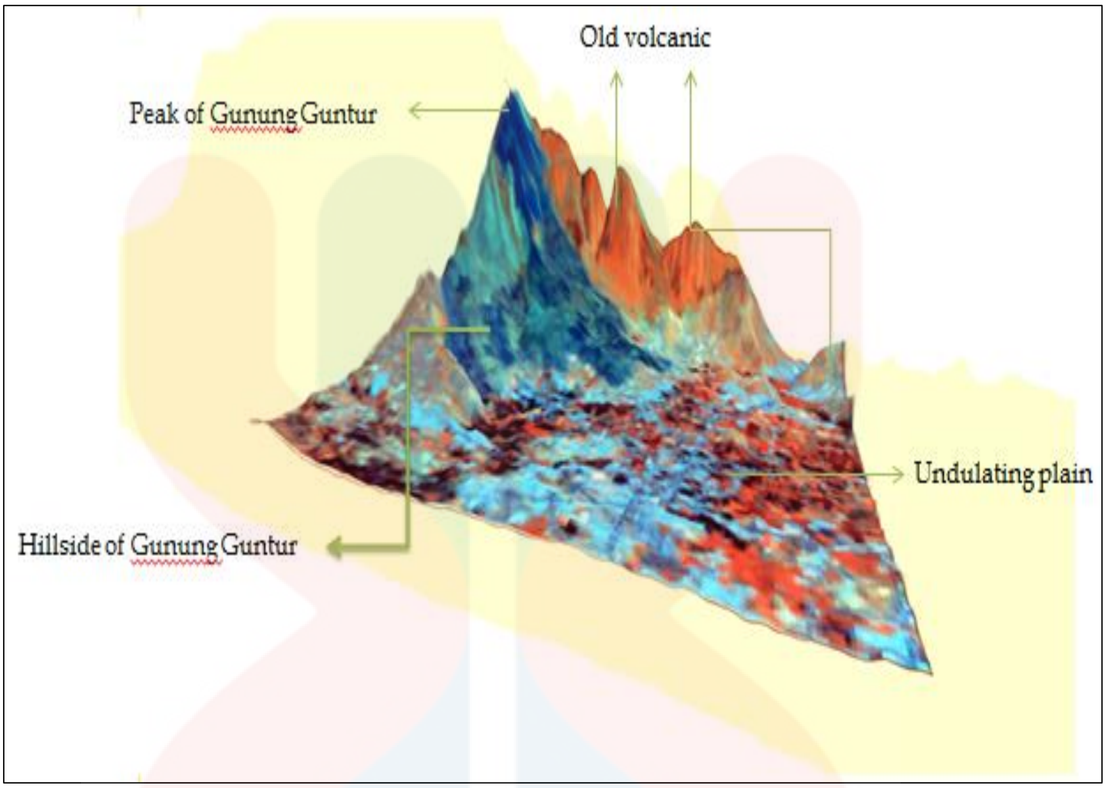

Figure 4.3 3D Topographic Map of Taragong area

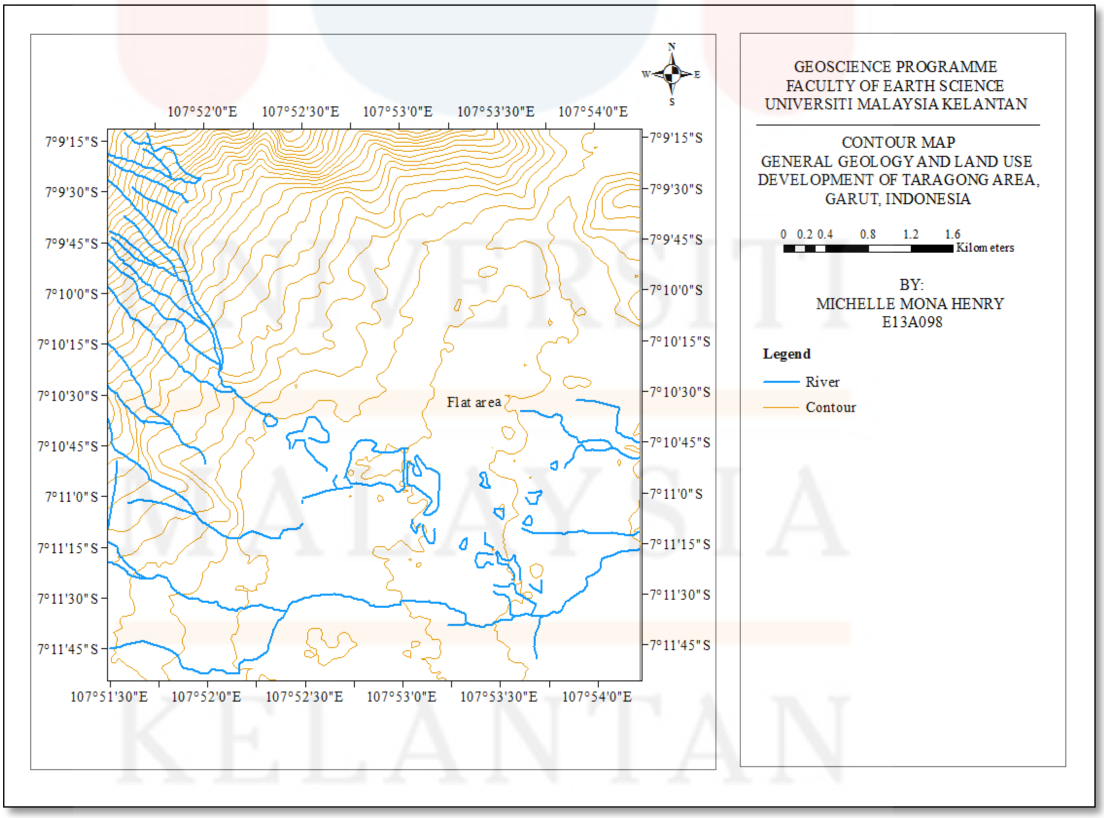

Figure 4.4 Contour Map of Taragong area

4.2.2 Drainage System

By definition, drainage system is the pattern produced by the streams, rivers and lakes in the drainage basins. These drainage systems are controlled by local geologic factors such as land inclination and land topography in terms of rock hardness of a particular area. Their forms and textures are used as the basis in categorization of the drainage patterns. The development of the drainage channels occur when the surface runoff is intensified and the Earth materials are least resistant to erosion. The texture is administered by the soil infiltration and the availability of the water volume to enter the surface in a given time frame. On ground level, soil with limited capacity of infiltration will cause small amount of water to be soaked in into the surface rather than be evaporated. However, when large amount of water strikes, more water will dissipate and soak in. This excess water is known as runoff in ground with sloped surfaces. In the event where the soil infiltration capacity is high, the development of the drainage channels are less.

In the area of study, there are four types of drainage patterns that can be observed namely dendritic, parallel and rectangular as well as deranged. A dendritic drainage pattern which looks like a branching tree is the most common form of drainage system. This randomly developed pattern is composed of branching tributaries of the main river. It is characterized by impervious soils ad relatively homogeneous rocks. Thus, there is no apparent control over the direction of the tributaries as the subsurface geology has a similar resistance to weathering.

A parallel drainage pattern is characterized by major streams which are straight with few tributaries drifting in the same direction caused by surface with steep slopes. The tributaries streams tend to stretch out in a parallel-like following the surface's slope. They usually join the main stream at approximately the same angles. Sometimes, a parallel drainage patter is an indicator of gently dipping beds or uniformly sloping topography.

Furthermore, rectangular drainage develops on rocks that are resistance to erosion. The streams follow the path of least resistance and thus are concentrated in places were exposed rock is the weakest, eventually developing streams along the paths. The result is a stream system of straight line segments at sharp bends and tributaries join larger streams at right angles.

Last but not least, a deranged drainage pattern is a poorly defined drainage system resulting from a high water table and a flat or gently undulating topographic surface. Also known as contorted drainage pattern, this tributary streams occurred in area of geological disruption with no coherent pattern to the rivers and lakes.

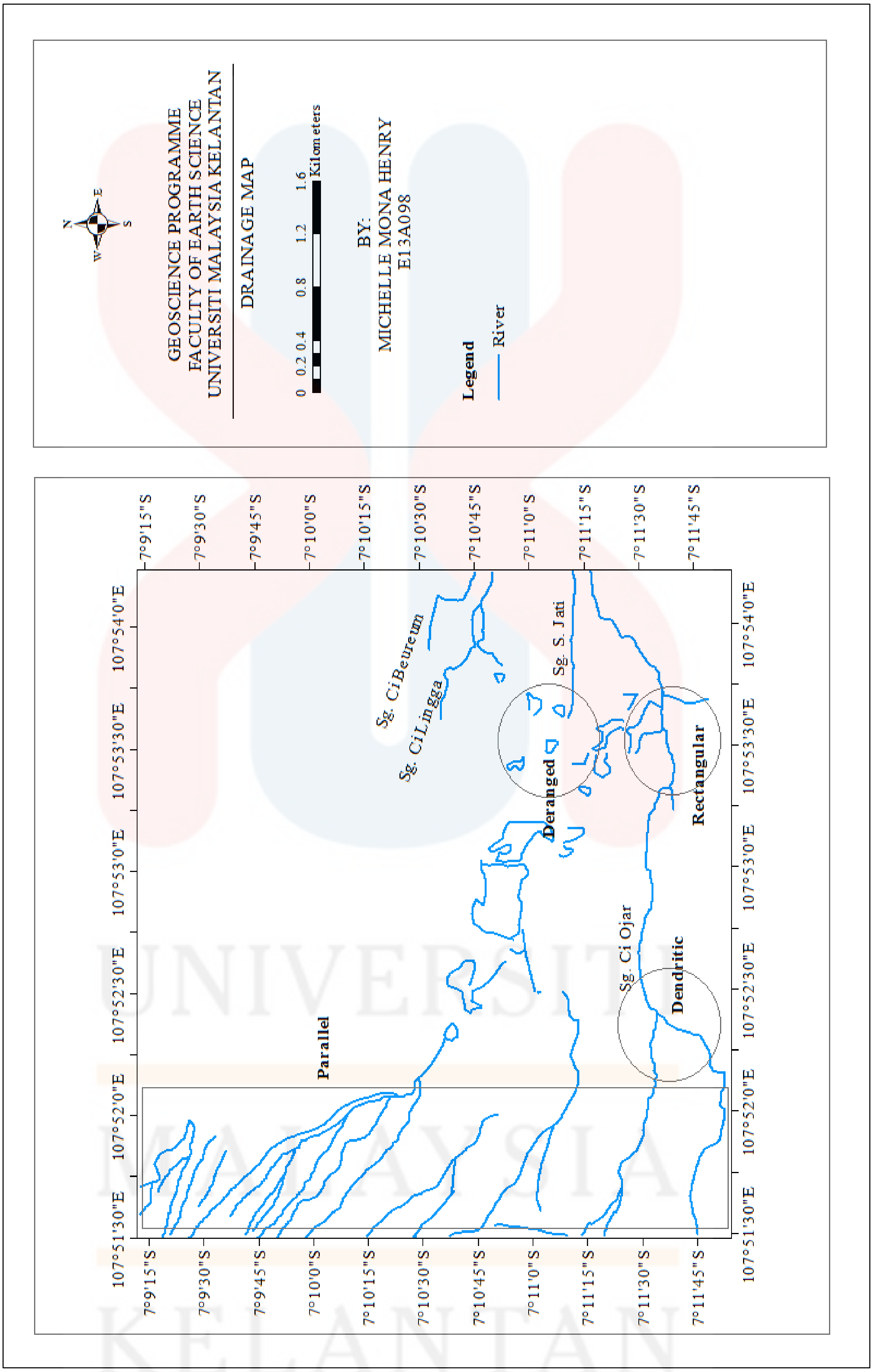

Figure 4.5 Drainage Map of Taragong area

4.2.3 Weathering

Weathering is a process of breaking down or dissolving of rocks and minerals on the Earth's surface through the contact with Earth's atmosphere, water and biological livings. It alters the chemical and physical properties of the affected rocks. It is an in-situ process which means it does not require transportation processes to occur. Weathering can be divided into three types.

Firstly, physical weathering. Also known as mechanical weathering, physical weathering is the breaking down of larger rocks into smaller rocks. The chemical compositions of the rocks are left undisturbed. The changing in temperature experienced by the rocks causes the rock to break apart. Chemical weathering by definition is a chemical reaction that occur in the rock causing it to dissolve and therefore, forming new substances. It is an ongoing process as the mineralogy of the rock adjusts to the near surface environment. Lastly, biological weathering. It is the weakening and subsequent disintegration of rocks due to action of living organisms like animals and plants. The releasing of acidic materials by plants and animals caused plant roots to get into cracks of rocks to find moisture and grow from there. The cracks then widen and eventually split away as the plant grows bigger.

Figure 4.6 Biological weathering

4.3 Stratigraphy

Stratigraphy is a branch of geology which studies rock layers (strata) and layering (stratification) in the Earth's crust. It is a scientific discipline concerned with the description of rock successions and their interpretation in terms of a general time scale thus, provides a basis for historical geology Stratigraphy deals primarily with the study of sedimentary and layered volcanic rocks.

Based on the map produced by (Surmayad *et. al*, 1998), the volcanic rocks in Kompleks Gunung Guntur are of Quaternary Age. The deposition of the of rocks as the result from the eruption of Kompleks Gunung Guntur in the beginning of Holocene Epoch that is the building blocks of Kamojang Caldera. This is continued with the deposition of building blocks of Gandapura Caldera until Early Quaternary Period (Recent Epoch) which is also known as the present time. The building blocks of Gunung Guntur were deposited after the Gandapura Caldera and continue to occur until the last eruption in 1847.

The product of Kamojang Caldera is the oldest rock that occupied the western part and the southern part of Kompleks Gunung Guntur. The product of Gunung Cakra is of younger rock and filled the eastern part of Kamojang whereas the product of Gandapura Caldera is the youngest rock which is located at the further east. It is found that the age of Gandapura products is 0.33 million years ago based on the absolute age (dating) determination results.

The products of Gunung Putri, Gunung Cidadali, Pasir Cileunsing, Gunung Picung, Gunung Agung, Gunung Pasir Malang and Gunung Gajar are in younger-arranged sequence. Meanwhile, the youngest-arranged sequence is the products of Gunung Masigit, Gunung Parupuyan, Gunung Kabuyutan and Gunung Guntur.

Based on the mapping carried out, there are two geological units which can be found in Taragong area. These two geological units are andesite and basalt. Lava flows, pyroclastic flows, pyroclastic falls as well as lahar are the deposition unit in the area of study. Lava flows, pyroclastic flows and pyroclastic falls are classified under primary deposits while lahar is classified under secondary deposits. The lithology unit of lava flow can further be divided into Guntur Lava Flow A, Guntur Lava Flow B, Guntur lava Flow C, Volcanic Product of Picung, Volcanic Product of Cileungsing and Volcanic Product of Putri – Katomas as well as Volcanic Product of Kamojang. Besides that, Guntur Pyroclastic A and Guntur Pyroclastic B are classified under the lithology unit of pyroclastic fall. For pyroclastic flow, Volcanic Debris Avalanche of Gandapura is classified under the mentioned class. The lithology unit of lahar has the lahar itself under it.

Purbawinata M.A. (1990) stated that among the young mountains, only Gunung Guntur activity is recorded in history with the last eruption producing basaltic rocks containing SiO_2 of 52% - 63%. This is contrary with the previous eruption that produced andesitic rocks instead. Dominantly, the eruption product of Gunung Guntur is flowing basaltic and andesitic lava in North West direction and South West direction as well. Pyroclastic flow filled the North East area and pyroclastic falls filled the North West area. Lahar occupied the East part of the area. as well as pyroclastic falls East, South East and South direction.

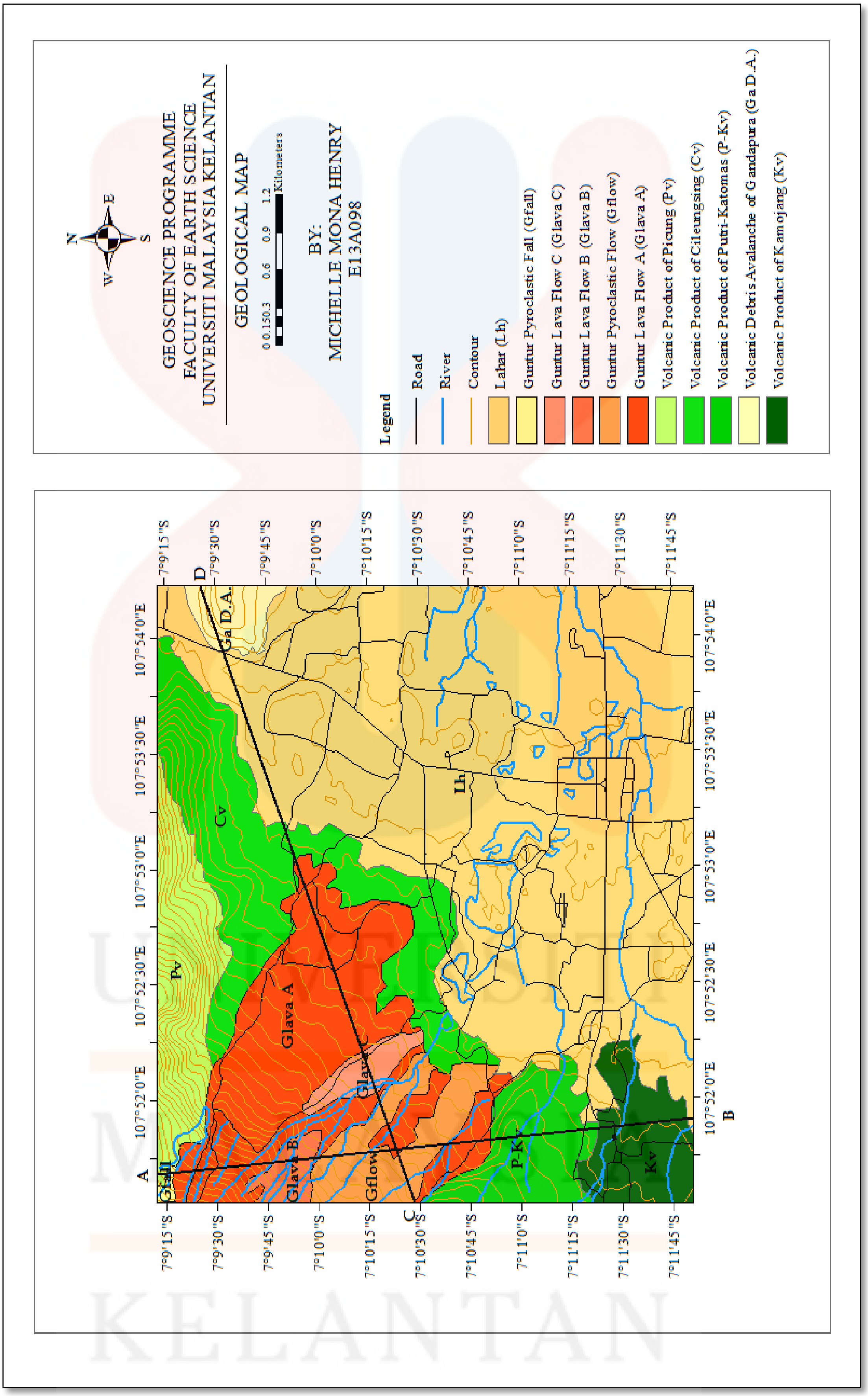

Figure 4.7 Geological Map of Tarogong area

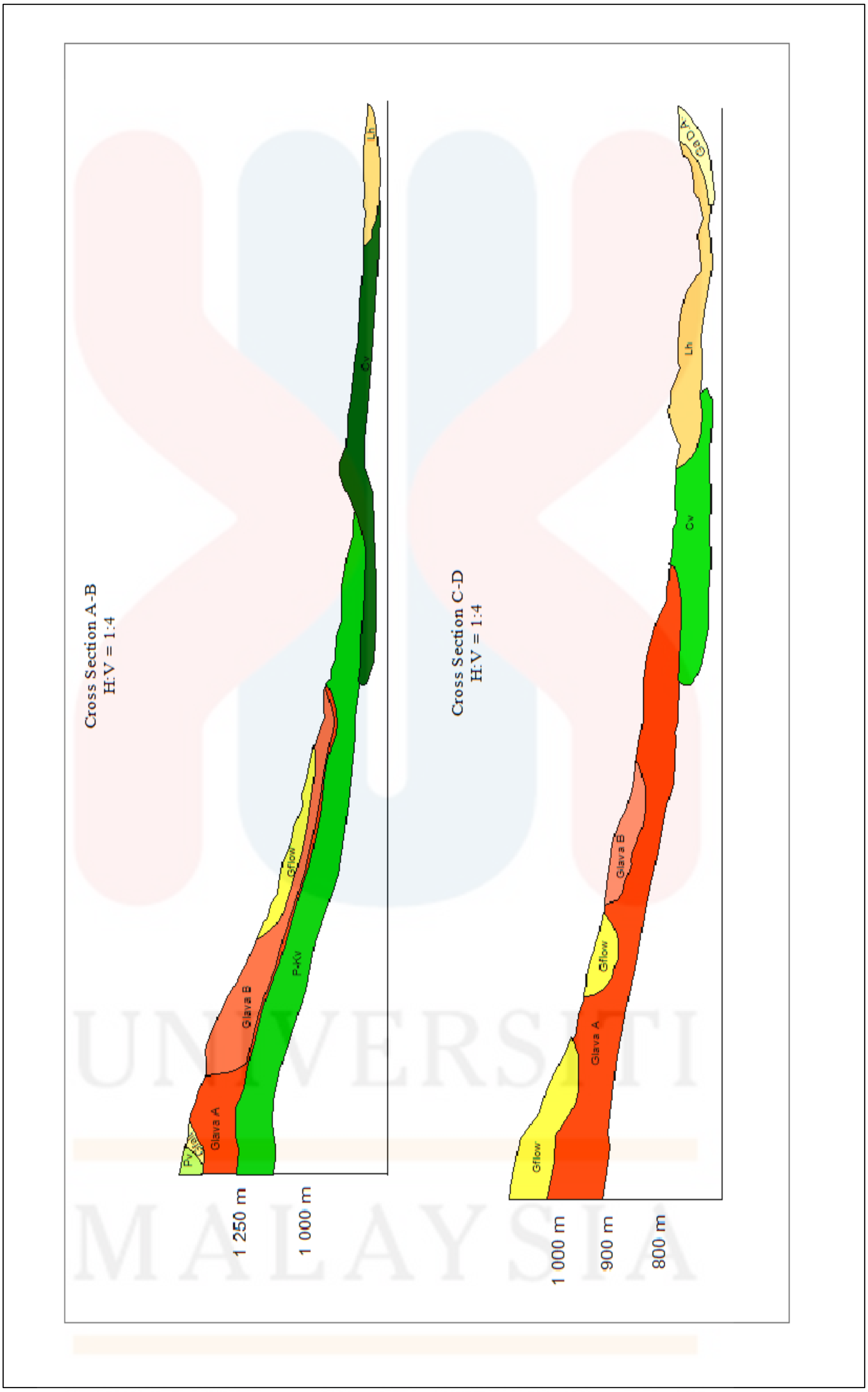

Figure 4.7 Geological Cross Section of Tarogong area

4.3.1 Lithostratigraphy Unit

Based on the geological mapping conducted, two types of rock lithology have been identified. They are basalt and andesite.

Basalt is an extrusive igneous (volcanic) rock on the Earth's surface as a result of rapid cooling of basaltic lava. They are usually dark in colour and are categorized under mafic igneous rocks due to their low silica content. They are usually fine – grained and exhibit porphyritic features which are also known as porphyry – aphanitic. The common phenocrysts that can be found in basalt are olivine, pyroxene, hornblende and plagioclase as well as feldspar. Flood basalt is a series of basalt flows.

Andesite is also an extrusive igneous (volcanic) rock. However, they are usually light in colour and are categorized under intermediate igneous rocks due to their high silica content. Similar like basalt, they are usually fine – grained and exhibit porphyritic features which are also known as porphyry – aphanitic. Their fine grains are the result of the rapid cooling of andesitic basalt. The common phenocrysts that can be found in basalt are pyroxene, hornblende, biotie and plagioclase as well as feldspar. Andesite usually does not contain olivine.

4.3.2 Lithostratigraphy Column

Lithostratigraphy is defined as the study and description of stratified rocks solely with reference to their physical and petrographic features, particularly in hand specimens, outcrops and thin sections. It is also used to describe the physical characteristics such as colour, type of rock, mineral compositions and grain sizes. Based on the gathered information, the stratigraphy and lithostratigraphy can be correlated with each other to determine the type of rocks present in the study area and the age of those rocks.

Table 4.2 Lithostratigraphic Column of Guntur area

Age	Deposits				Description
	Primary			Secondary	
Quaternary	Lava Flow	Pyroclastic Flow	Pyroclastic Fall	Lahar	
					Lava block of andesite and basalt
			G_{fall}		Mixture blocks of andesite and basalt
	G_{lava} C				Porphyritic basaltic lava
	G_{lava} B				Porphyritic basaltic lava
		G_{flow}		Lh	Basaltic lava blocks and scorious volcanic bombs
	G_{lava} A				Porphyritic basaltic lava
	P_V				Porphyritic basaltic, basaltic andesite and andesite lava
		C_V			Andesitic lava flows and pyroclastic flows

	$P\text{-}K_V$	Porphyritic basaltic lava
	$Ga_{D.A}$	Andesitic lava blocks embedded in pyroclastic flows deposit
	K_V	Lava flows and pyroclastic deposit

With reference to map produced by (Sumayadi *et al*, 1998) and (Saepuloh, Sumintadireja, & Suryantini, 2004) as well as the lithostratigraphic column constructed above, there are eleven rock units that are mapped on the geological map according to their deposition units. Arranged from the oldest to youngest, they are:

1. Volcanic Products of Kamojang (K_V)

The deposits are made up of lava flows and pyroclastic deposits (Sumayadi, *et al*, 1998).

2. Volcanic Debris Avalanche of Gandapura ($G_{aD.A.}$)

The debris is built up from andesitic lava blocks embedded in pinkish pyroclastic flows deposit. They form hill morphology at the East part of the area. Plagioclase ranging from 0.1 cm – 0.5 cm and feldspar as the main phenocrysts. Pyroxene is present too.

3. Volcanic Products of Putri – Katomas ($P\text{-}K_V$)

The products are made up of dark grey – coloured porphyritic basaltic. They have vesicles and fine groundmass. Plagioclase is ranging from 0.1 cm – 0.6 cm and feldspar are the main phenocrysts. Pyroxene, Olivine and biotite are present too. They flow in the South West direction.

4. Volcanic Products of Cileungsing (C_V)

The products are made up of andesitic lava flow and pyroclastic flows of andesitic lava blocks. Both of them are porphyry – aphanitic and are grey in colour. Plagioclase ranging from 0.1 cm – 0.6 cm is the main phenocrysts. Pyroxene ranging from 0.1 cm – 0.7 cm, hornblende and biotite are also present.They covered the North part of the area.

5. Volcanic Products of Picung (P_V)

The products are mainly made up of basaltic lava flow (SiO2) of 48.8% - 51.88%, basaltic andesitic (SiO2) of 53.31% - 54.42% and andesitic lava (SiO2) of 58.04% - 61.26%. All of them show porphyritic features in glassy, intergranular and intersertal groundmass (Saepuloh, Sumintadireja, & Suryantini, 2004).

6. Guntur Lava Flow A (G_{lava} A)

The lava is composed of dark grey – coloured porphyritic basalt set in course – grained groundmass. They show angular blocky and vesicularity. Plagioclase, feldspar and hornblende are the main phenocrysts. They covered the North West part of the area.

7. Guntur Pyroclastic Flows (G_{flow})

The pyroclastic flows consist of ash – coloured basaltic lava blocks and scorious volcanic bombs. They are distributed in the South – South East of Guntur and hence formed a fan (Sumayadi, *et al*, 1998).

8. Guntur Lava Flow B (G_{lava} B)

The lava is composed of porphyritic basalt. They are dark in colour and show angular blocky and vesicles on the surface. Plagioclase mostly ranging from 0.5 cm and hornblende are the main phenocrysts. Pyroxene ranging from 0.1 cm – 0.8 cm and biotite are present too. They flow in North West direction.

9. Guntur Lava Flow C (G_{lava} C)

The lava is composed of dark – coloured basalt with the composition of Silicon Oxide (SiO_2) of 51.56%. It has a vesicular surface and is a product of the Gunung Guntur's eruption in 1840 (Sumayadi *et al*, 1998).

10. Guntur Pyroclastic Falls (G_{fall})

The pyroclastic falls consist of basaltic lithics which are dark in colour and have porphyritic features. On the surface, they also show angular blocky and vesicles. Plagioclase mostly ranging from 0.7 cm and pyroxene as well as feldspar, olivine and hornblende are the main phenocrysts. They flow in the North West direction.

11. Lahar (Lh)

The lahar consists of non-vesicular porphyritic andesitic and basaltic lava blocks. They are pebble – cobble sized with rounded – sub-rounded shape set in course sandy groundmass. They occupied largely of the East part of the area. Plagioclase, feldspar, pyroxene, hornblende and biotite are the main phenocrysts.

4.3.2 Petrology

<u>Sample 1: Lahar Fragment - Basalt (Lh)</u>

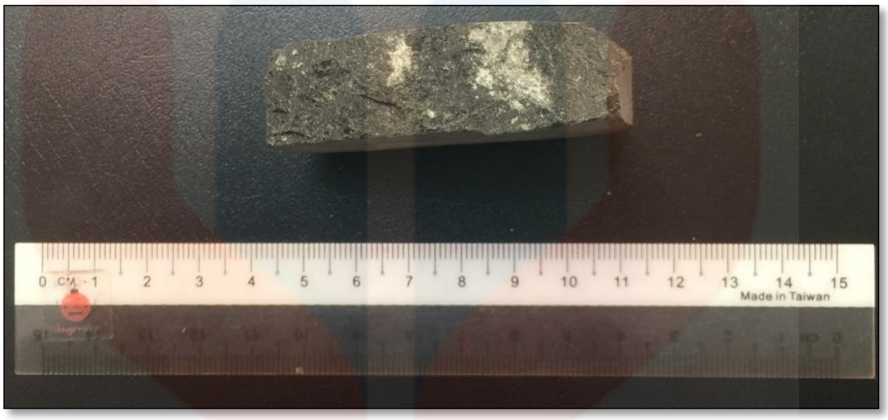

Figure 4.8 Hand specimen of Lahar fragment - Basalt

Rock type: Basalt

Co-ordinate: S 07°11'28.1" E 107°53'28.5"

The rock is dark grey in colour. It is non-vesicular and has a fine grain. The rock has a porphyritic feature with plagioclase and hornblende as the main phenocrysts. Pyroxene and biotite are present too.

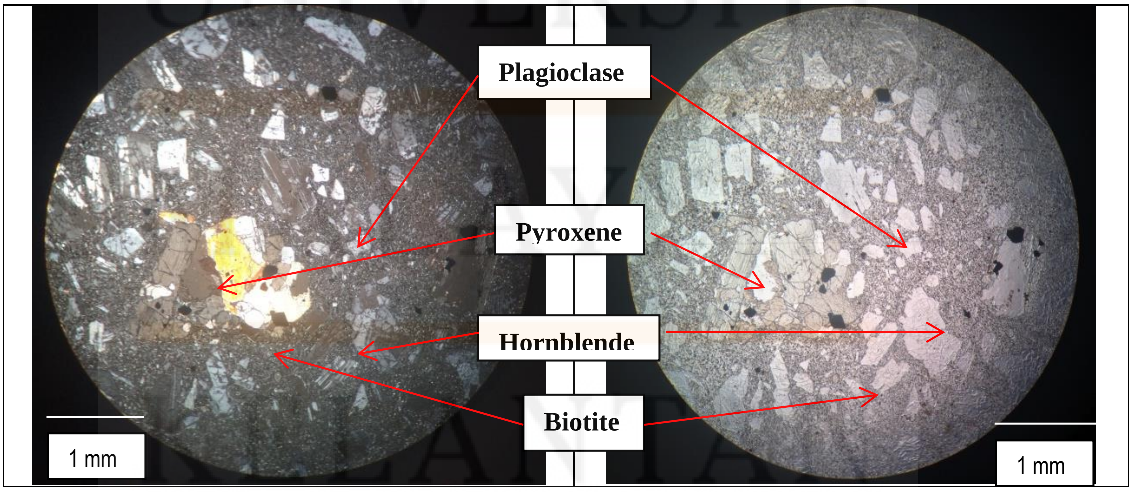

Figure 4.9 XPL & PPL view of Lahar fragment - Basalt

Sample 2: Lahar Fragment – Andesite (Lh)

Figure 4.10 Hand specimen of Lahar fragment - Andesite

Rock type: Andesite

Co-ordinate: S 07°11'21.8" E 107°52'44.6"

The rock is grey in colour, non-vesicular and has a fine grain. The rock has a porphyritic feature with plagioclase ranging from 0.1 cm – 0.7 as the main phenocryst. A pale brown xenolith measuring 3.9 cm within the andesite is spotted.

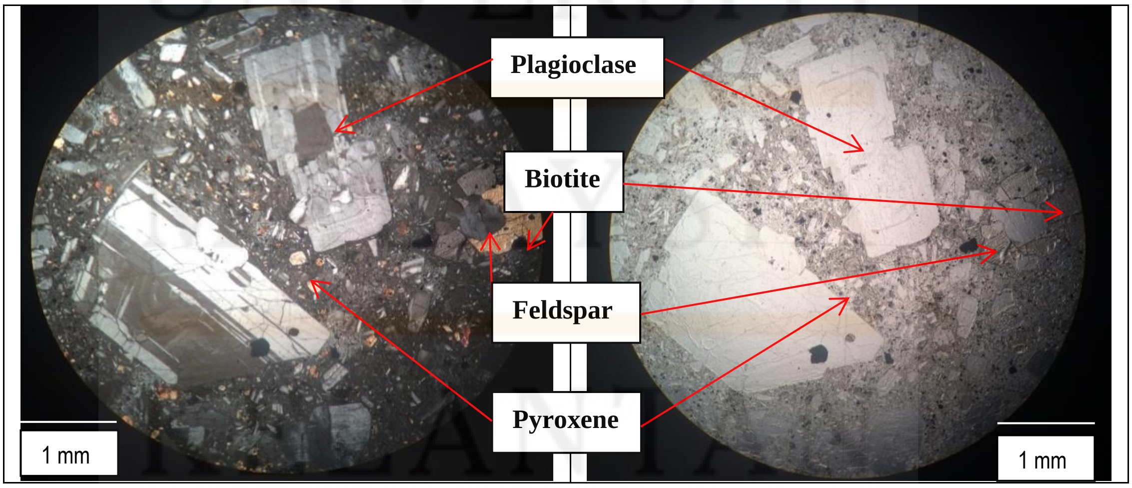

Figure 4.11 XPL & PPL view of Lahar fragment - Andesite

Sample 3: Tuff in Guntur Lava Flow B (G_{lava} B)

Figure 4.12 Hand specimen of tuff in Guntur Lava Flow B

Rock type: Andesite

Co-ordinate: S 07°09'48.5" E 107°51'41.6"

The rock is grey in colour and non-vesicular. The rock has a porphyritic feature with plagioclase mostly ranging from 0.5 cm and hornblende are the main phenocrysts. Pyroxene ranging from 0.1 cm – 0.8 cm and biotite are present

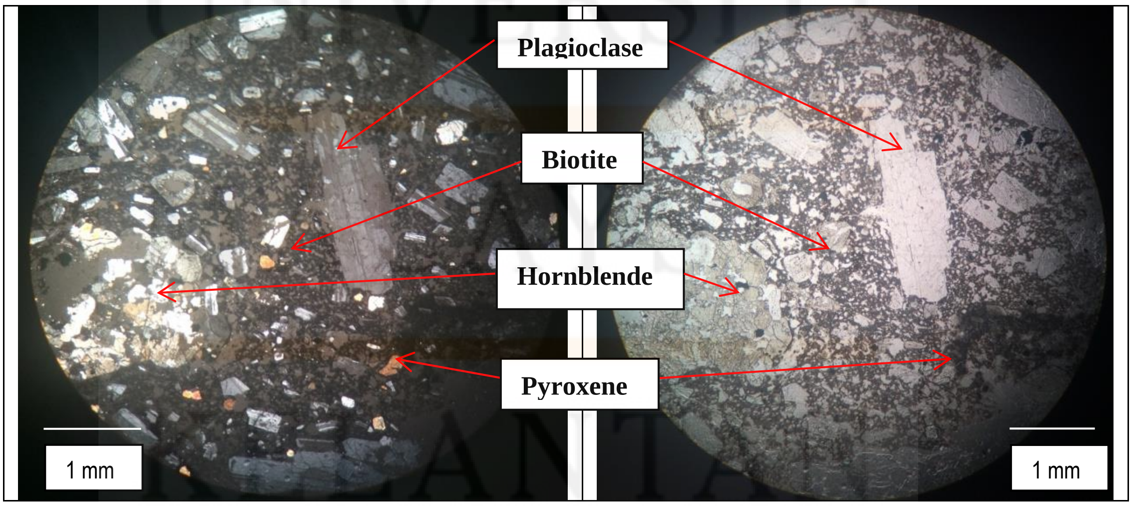

Figure 4.13 XPL & PPL view of tuff in Guntur Lava Flow B

Sample 4: Tuff in Guntur Lava Flow A (G_{lava} A)

Figure 4.14 Hand specimen of tuff in Guntur Lava A

Rock type: Basalt

Co-ordinate: S 07°10'33.1" E 107°52'02.2"

It is dark grey in colour. It is vesicular and has a coarse grain. The rock has a porphyritic feature with feldspar, plagioclase and hornblende and as the main phenocrysts. The size of the plagioclase is ranging from 0.1cm – 0.6cm.

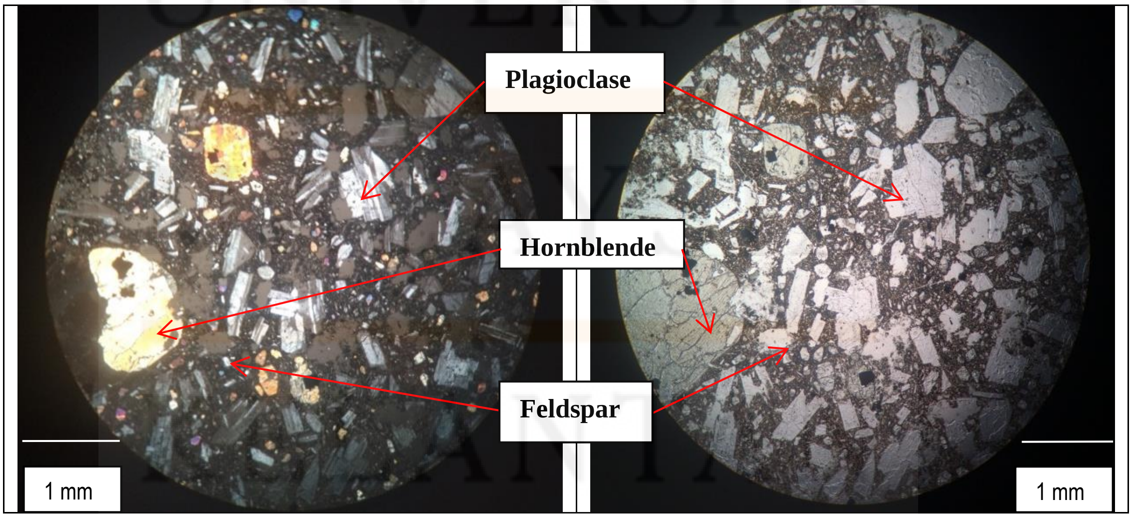

Figure 4.15 XPL & PPL view of tuff in Guntur Lava A

Sample 5: Tuff in Volcanic Product of Cileungsing (C_V)

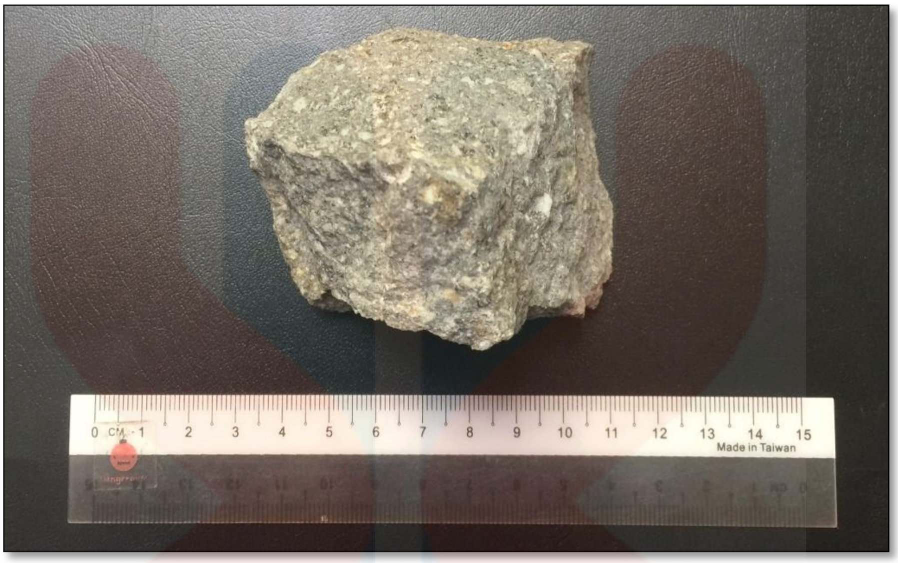

Figure 4.16 Hand specimen on tuff in Volcanic Product of Cileungsing (C_V)

Rock type **:** Andesite

Co-ordinate: S 07°09'46.7" E 107°53'00.8"

The rock is grey in colour. It is non-vesicular and has a fine grain. The rock has a porphyritic feature with plagioclase ranging from 0.1 cm – 0.6 cm is the main phenocrysts. Pyroxene ranging from 0.1 cm – 0.7 cm, hornblende and biotite are also present.

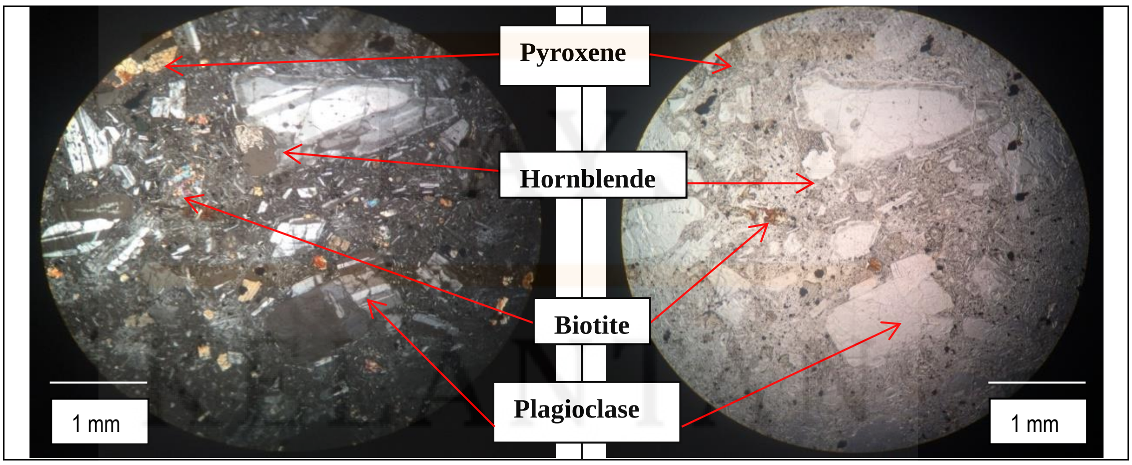

Figure 4.17 XPL & PPL view of tuff in Volcanic Product of Cileungsing (C_V)

Sample 6: Tuff in Volcanic Product of Putri – Katomas (P-K_V)

Figure 4.18 Hand specimen on tuff in Volcanic Product of Putri – Katomas (P-K_V)

Rock type: Basalt

Co-ordinate: S 07°11’00.6” E 107°52’08.1”

It is dark grey in colour. It is vesicular and has a fine grain. The rock has a porphyritic feature with the plagioclase is ranging from 0.1 cm – 0.6 cm and feldspar are the main phenocrysts. Pyroxene, Olivine and biotite are present too.

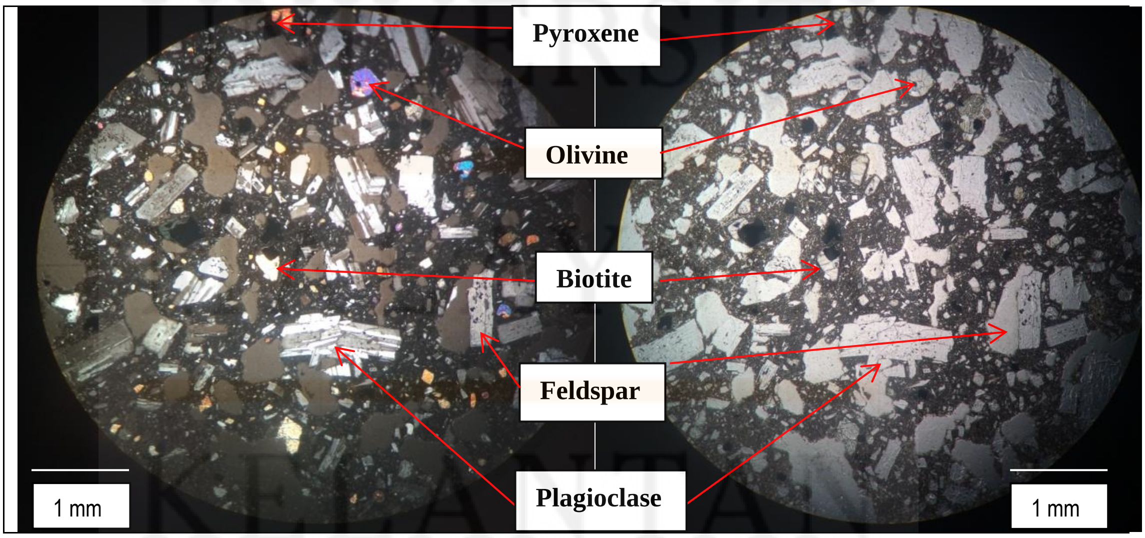

Figure 4.19 Hand specimen on tuff in Volcanic Product of Putri - Katomas (P-K_V)

Sample 7 – Volcanic Debris Avalanche of Gandapura ($Ga_{D.A}$)

Figure 4.20 Hand specimen on Volcanic Product of Gandapura (Ga D.A)

Rock type: Andesite

Co-ordinate: S 07°09’31.7” E 107°53’57.8”

The rock is light grey in colour. It is vesicular and has a fine grain. The rock has a porphyritic feature with plagioclase ranging from 0.1 cm – 0.5 cm and feldspar as the main phenocrysts. Pyroxene is present too.

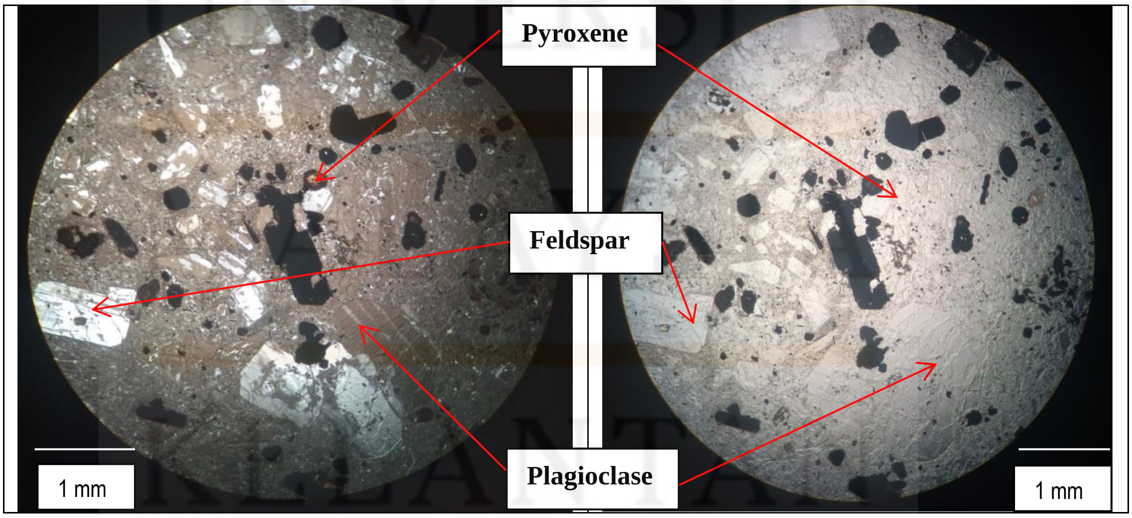

Figure 4.21 Hand specimen on Volcanic Product of Gandapura (Ga D.A)

4.4 Structural Geology

Structural geology is the study of the three-dimensional distribution of rock units with respect to their deformational histories. It is being studied to learn about their tectonic history, past geological environments and events that could have changed or deformed them. These can be dated to determine when the structural features formed.

Based on the interpretations from the topographic maps and aerial photography, the geological structures present in the study area are reverse faults, normal faults and anticlines. These faults are developing due to major pressure from the subduction of districts in the southern of Java Island between Indo – Australian oceanic plate and Eurasia continental plate. Generally, the directions of these faults are Northwest – Southeast and Northeast – Southwest (Suantika, 2009).

Active faults in the western part of Java are regions of seismic sources which are grouped into Cimandiri Active Fault, Baribis Active Fault and Bumiayu Active Fault (Kertapati et al., 2001) (Figure 2.2). The activity of these faults are marked earthquake records in western part of Java. Since 1800 – 2000, the area had been experiencing 15 damaging earthquakes (Supartoyo *et al.*, 2006). It is assumed that these earthquakes are associated with active faults of tectonic activity. Most of them are shallow earthquakes of 0 – 35 km. Based on the calculation of the maximum intensity distibution in the active fault areas in Cimandiri, Baribis, Bumiayu and its surroundings, the earthquakes are classified as level VII – IX on Modified Mercalli Intensity (MMI) scale. Tectonic activity can trigger a rise in the volcanic activity. Kompleks Gunung Guntur is not included in those three main active fault territories but are passed through by smaller active faults in Northeast – Southwest direction.

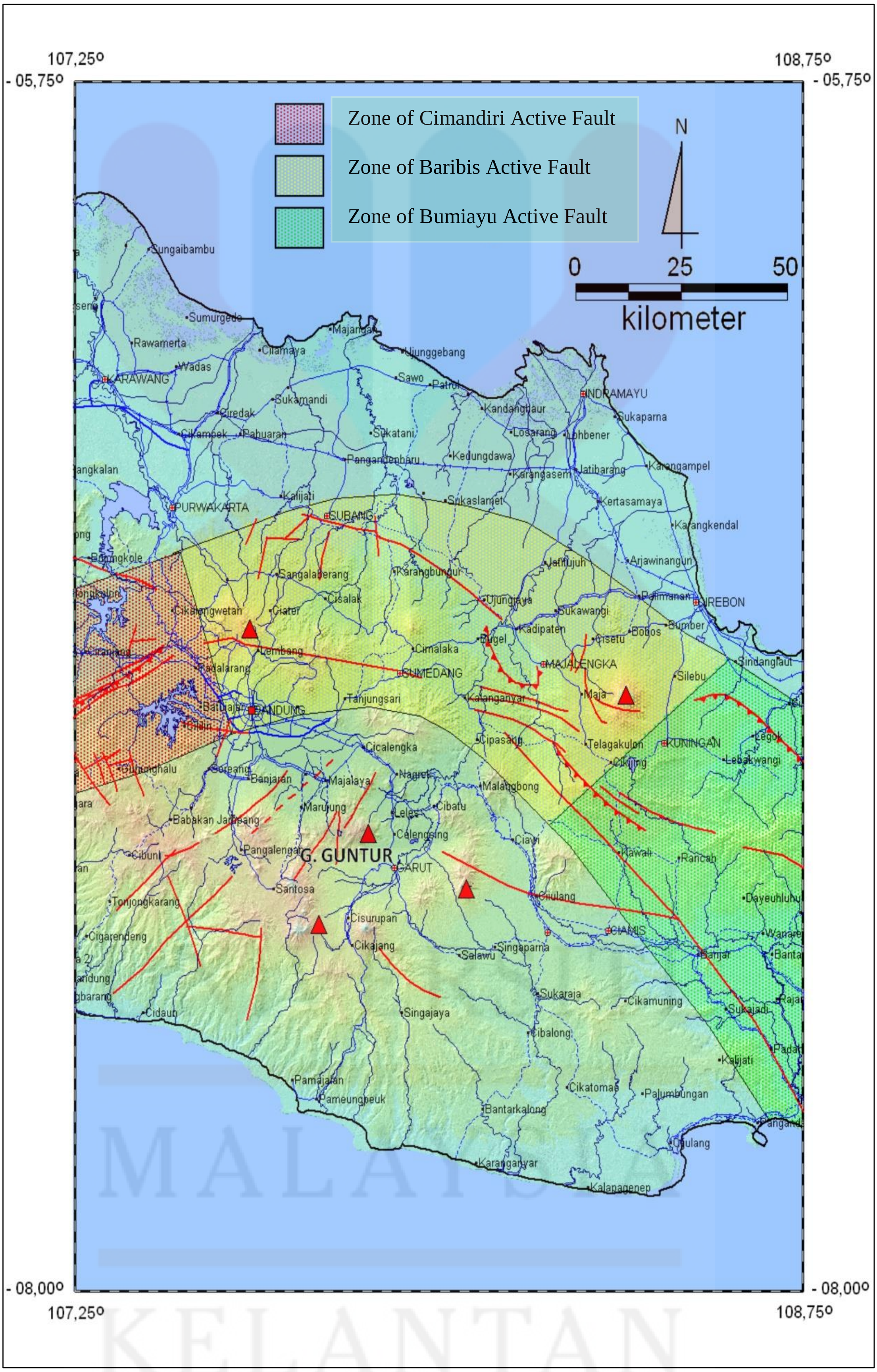

Figure 4.24 Cimandiri Active Fault, Baribis Active Fault and Bumiayu Active Fault

(Suantika, 2009)

4.4.1 Lineament Analysis

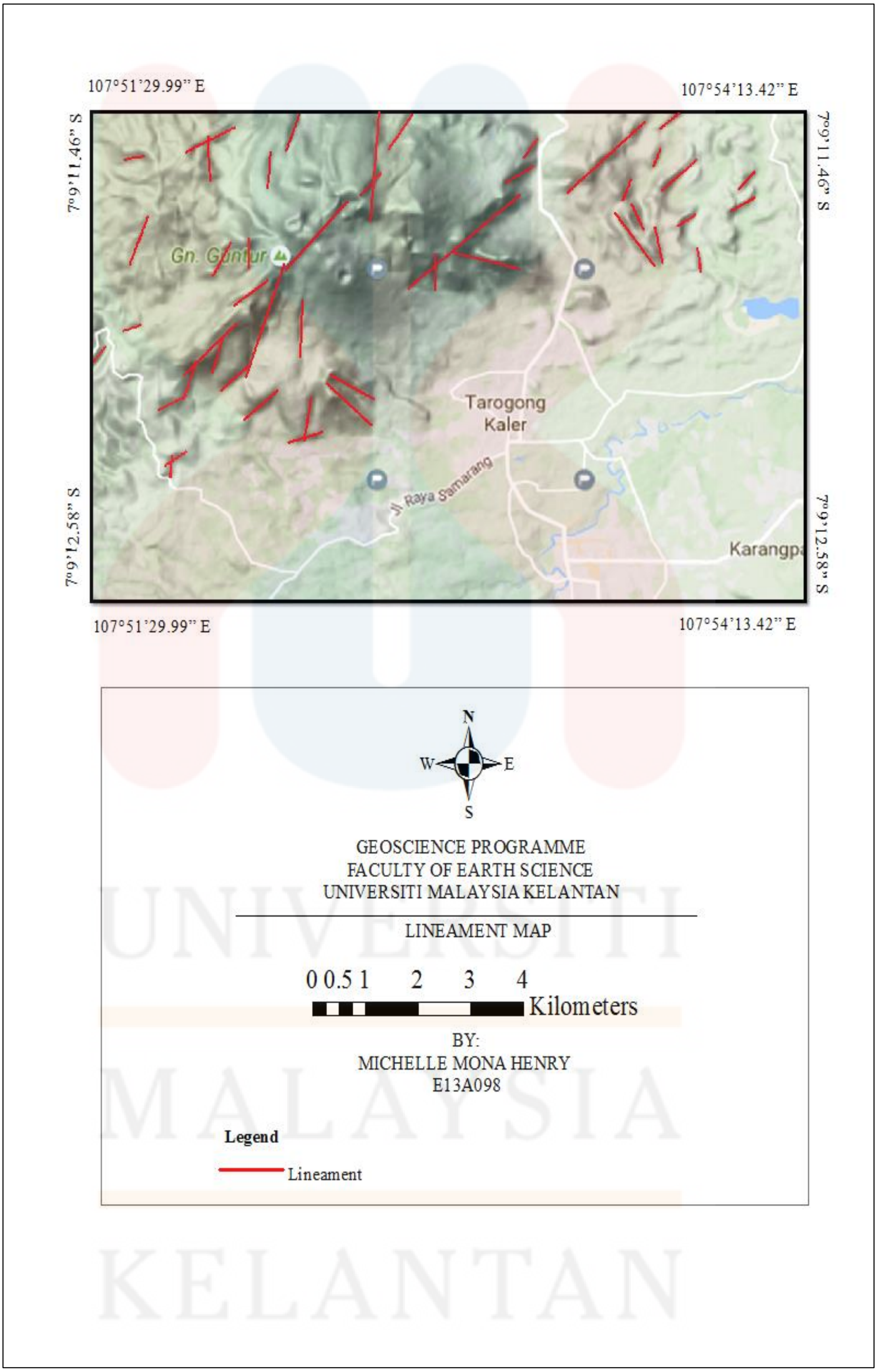

Figure 4.25 Lineament Map of Tarogong area

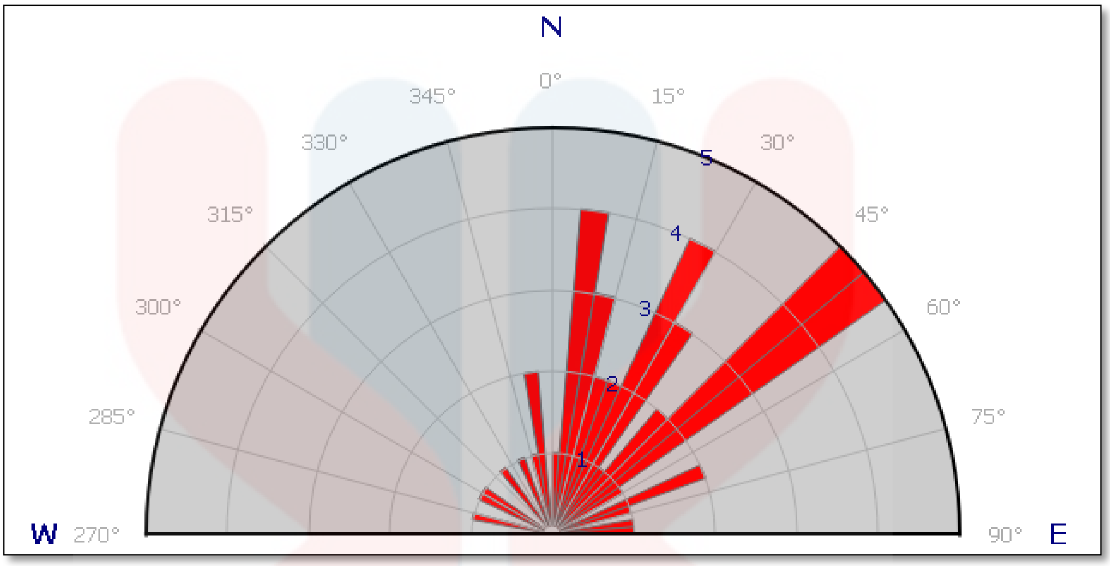

Figure 4.26 GeoRose diagram

Based on the lineament readings which have been converted into the Rose Diagram above, it can be said the lineament is more dominant in the North – West direction.

4.5 Historical Geology

Historical geology by definition is a discipline that uses the principles and techniques of geology to understand the geological history of Earth. In brief, it is the branch of geology dealing with the changes in Earth and its life forms over time. It focuses on geologic processes that change the Earth's surface and subsurface and the evolution of plants and animals during different time periods in the geological timescale.

According to (Suharsono & Suwarti, 1987), the depositional history and development of tectonic had started during Pliocene Epoch (Tertiary Period) – Pleistocene Epoch (Quaternary Period). The increment in the tectonic activities had caused the lifting in the study area and its environment. Besides that, these tectonic activities had triggered the volcanic activities which are shown by the rock formation of Gunungapi Pandak as well as the breakthrough of microgabbro and andesite basalt (outside the area of study). During the precipitation which started during Middle Pleistocene Epoch – Late Pleistocene Epoch, rapid development of tectonic activities occurred, resulting in more intensified lifting before the previous period. Due to that reason, the volcanic activities in the area of study increase as well. The volcanic activities are marked with sequence of Rock of Gunungapi Tengger, Rock of Gunungapi Argopuro and Rock of Gunungapi Lamongan.

CHAPTER 5

LAND USE DEVELOPMENT OF THE TAROGONG AREA

For my research specification, the study area has a total of 225 km^2. It lies at longitude of 107°49’10.50” E to 107°57’17.20” E and latitude of 7°6’28.08” S to 7°14’33.72” S. Taragong area is located in the District of Garut. This area is accessible by road with a total length is 402 292 km of national road, provincial road, district road and village road. During mapping, both the main road and village road are traversed by using motorcycle and walking. As of 2015, the District of Garut has a total population of approximately 2 548 723 people occupying an area of 306 519 km^2 giving the population density of 832 people / km^2. The land use/cover in Taragong area is covered largely by woods with 26.76% of both forests and mangrove forests. Vegetation area comes second with 22.02% for plantations such as banana and tobacco as well as paddy field for irrigation and rain fed purposes with 13.06% and 3.20% respectively. The remaining percentage of land uses are in forms of estate, bushes, villages, buildings and others (Gunawan, 2015).

5.1 Results

In this chapter, the land use development of Tarogong area by using remote sensing analysis is being focussed. Based on the satellites imageries of Landsat 7 and Landsat 8, the results are illustrated diagrammatically. Different generation of Landsat are used because Landsat 8 only started to be in operation in 2013. Both the satellite imageries from Landsat 7 (ETM+) recording the date of May 16, 2005 and

Landsat 8 (OLI and TIRS) recording the date of September 25, 2015 were obtained from the earth explorer site (https://earthexplorer.usgs.gov/). Figure 5.1 shows the land use/cover map of 2005 whereas Figure 5.2 shows the land use/cover map of 2015. On the other hand, Figure 5.3 – Figure 5.7 depicts the land use/cover change map in five different classes which are built up (Figure 5.3), vegetation (Figure 5.4), agriculture (Figure 5.5) and barren (Figure 5.6) as well as water body (Figure 5.7) in the last decade from 2005 to 2015.

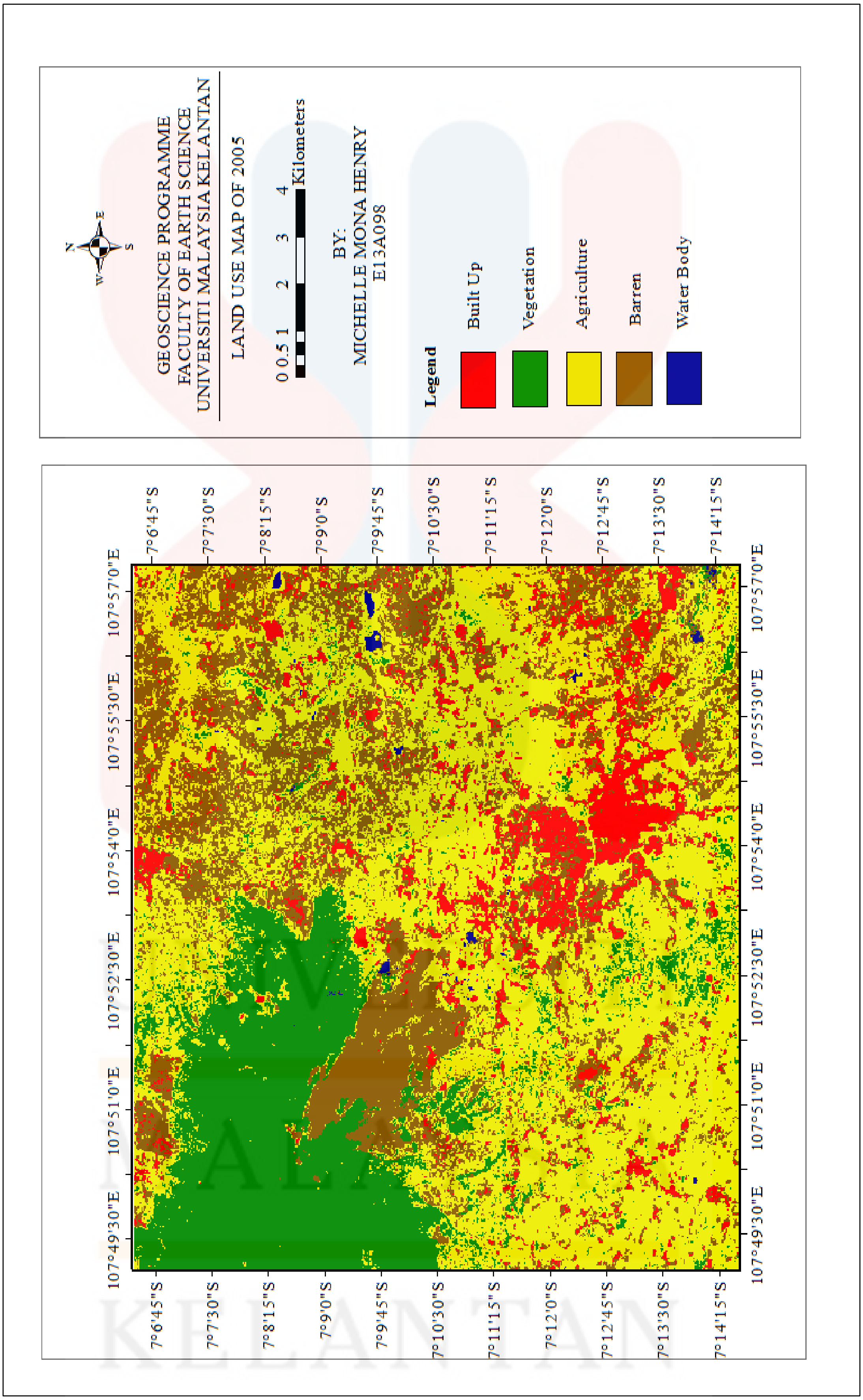

Figure 5.1 Land use map of 2005

The figure above illustrates the land use map of the year 2005. Based on the map, it can be interpreted that the land use in Taragong area is covered vastly by agriculture area by 48.195% which is equivalent to 108.651 km^2 of the total area. Water body area covered the total area slightly by 0.313% only which is equivalent to 0.705 km^2. 9.301% which is equivalent to 20.968 km^2 of the total area is covered by built up area. As for vegetation area, it covers 18.464% which is equivalent to 41.625 km^2 of the total area. The remaining area of 23.727% which is equivalent to 53.491 $km^2$of the area is covered by barren area.

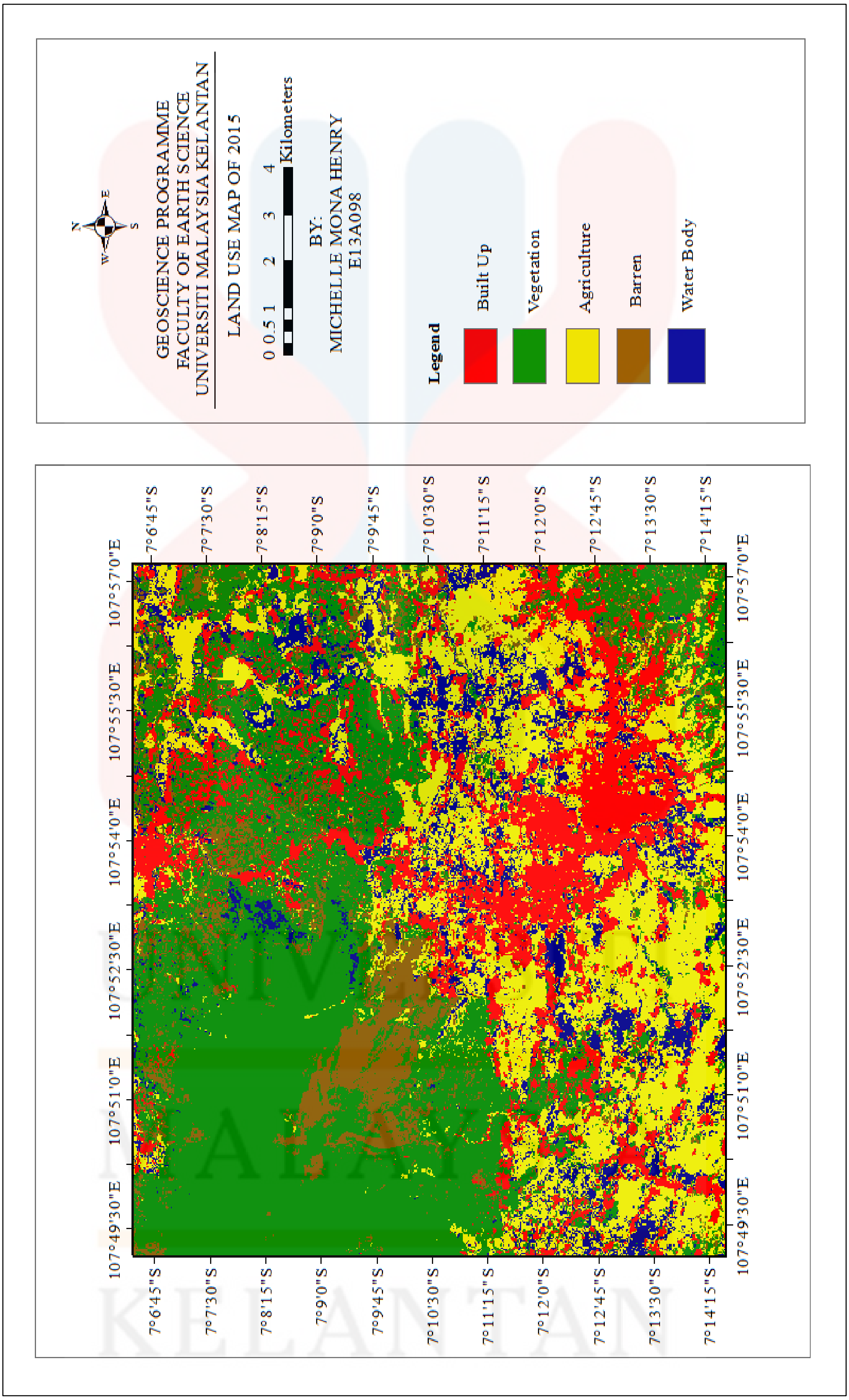

Figure 5.2 Land use map of 2015

The figure above illustrates the land use map of the year 2015. Based on the map, it can be interpreted that the land use in Taragong area is covered greatly by vegetation area by 38.932% that is approximately 87.768 km^2 of the total area. The barren area covered the total area in small-scale by 8.521% only that is approximately 19.210 km^2. 17.128% that is approximately 38.614 km^2 of the total area is covered by built up area. As for agriculture area, it covers 25.429% of the total area that is approximately 57.327 km^2. The remaining area of 9.990% that is approximately 22.521 km^2 of the area is covered by water body area.

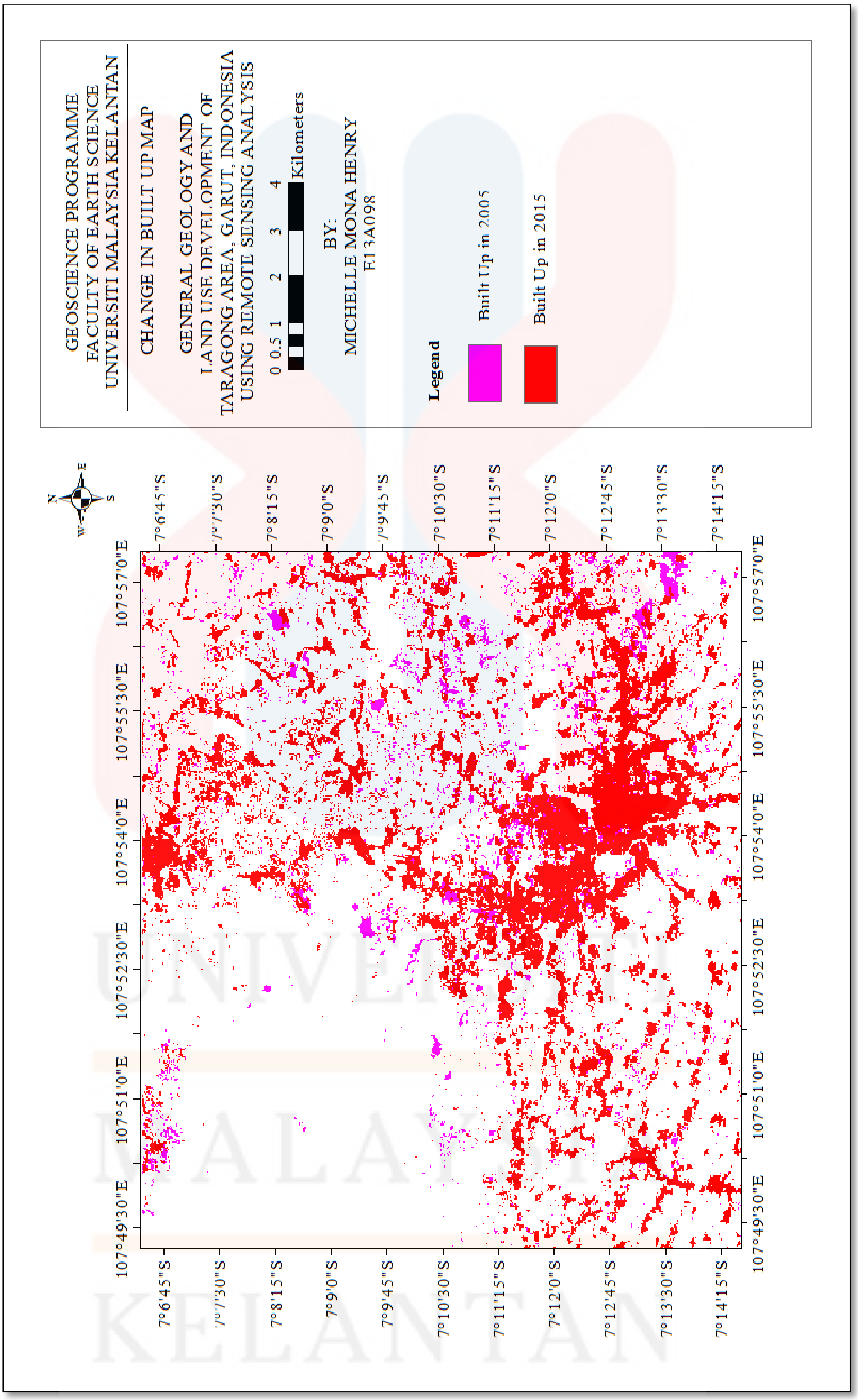

Figure 5.3 Land use change map of built up area from 2005 – 2015

The figure above portrays the land use map of the year 2005 and 2015 in terms of built up area. The magenta coloured represented the built up area for the year 2005 whereas the dark red coloured represented the built up area for the year 2015. With reference to the map, it can be said that the built up area has increased slightly by 7.827% that is 17.646 km^2 over the last decade.

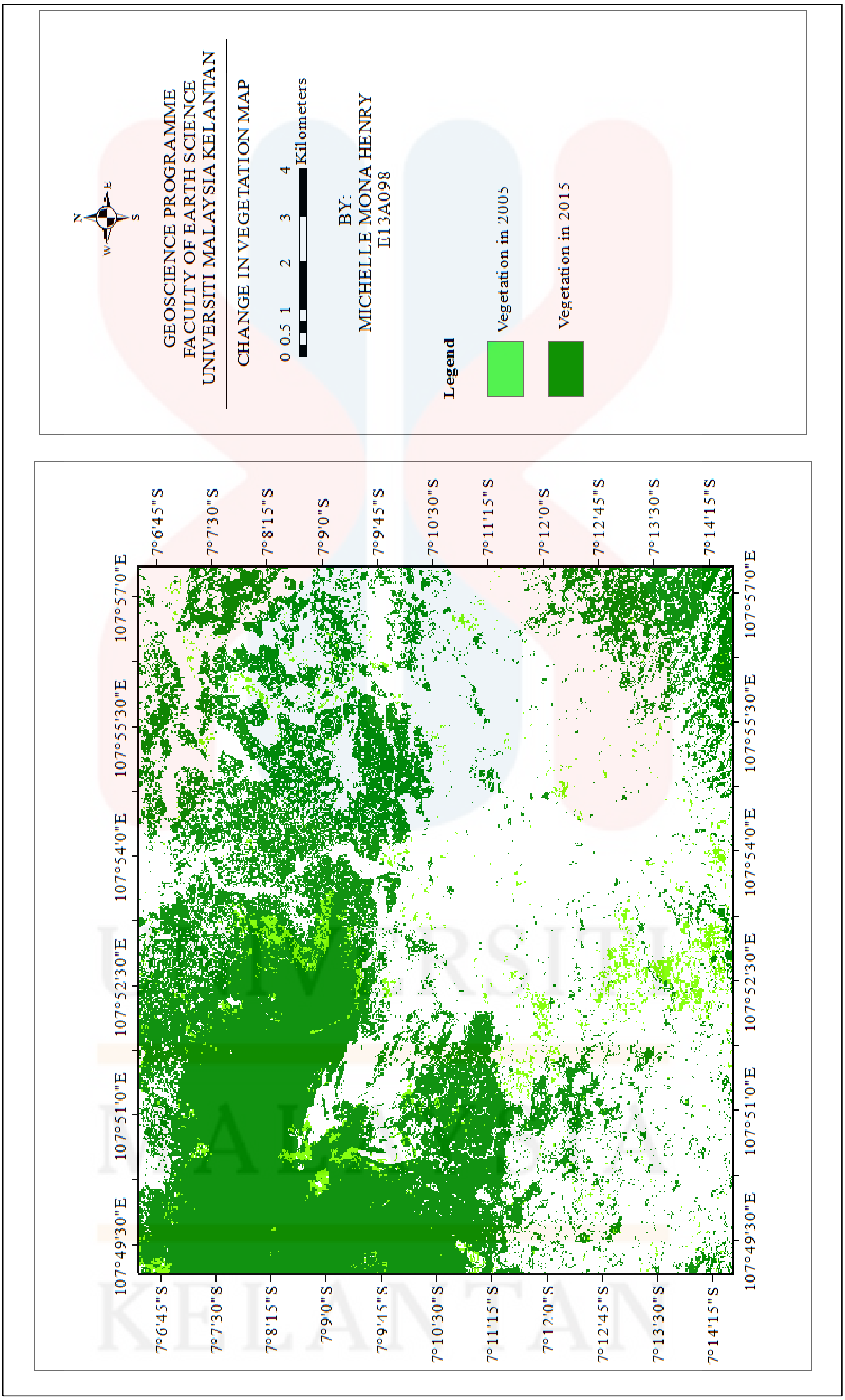

Figure 5.4 Land use change map of vegetation area from 2005 – 2015

The figure above portrays the land use map of the year 2005 and 2015 in terms of vegetation area. The light green coloured represented the built up area for the year 2005 whereas the dark green coloured represented the vegetation area for the year 2015. With reference to the map, it can be seen that the vegetation area has increased vastly by 20.468% that is 46.143 km^2 over the last decade.

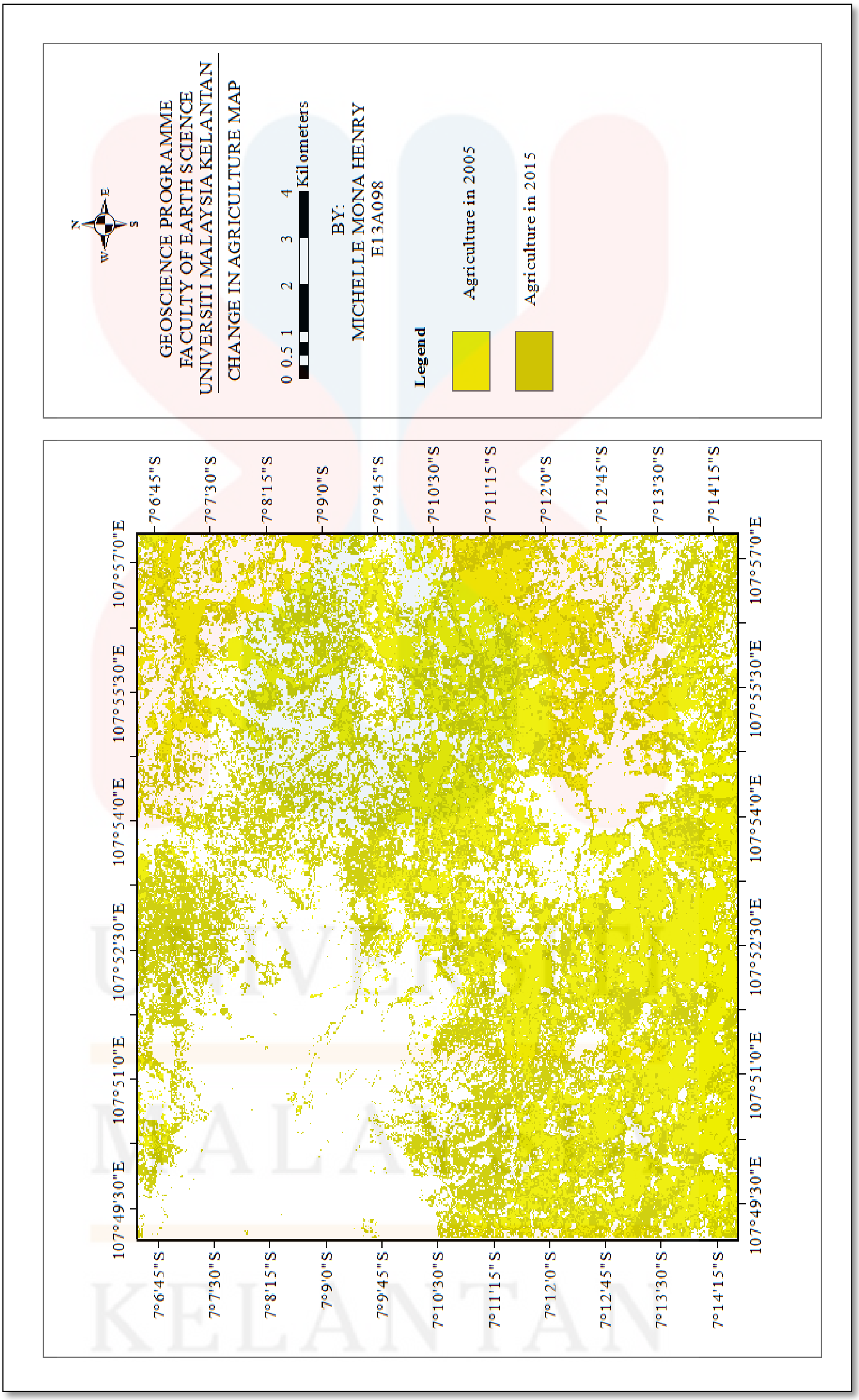

Figure 5.5 Land use change map of agriculture area from 2005 – 2015

The figure above portrays the land use map of the year 2005 and 2015 in terms of agriculture area. The light yellow coloured represented the built up area for the year 2005 whereas the dark yellow coloured represented the agriculture area for the year 2015. With reference to the map, it can be observed that the agriculture area has decreased largely by -22.766% that is -51.324 km^2 over the last decade.

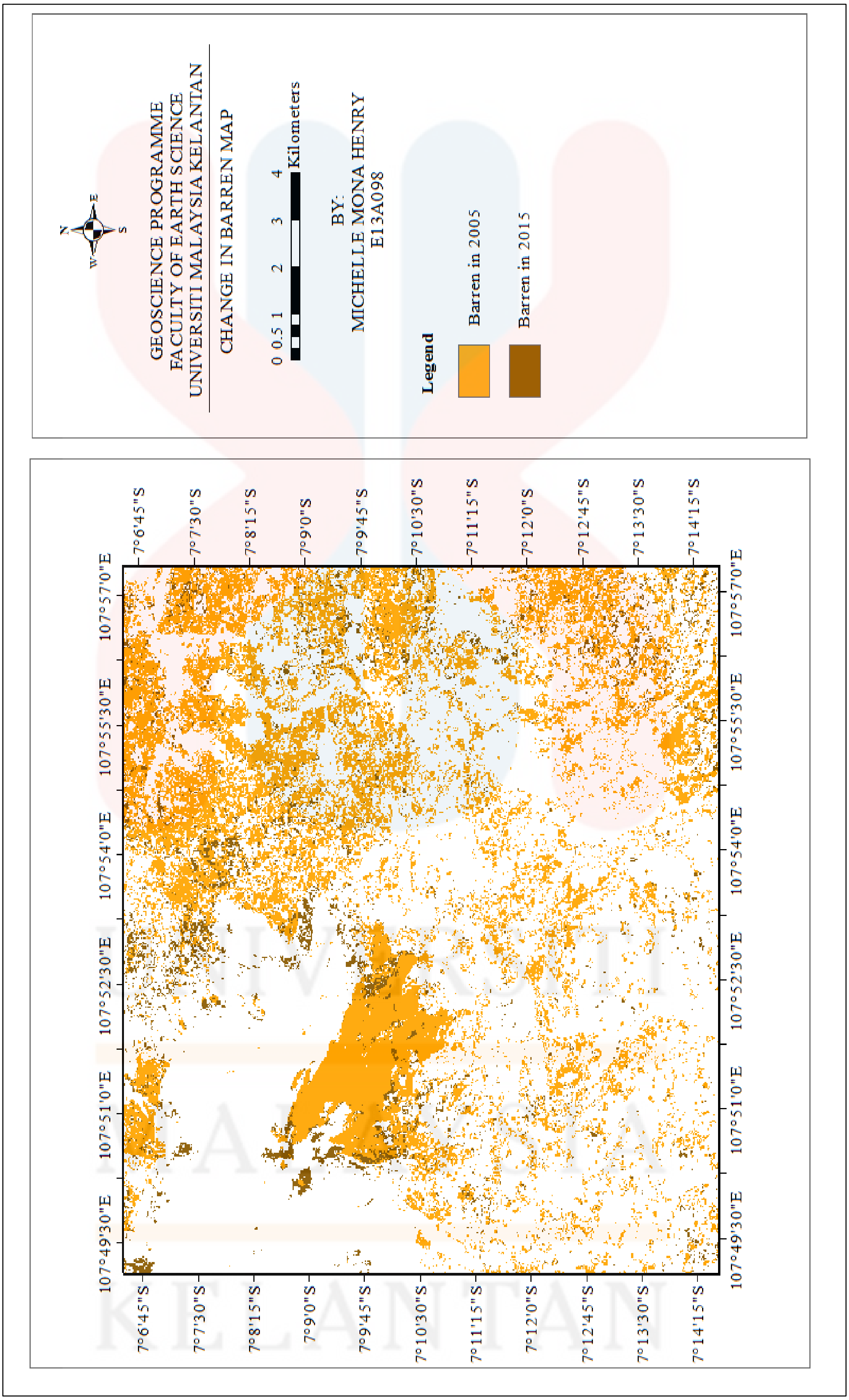

Figure 5.6 Land use change map of barren area from 2005 – 2015

The figure above portrays the land use map of the year 2005 and 2015 in terms of agriculture area. The light brown coloured represented the barren area for the year 2005 whereas the dark brown coloured represented the barren area for the year 2015. With reference to the map, it can be noticed that the barren area has decreased as well by -15.206% that is -34.281 km^2 over the last decade.

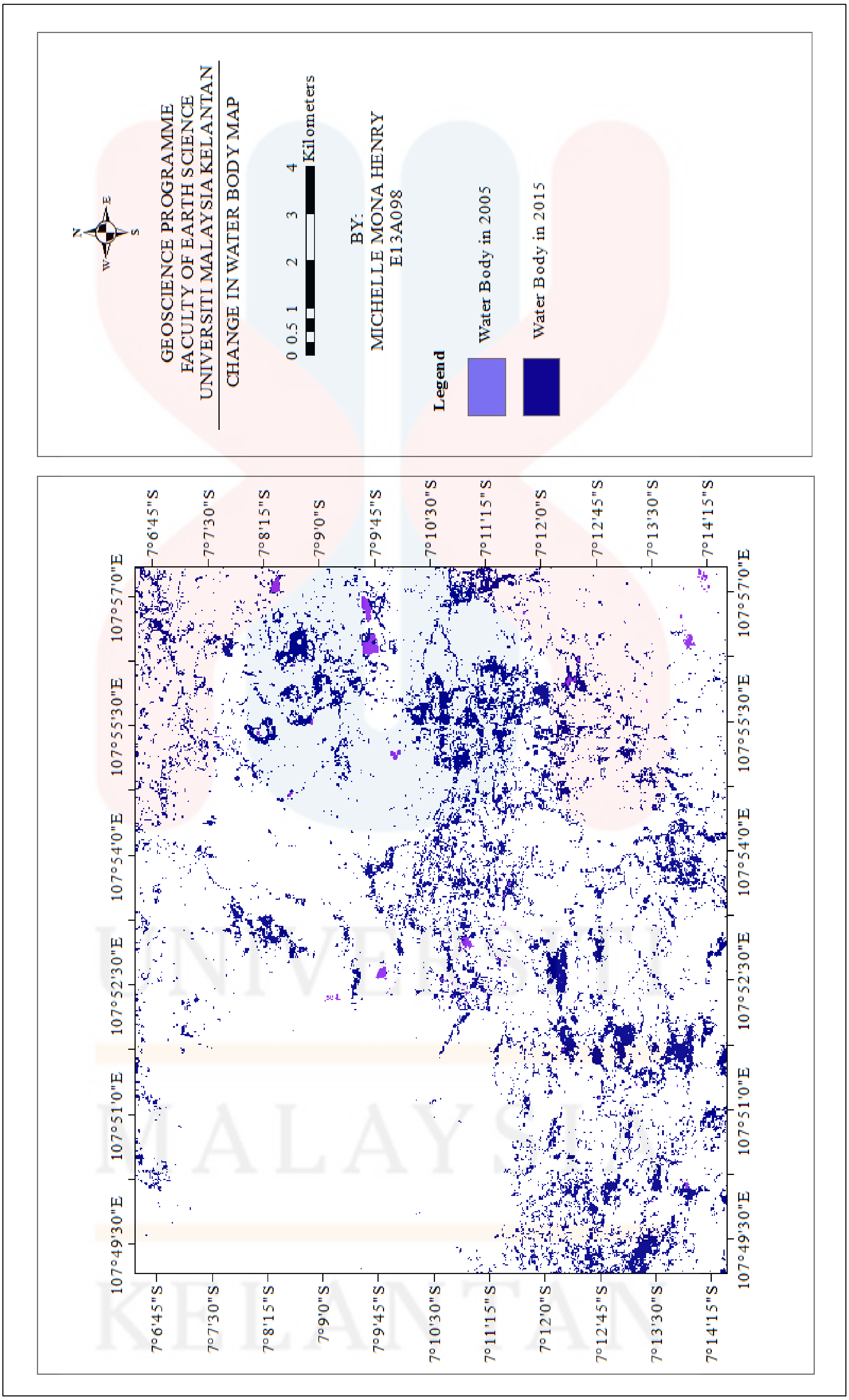

Figure 5.7 Land use change map of water body area from 2005 – 2015

The figure above portrays the land use map of the year 2005 and 2015 in terms of agriculture area. The light blue coloured represented the water body area for the year 2005 whereas the dark blue coloured represented the water body area for the year 2015. With reference to the map, it can be identified that the water body area has increased by 9.677% that is 21.816 km^2 over the last decade.

5.2 Land use Status

Table 5.1 Change in area in different land use classes in Tarogong area

Land use/cover Classes	2005		2015		Change 2005 - 2015	
	km^2	%	km^2	%	km^2	%
Built Up	20.968	9.301	38.614	17.128	17.646	7.827
Vegetation	41.625	18.464	87.768	38.932	46.143	20.468
Agriculture	108.651	48.195	57.327	25.429	-51.324	-22.766
Barren	53.491	23.727	19.210	8.521	-34.281	-15.206
Water Body	0.705	0.313	22.521	9.990	21.816	9.677
Total	225.44	100	225.44	100	0	0

The land use is classified using Landsat 7 for the year 2005 and Landsat 8 for the year 2015 both at a resolution of 30 m. By using the most popular supervised classification technique that is the Maximum Likelihood Classification (MLC) method, it is found that the overall accuracy of the land use classification results obtained for 2005 and 2015 are 94.77% and 86.17% respectively.

The land use for the year 2005 with a Kappa coefficient of 0.9161 reveals that the area which is covered by built up is 9.301% (20.968 km^2). 18.464% (41.625 km^2) of the area is covered by vegetation. Agriculture covers the area largely by 48.195%

(108.651 km^2). As for barren, it covers 23.727% (53.491 km^2) of the area. Lastly, the water body has the smallest area coverage of 0.313% (0.705 km^2).

Furthermore, the land use of the year 2015 with a Kappa coefficient of 0.7924 shows that the area which is covered by built up is 17.128% (38.641 km^2). In comparison with 2005, vegetation covers the area largely by 38.932% (87.768 km^2) instead of agriculture which covers the area largely in 2005. 25.429% (57.327 km^2) of the area is covered by agriculture. On the contrary with the land use status in 2005, the barren has the smallest area coverage of 8.521% (19.210 km^2). Lastly, as for the water, it covers 9.990% (22.521 km^2) of the area.

5.3 Land use Analysis

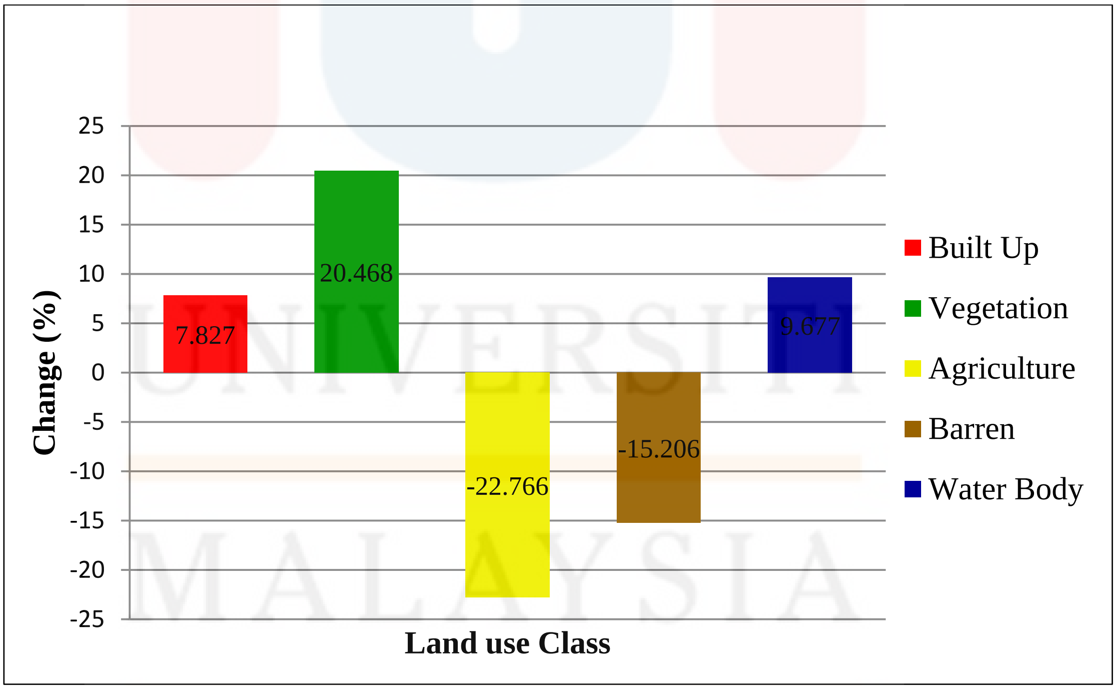

Figure 5.8 Diagrammatic illustration of land use change from 2005 – 2015

With reference to Table 5.1 as well as Figure 5.1 – Figure 5.8, the study area, Tarogong area has experienced both positive and negative changes in terms of land use. For the last decade, from 2005 to 2015, the built up area has piled up from 20.968 km^2 in 2005 to 38.614 km^2 in 2015 bringing up about 7.827%. The vegetation area has rocketed as well by 20.468% from 41.625 km^2 in 2005 to 87.768 km^2 in 2015. However, the agriculture area has decreased from 108.651 km^2 in 2005 to 57.327 km^2 in 2015 which accounts for -22.766%. The barren area showed a similar pattern as the agriculture area with a reduction from 53.491 km^2 in 2005 to 19.210 km^2 and hence gives a change of -22.766%. Last but not least, as for the water body area, in 2005, the area has a total of 0.705 km^2 which increased to 22.521 km^2 in 2015 giving a rise of 9.677%.

Table 5.2 Land encroachment of land use

Year / **Land Use Categories**		**2005**				
		Built Up	**Vegetation**	**Agriculture**	**Barren**	**Water Body**
2015	**Built Up**	70.049	0.381	10.706	22.554	9.962
	Vegetation	10.975	85.319	26.206	39.972	13.921
	Agriculture	12.151	6.897	40.550	14.209	35.504
	Barren	2.966	4.285	6.022	19.117	4.981
	Water Body	3.859	3.118	16.515	4.147	35.632
	Class Total	100.000	100.000	100.000	100.000	100.000

Table 5.2 demonstrates the land encroachment for different land categories during the year 2005 to the year 2015. From the data obtained through the post classification of change detection matrix, it is revealed that:

1. for built up area: 10.975% has been converted into vegetation area, 12.151% into agriculture area, 2.966% into barren area and 3.859% into water body area
2. for vegetation area: 0.381% has been regenerated into built up area, 6.897% into

agriculture area, 4.285% into barren area and 3.118% into water body area

3. for agriculture area: 10.706% has been transformed into built up area, 26.206% into vegetation area, 6.022% into barren area and 16.515% into water body area
4. for barren area: 22.554% has been shifted into built up area, 39.972% into vegetation area, 14.209 % into agriculture area and 4.147% into water body area
5. for water body area: 9.962% has been replaced into built up area, 13.921% into vegetation area, 35.504% into agriculture area and 4.981% into barren area

5.4 Discussion

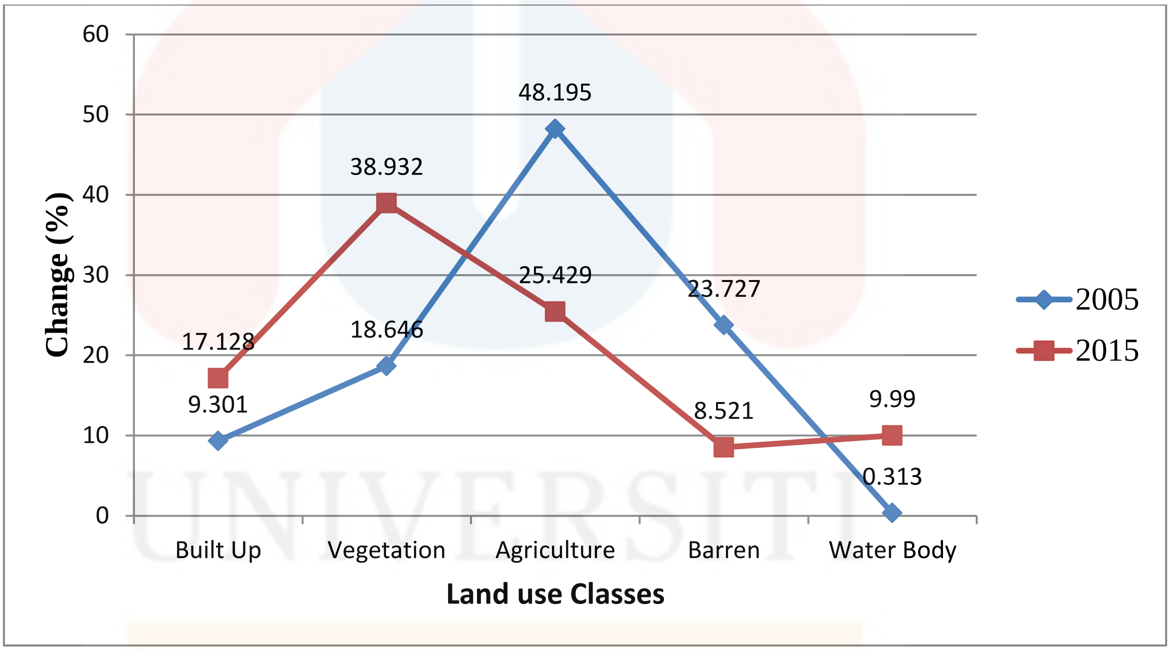

Figure 5.9 Diagrammatic illustration of land use of 2005 & 2015

The information on the land use is important in aiding the monitoring of the dynamics change of land use/cover that resulted from the increasing population.

Built up area by definition includes villages, towns, cities and man-made buildings. With reference to (Badan Pusat Statistik Kabupaten Garut, 2016), the total number of population in 2005 is 2 216 820 while the total number of population in 2015 is 2 548 723. This shows a big addition in the total number of population by 331 903 and has affected the built up area by 7.827% (17.646 km^2). As the number of population increases, the built up area increases as well in order to support the needs of shelter for the people. Based on the land use map of 2005 (Figure 5.1) and land use map of 2015 (Figure 5.2), it can be seen that the built up area is becoming more dense in the South East (SE) direction of the map. This is due the fact that an active stratovolcano lies on the North West (NW) of the study area. Hence, the people are taking pre-caution and expand the built up area in the opposite direction of the stratovolcano to prevent any unwanted incidents in the event of volcanic eruption.

Besides that, the vegetation area discussed in this finding is divided into plantations, forests, mangrove forests and estates. As the number of population increases, the vegetation area increases as well by 20.468% (46.143 km^2). This is closely related because the rising up in the number of population adds up the labor forces for vegetation activities as more job opportunities can be created. Vegetation plays a very crucial part for the people in the area of study because they need food to survive and income to support their lives. There are various vegetation comodities, for instance, tea, rubber, cocoa, quinine and palm oil are the main comodities. To put it simply, the higher the number of population, the higher the area of vegetation area as more people participated in the sustaining economy.

Irrigation pady field and rainfed paddy field are categorized into agriculture area. As shown in Table 5.1, the agriculture area displays a huge decrease by -22.766% (-51.324 km^2). According to the analysis result from the land enroachment as shown in Figure 5.2, 10.706% of the agriculture area has been transformed into built up area, 26.206% into vegetation area, 6.022% into barren area and 16.515% into water body area. As discussed in the previous paragraph, the production of vegetation products hiked up as the vegetation area increases giving more job placements for the people in the study area. Thus, it is possible that the people have shifted from planting paddy and started to get involved in vegetation activities.

Furthermore, barren area which is dry and empty with the incapability to grow any vegetation or known as vacant land portrays a reduction of -15.206% (-34.281 km^2). The increment in the number of population and the decrement of thr barren area are correlated to one another. When the number of population increases, the build up area increases too. This affect the barren area in a way in that the barren area is replaced by the build up area by 22.554% as more developments are taking places in the area of study especially in terms of buildings and houses. Moreover, the barren area is converted into vegetation area by 39.972% to support the life of the people.

Finally, the water body in this research not only refers to rivers and lakes but generally referring to any significant accumulation of water on the Earth's surface such as run off from rain. Based on Table 5.1, the water body area rises up by 9.677% (21.816 km^2). It should be noted that the data for the year 2005 obtained by Landsat 7 (ETM+) was taken on the 16th May 2005 whereas the data for the year 2015 obtained by Landsat 8 (OLI & TIRS) was taken on the 25th September 2015. In Indonesia, the rainy season are from October to March. On the contrary, the dry season are from April to September. Thus, as the data for Landsat 8 are acquired at the end of September, the water body shows an increase due to the influence of high rain fall. Another point to be taken into consideration is the guttation process which is the loss of water from plants in the form of liquids. Guttation occurs only during heavy rains where there is a very high relative humidity in the atmosphere. During this process, the plants' roots absorb more water and therefore creating root pressure. This root pressure will then push the water up and out from the plants via hydathodes, the openings that can be found on the tip of the leaves. As the vegetation area increases and together with the occurrence of the rainy season, more water body area is being detected by the satellite.

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

In a nutshell, all the research objectives listed earlier in Chapter 1 had been achieved namely; to produce a geological map of Tarogong area with 1:25000 scale, to identify the land use development of Tarogong area using remote sensing analysis and to generate a land use map of Tarogong area.

A geological map of Taragong area with a scale of 1:25000 has been produced. Chapter 4 basically cover geological mapping and general geology of Taragong area, Garut. The general geology part includes geomorphology, stratigraphy, structural geology and historical geology. The study area has a highest elevation of 1 450 m and the lowest elevation of 700 m where both area are considered to be mountainous areas. There are four types of drainage patterns that can be found in the area of study which are dendritic, parallel, rectangular and deranged. A biological weathering has been observed as well during the mapping period. Based on the geological map and the mapping conducted, the geology of Taragong area can be divided into two main geological units namely andesite and basalt with four types of deposition units which are lava flow, pyroclastic falls and pyroclastic flow as well as lahar. Lava flow, pyroclastic flows and pyroclastic falls falls under primary deposits while the latter falls under secondary deposits. The lithology unit of lava flow can further be classified into Guntur Lava Flow A, Guntur Lava Flow B, Guntur lava Flow C, Volcanic Product of Picung, Volcanic Product of

Cileungsing, Volcanic Product of Putri – Katomas and Volcanic Product of Kamojang. Besides that, Guntur Pyroclastic A and Guntur Pyroclastic B are classified under the lithology unit of pyroclastic fall. For pyroclastic flow, Volcanic Debris Avalanche of Gandapura is classified under the mentioned class. The lithology unit of lahar has the lahar itself under it. In general, the rocks present in the study area are andesite, basalt and andesite – dacite. As for the structural geology, a number of faults are found. For lineament analysis, the strongest force in is acting from the North – East direction while the weakest force is acting in the North – West direction.

Furthermore, using the remote sensing analysis, the land use development of Taragong area has been identified. By using the maximum Likelihood Classification (MLC) technique which is the most popular supervised classification method, the built up area has piled up to 7.87% due to an increase from 20.968 km^2 in 2005 to 38.614 km^2 in 2015. The vegetation area has rocketed as well from 41.625 km^2 in 2005 to 87.768 km^2 in 2015 bringing up about 20.468%. However, the agriculture area accounts for -22.766% as it has decreased from 108.651 km^2 in 2005 to 57.327 km^2 in 2015. The barren area showed a similar pattern as the agriculture area gives a change of -22.766%with a reduction from 53.491 km^2 in 2005 to 19.210 km^2. Last but not least, there is a rise of 9.677% for the water body area as in 2005, the area has a total of 0.705 km^2 which increased to 22.521 km^2 in 2015.

Finally, a land use map of Taragong area has been generated too by using the satellite image of Landsat 8 that is then analysed by using a software called ENVI. Based on the map with a Kappa coefficient of 0.7924, it shows the built up area covers the area by 38.641 km^2 that is equals to 17.128%. The vegetation covers the area largely by 87.768 km^2 bringing up 38.932%. As for the agriculture area, a total of 57.327 km^2 covers the area that is about 25.429%. The barren area has the smallest area coverage of 19.210 km^2 which gives only 8.521%. Lastly, as for the water, it covers 22.521 km^2 of the area which is equivalent to 9.990%.

6.2 Recommendation

For future research, there are a few suggestions that can be taken into consideration. Firstly, a petrography study on the rocks in Taragong area, Garut can be performed in order to study mineral content and the textural relationship within the rocks by means of microscopic examination. This will lead to detailed description and classification of the rocks present in the area of study.

In terms of specification, remote sensing analysis can be used in hazard assessments in the study area. For instance, volcanic eruption. Taragong area, Garut which lies at the longitude of 107°51’30.09” E to 107°54’13.45” E and the latitude of 7°9’12.52” S to 7°11’54.55” S is located near a stratovolcano type of volcano that is, Gunung Guntur. Through the use of remote sensing analysis, the hazard can be monitored without the need of *in situ* observation hence resulting in better mitigation plans. Remote sensing analysis includes ground surface deformation and topographic change mapping, earthquake analysis, thermal anomaly mapping and detecting, measuring and tracking volcanic gases and ash from eruption plumes and clouds. With such comprehensive volcanic eruption assessment, efficient strategies can be created to be used before and after the eruption.

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APPENDICES

Appendix A Elevation at 761 m

Appendix B Tobacco plantations in Taragong area

Coordinate: 107°51’38.63” E 7°10’30.79” S