# ASSESSMENT OF RAINFALL DISTRIBUTION OVER PENINSULAR MALAYSIA USING SATELLITE-BASED RAINFALL DATA

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## ABSTRACT

Rainfall distribution is spatial and temporal variability. High spatial and temporal resolution data are required for studying the rainfall distribution over Peninsular Malaysia. The availability of accurate rainfall data at proper temporal and spatial scale is vital for water resources sustainable planning and security. Thus, satellite-based is an alternative source of information especially for developing country like Malaysia where there are many areas that do not have ground observation. The main objective of this study was to assess rainfall distribution over Peninsular Malaysia using satellite-based rainfall. The specific objectives as follows; To produce monthly average rainfall satellite-based map; and To analyze the rainfall distribution statistically. Data is collected from TRMM Multi-satellite Precipitation Analysis (TMPA) version 7 based images as monthly rainfall from public domain for 5 years period of time (July 2009-June 2014). Rainfall data from the satellite were processed and converted into Geographical Information System (GIS) ready to produce map. Monthly rainfall distribution is statistically analysed and assessed. For study period, July 2009-June 2014, the average of annual rainfall distribution from TMPA satellite- based calibrated image is 2376 mm, 4.6% more than previous report. The annual rainfall distribution for 5 years period time of July 2009-June 2010, July 2010-June 2011, July 2011-June 2012, July 2012-June 2013 and July 2013-June 2014 are 2490 mm(equal previous report), 2439 mm (<2%), 2532 mm (>17%), 2372 mm (<5%) and 2048 mm (<18%), respectively.Error! Bookmark not defined.

# ABSTRAK

Taburan hujan adalah kepelbagaian ruang dan masa . Data resolusi ruang dan masa yang tinggi diperlukan untuk mengkaji taburan hujan di Semenanjung Malaysia . Ketersediaan data hujan tepat pada skala temporal dan spatial yang betul adalah penting untuk perancangan sumber air dan keselamatan yang berterusan . Oleh itu , berasaskan satelit merupakan saluran alternatif maklumat terutama untuk membangunkan negara seperti Malaysia di mana terdapat banyak kawasan yang tidak mempunyai pemerhatian tanah . Objektif utama kajian ini adalah untuk menilai taburan hujan di Semenanjung Malaysia menggunakan berasaskan satelit hujan. Objektif khusus seperti berikut ; Melahirkan bulanan peta berasaskan satelit hujan purata; Menganalisa dan taburan hujan yang statistik . Data dikumpulkan daripada TRMM Multi - satelit Analisis Pemendakan ( TMPa ) imej versi 7 berdasarkan sebagai hujan bulanan daripada domain awam selama 5 tahun tempoh masa (Julai 2009 -Jun 2014) . Data hujan dari satelit yang telah diproses dan ditukar ke dalam Sistem Maklumat Geografi ( GIS ) bersedia untuk menghasilkan peta . Taburan hujan bulanan statistik dianalisis dan dinilai . Bagi tempoh kajian , Julai 2009 -Jun 2014, purata taburan hujan tahunan dari TMPa satellite- berasaskan imej ditentukur adalah 2376 mm , 4.6 % lebih daripada laporan sebelum ini . Taburan hujan tahunan selama 5 tahun masa tempoh Julai 2009- Jun 2010, Julai 2010 - Jun 2011, Julai 2011 - Jun 2012, Julai 2012 -Jun 2013 dan Julai 2013 - Jun 2014 adalah 2490 mm ( laporan yang sama sebelumnya ) , 2439 mm , ( < 2 % ) , 2532 mm ( > 17 % ) , 2372 mm ( < 5 % ) dan 2048 mm ( < 18 % ) masing-masing .

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## LIST OF ABBREVIATION

| | |
|---|---|
| EMR | Electromagnetic Radiation |
| GIS | Geographical Information System |
| JAXA | Japanese Aerospace Exploration Agency |
| NASA | National Aeronautics and Space Administration |
| NASDA | National Space Development Agency |
| NEM | Northeast Monsoon |
| NWRS | National Water Resources Study |
| SWM | Southwest Monsoon |
| TMPA | TRMM Multisatellite Precipitation Analysis |
| TRMM | Tropical Rainfall Measuring Mission |

# CHAPTER 1

# INTRODUCTION

## 1.1 INTRODUCTION

The analysis of rainfall behavior, particularly in water-related sectors such as agriculture, hydrology and water resource management (Deni *et al.*, 2007) is an important factor in order to assess the amount of water available to meet various demands.Therefore, the study of the spatio-temporal distribution of rainfall is also very important for the welfare of a national economy. Reliable estimation of rainfall distribution in Peninsular Malaysia poses a great challenge due to undulating surface terrain and complex relationship between land elevation and precipitation, but also due to lacks of detailed quantitative studies because of limited number of measurement points or stations and the problem of missing data (Wong *et al.*, 2009). Installation and maintenance of a dense rain-gauge network will be difficult in hilly and remote areas. In this case, the utilization of satellite-based is a better way of estimating rainfall for wide as well as for remote area.

Over recent years, the global climate has change due to greenhouse effect (gas concentration in atmosphere) that leads in temperature raising and changing in precipitation pattern (Ymeti, 2007). Thus, climate change studies are also aimed to analyze the rainfall the rainfall intensity to find the decreasing/increasing trend for the different intensity episodes (Varikoden *et al.*, 2010). The Inter-Governmental Panel on Climate Change (IPCC) in 2007 conclude that more intense precipitation events would likely to be occur in the future over many areas, and these would cause increase flash-floods, landslides, soil erosion and avalanches (IPCC, 2007). Related to these changes, extreme events that occur such as excessive rainfall and droughts, give big impact to the society. Table 1.1 and 1.2 shows some of floods and drought issues that happen throughout Peninsular Malaysia.

**Table 1.1:** Floods issues throughout Peninsular Malaysia

| State | Date | Title | Issues |
|---|---|---|---|
| **Kuala Lumpur** | 12 May 2014 | Havoc in KL as floods hit major roads. | Several roads temporary closed due to flash flood, 2 cars stuck at Jln Duta heading to Damansara. |
| **Kelantan** | 2 January 2014 | Number of victims rises to above 1000 in Kelantan. | Number of victims in two districts affected by flood which are Jeli and Tanah Merah increased slightly to 1043 people compared to 897 yesterday. |
| **Terengganu** | 9 December 2013 | Flood: Tactical bridge restores main route to Chukai town. | Main route to Chukai town cut off after the Sg. Limbung bridge collapse due to heavy rain and flood. |
| **Pahang** | 8 December 2013 | Dire situation in Pahang, Terengganu, over 65, 000 evacuees in 4 states. | Pahang remained the hardest-hit with 40, 399 people in 9 districts meanwhile in Terengganu the number rose to 23, 102 people from 5 districts. |
| **Pahang** | 7 December 2013 | Worsening situation in Pahang and Terengganu. | Second wave of flooding continue to worsen in Pahang and Terengganu with the number of evacuees jumping drastically especially in Kemaman. |
| **Selangor** | 6 September 2013 | Prolonged downpour wreaks havoc. | Flash floods affected the Federal Highway near BatuTiga area. Area that affected were Bandar Puteri, Bandar Bukit Tinggi, Tmn Eng Ann and Taman Selatan |
| **Pulau Pinang** | 6 April 2013 | Penang flooded this morning. | Major low-lying areas in Penang were flooded following a downpour last night. Streets affected is closed |

| | | | |
|---|---|---|---|
| | | | and motorists being stranded this morning. |
| **Selangor** | 18 February 2013 | Puchong under water. | 2-hour downpour in Puchong brought flash floods to several low-lying areas that result in massive traffic jam along Lebuhraya Damansara-Puchong (LDP) highway. |
| **Kuala Lumpur** | 7 March 2012 | Flash flood hits Klang Valley, 1 killed in landslide. | Raja Mohd Irfan Raja Azlan, 13, was killed in a landslip that trapped him under mounds of mud behind his house. |
| **Pahang** | 13 December 2011 | Flood situation improves in Pahang. | Fairer weather in afternoon allowed flood situation in Pahang to improve with only 847 people still seeking shelter at 13 relief center in Rompin. |
| **Johor Bharu** | 1 February 2011 | Johor, Negeri Sembilan and Malacca reel from rain and flood havoc. | Floodwaters have cut off communications, KTM have to stop train services to east and south of the country, 3 people were killed, fews swept away by strong current and 2 people missing. |

Source: New Straits Times (2009-2014)

**Table 1.2:** Drought issues throughout Peninsular Malaysia

| State | Date | Title | Issues |
|---|---|---|---|
| **Kuala Lumpur** | 1 March 2014 | Asean drought worse than usual. | The drought parching Singapore and parts of Malaysia and Indonesia threatens to raise food prices, slow economic growth and disrupt water supply. |
| **Kuala Lumpur** | 26 February 2014 | Malaysia, Singapore grapple with prolonged dry spell | In Peninsular Malaysia, 15 areas have not had rainfall in more than 20 days, some dry for more than a month. The dry weather is expected to run for another two weeks. |

| | | | |
|---|---|---|---|
| **Selangor** | 25 February 2014 | Drought-hit Malaysian state rations water | The lack of significant rainfall has caused increasing alarm, particularly in the state of Selangor, as meteorologists have warned the dry spell could last another month. |
| **Negeri Sembilan** | 20 February 2014 | 41 DAYS TO DISASTER: Negeri Sembilan feels the drought. | 41 days was the deadline given by Menteri Besar for state authorities to act before the water shortage problem affecting 7,000 households in Seremban hits 200,000 households. |
| **Kelantan** | 19 June 2012 | Water shortage puts Kelantan rice crop at risk. | The paddy planting season in 5 districts covering almost 30,000ha in Kelantan is at risk of being aborted as there is severe lack of water to irrigate the farms. |

Source: Star and New Straits Times (2012-2014)

In this research, efforts had been made to utilize remote sensing technology in order to estimate the rainfall over Peninsular Malaysia. Remote sensing techniques using space borne sensors provide an excellent complement to continuous monitoring of rain events both spatially and temporally (Chokngamwong and Chiu, 2007). The rain rate data of the rainfall distribution derived from TRMM Multisatellite Precipitation Analysis (TMPA). The high resolution of TMPAin temporal and spatial domain provides good opportunity to study rainfall distribution and characteristics due to monsoon season and climate change effect (Ali, 2014).

## 1.2 OBJECTIVE OF STUDY

The main objective of this study was to assess rainfall distribution over Peninsular Malaysia by using satellite-based rainfall. The specific objectives of this study were as follow:

i. To produce monthly satellite-based rainfall map.

ii. To analyze the rainfall distribution statistically.

## 1.3 SCOPE OF STUDY

In this study, satellite-based image of TMPA rainfall data (3B43verison 7) was collected from for five consecutive years (July 2009 until June 2014), over Peninsular Malaysia. Based from previous literature reviews, these data were obtained from public domain (http://neo.sci.gsfc.nasa.gov/). Satellite-based image of TMPA rainfall data were calibrated using model produced by Ali (2014). The states in Peninsular Malaysia were divided into four parts; a) South Zone (Johor, Melaka and Negeri Sembilan), b) North Zone (Perlis, Pulau Pinang and Kedah), c) East Zone (Terengganu, Pahang and Kelantan), and d) West Zone (Selangor, Kuala Lumpur and Perak).

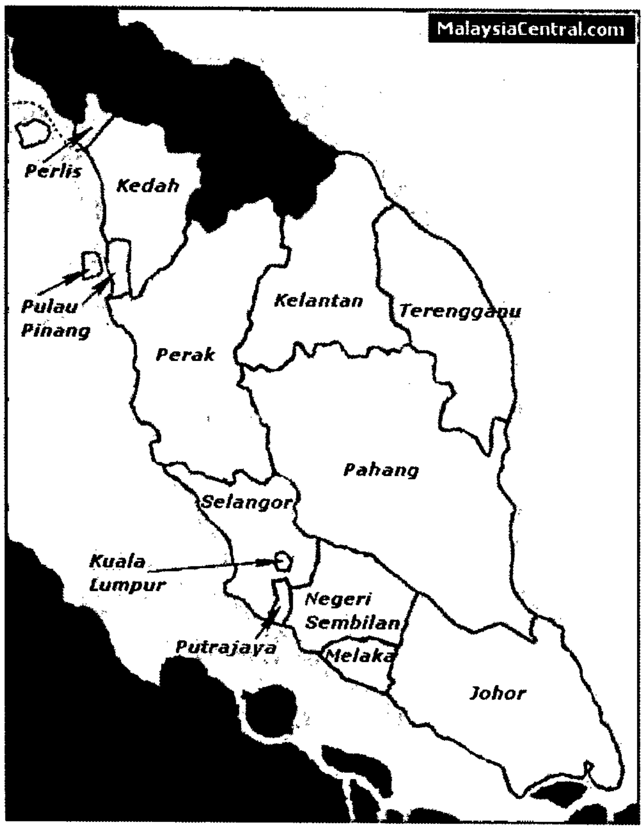


**Figure 1.1:** States in Peninsular Malaysia

Source: www.malaysiacentral.com/states-in-malaysia/ (2 January 2015)

## 1.4 SIGNIFICANCE OF STUDY

This study provides a good knowledge of rainfall which is essential for hydrological operational purposes such as estimating flood and drought. By using reliable satellite-based image of TMPA rainfall data (3B43verison 7), value of the rainfall data could be obtain over the large area as well as the area for this study. The collected data were analyzing and calibrate using *Geographical Information System* (*GIS*), the digital format data can be analyzing practically faster (Ali, 2014). Monthly satellite-based rainfall map and annual rainfall distribution were then analyzed.

The results were compared to the previous study of NWRS (2011). Within study period from July 2009 until June 2014, the average of annual rainfall distribution from *TMPA*-calibrated satellite-based image is 2376 mm, which is 4.6% more than annual average rainfall distribution from previous report, 2490 mm prepared by a consultant that appointed by government (NWRS, 2011).

## 1.5 THESIS STRUCTURE

This thesis consists of five chapters. Chapter one comprises the introduction section. It states the study background, objectives of study, scope of study and lastly significance of study. For chapter two, describe the key term in-purpose of these study and comprises the literature review that related and suitable for these research. Chapter three explains the research methodology that used for planning research type of data collected and the method of data analysis to be employed. For chapter four present the result that obtained from the study area and year of study and discussed the result from analysis. Finally, chapter five comprises the conclusion from the overall chapter and relates some recommendation for future work on research field.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 INTRODUCTION

Rainfall is an important process in the hydrological cycle. Variability of rainfall intensity is one of the primary elements in climate factor, however large space and time makes it difficult to be measured. Historically rain-gauges have been the primary data source in rainfall estimation. It also acts as measurement used to tune hydrologic models, but limited by their spatial coverage (Chokngamwong and Chiu, 2007). Conventional measurements from rain gauges cannot provide an adequate and reliable spatial representation of precipitation due to the spatial limitation of point-based measurement and relatively sparse distribution of gauge network (Javanmard*et al.*, 2010). Additionally, due to lack of data from rain-gauge, (Duan and Bastiaansen, 2013) stated that remote sensing can potentially solve this limitation by directly providing spatial rainfall over large areas.

## 2.2 REMOTE SENSING

Remote sensing is the science of obtaining information about an object, area or phenomenon without any physical contact with the target of investigation by using sensors to measure the *Electromagnetic Radiation (EMR)* reflected, or emitted by the target (Kumar and Reshmidevi, 2013). Remote sensing technology has been used for a long time because of the advanced capabilities of computers and the widespread use of spatial data, also (Ritchie *et al.*,2003) used to monitor water quality parameters. Physical, chemical and biological characteristics are the parameters of water quality that are suitable for human consumption. Ritchie *et al.*, (2003) stated that remote sensing techniques depend on the ability to measure changes in the spectral signature backscattered from water and relate these by empirical or analytical models to a water quality parameter. Current remote sensing systems offer unique methods for detecting patterns at the surface and for obtaining data for essential processes at different spatial scales ranging from centimeters to kilometers (Ymeti, 2007). Among the involved aspects, the availability of remote sensed data provided the knowledge of precipitation distribution at global scale and with spatio-temporal resolutions useful for those climatological applications that do not require a long observation period (Conti *et al.*, 2014).

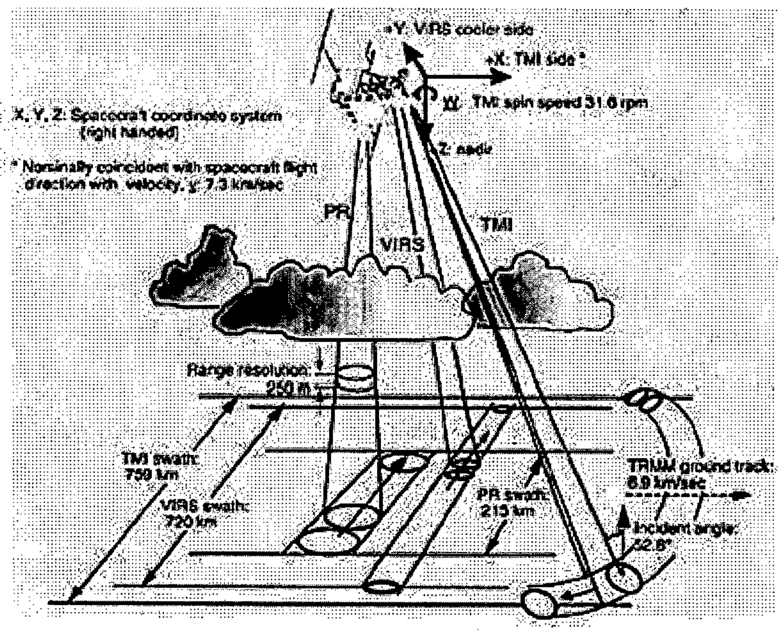


**Figure 2.1:** *TRMM* Sensor (Huey and Ibrahim, 2012)

### 2.2.1 *TRMM Multisatellite Precipitation Analysis (TMPA)*

Vrielinget *al.*, (2010) state that *TMPA* products are based on a several input sources; passive microwave data that derived from low earth orbit satellite is the first one, which has a strong physical relationship with precipitation, but a very sparse temporal sampling of rainfall. The "snapshot" precipitation estimate from the passive microwave data are calibrated using the *TRMM* precipitation radar, then integrated with brightness temperature information derived from long-wave infrared imagery from geostationary satellites, offering an excellent spatio-temporal coverage. Cloud-top brightness temperatures are well correlated to precipitation at coarse spatio-temporal scales, gives estimates of infrared precipitation.

*TRMM* is a long-term research program designed to study the Earth's land, ocean, air, ice and life as a total system (Islam and Uyeda, 2007). Both of (Islam and Uyeda, 2007; Chokngamwong and Chiu, 2007) mentioned that the launch of *Tropical Rainfall Measuring Mission (TRMM)* satellite in November 1997 cosponsored by *National Aeronautics and Space Administration (NASA)* of United States and the *Japanese Aerospace Exploration Agency* (*JAXA*, previously known as the *National Space Development Agency*, or *NASDA*) and, is the first coordinated international satellite mission to study tropical and sub-tropical areas (Huey and Ibrahim, 2012). *TRMM* has ability to estimate worldwide precipitation because ground-based radars that measure precipitation cover a very small part of the planet (Islam and Uyeda, 2007). TRMM has provided quality rainfall data (*TMPA*) for over 10 years (1998 until nowadays) (Ali., 2014).

*TRMM* rotates the earth on the inclinator between 35°Nand 35°S, low altitude (350 km) on *non-sun synchronous* orbit within 91.5 minutes for one rotation (15 rotations a day) which is able to penetrate through clouds and thus rainfall estimation will be precise (Ali, 2014). Meanwhile, Chongkamwong and Chiu, (2006) stated that *TRMM* version 6 (V6) algorithms have been reprocessing in order to improve the data quality, products as well as algorithm.*NASA* has been improving more of the data quality, products and also algorithms when the latest version (Version 7) of *TRMM* was posted on public websites on May 22 (2012) (Duan and Bastiaanssen, 2013). Therefore, *TRMM* 3B43 v7 have been used in this study. Source of data of *TRMM* is easy to be obtained only by downloading from public domain. From Ali, (2014), satellite-based image data is digital format, give continuous information in the study area as compared to discrete ground measurement. By using *Geographical Information System* (*GIS*), the digital format data can be analyzingpractically faster (Ali, 2014). *GIS* provides extraordinary ways to achieve significant progress in modeling, also provides opportunities to create multiscale representation by incorporating and linking digital maps at different scales and beneficial for analyzing the relationship between variables at different scales and for assessing the impact of scale in modeling (Ymeti, 2007).

## 2.3 CLIMATE CHANGE

Climate change is a change in the statistical distribution of weather patterns in global, occurs when long-term weather patterns are altered (i.e., human activities) that leads to global warming. Global warming is rising in global average temperature near Earth's surface which caused by increasing concentrations of greenhouse effect.On the other hand, climate change is variability that continues over a longer period and is statiscally significant (Loo *et al.*, 2014). Climate change give impacts on water quantity and water quality, where excess of water (extreme rainfalls and flow) will leads to increasing of floods and soil erosion (scouring of drainage structures and sedimentation in rivers) for quantity also increase in pollution (litters, nutrients and sediments) for quality and shortage of water (drought) may reduce the inflows to reservoirs, recharge of groundwater and stream-flows (affect raw water abstraction) for quantity and concentrated pollutant level in streams for quality. Climate change also gives impact on coastal resources due to sea level rise (SLR) which leads to increasing in sea surface elevations along the waterfront, increasing in wave height and current speed along the shoreline, salt water intrusion (affect surface and groundwater) and shifting the ecosystem.

### 2.3.1 Topography and Monsoon

Malaysia is located in Southeast Asia, separated by two main lands of South China Sea where Peninsular Malaysia to the west and East Malaysia to the east. Malaysia's climate is categorized as equatorial however some from northern Peninsular Malaysia experience tropical monsoon, thus, being hot and humid throughout the year with light winds are characterized by high annual rainfall, humidity and temperature (Suhaila and Jemain, 2008). Peninsular Malaysia is located south of Thailand, north of Singapore and east of the Indonesian island of Sumatra. Peninsular Malaysia is located between latitude 1° and 7° north and longitude 99° and 104.5° east (Wong *et al.*, 2009; Ali, 2014), composed of highland, floodplain and coastal zone (Wong *et al.*, 2009).

The climate of Peninsular Malaysia is described by four seasons, namely two monsoon seasonsand two inter-monsoon seasons. *The Northeast Monsoon (NEM)* start from early November and ends in March, originating from China and the north Pacific which brings heavy rainfall to the east coast states of Peninsular Malaysia (Huey and Ibrahim, 2012; Ali, 2014), where the wind may reach more than 30 knots (Suhaila and Jemain, 2008).During the *NEM*, the consequences of heavy rainfall leads to widespread floods in the exposed area (Huey and Ibrahim, 2012) however, the areas that sheltered by the mountain ranges (the Titiwangsa Range) are more or less free from its influence (Suhaila and Jemain, 2010). Meanwhile, for the *Southwest Monsoon (SWM)*, from the desserts of Australia usually occurred in mid of May and ends in September, is dried period for the whole country (Huey and Ibrahim 2012), particularly for the other states of the west coast of Peninsular. In contrast, the changes of period between monsoons are two inter-monsoon seasons which are April and October, often results in heavy rainfall that usually occurs in the form of convective rains. Mote details and information about monsoon of Peninsular Malaysia can be referred to website of Malaysian Meteorological Department (http://www.met.gov.my/).

## 2.4 SUMMARY

The literature review explains that the studies of remote sensing and climate change are important in assessing the rainfall distribution. From the understanding of all parameters, rainfall data can be obtained from recent technology of remote sensing meanwhile topography and monsoon are relates with climate change.

# CHAPTER 3

# METHODOLOGY

## 3.1 INTRODUCTION

This chapter describes the phases involved in research methodology to achieve the study objectives. There were FOUR (4) phases, namely; i) data collecting, ii) pre-processing data, iii) processing and iv) results and analysis (Figure 3.1). First phase, explained about rainfalls data collecting. Second phase, explained about pre-processing of the collected data before process phase takes place. For third phase, explained about on how processing data from *TMPA* satellite-based image and all the phase will be explained in following sections in this chapter. While the results and analyses are described in Chapter 4.

This research is taken over Peninsular Malaysia located between latitude 1°-7°N and longitude 99°-104.5°E which has total area of 131, 798.35 km², divided into 11 states and two federal territories of Kuala Lumpur and Putrajaya. Pahang is the largest state in Peninsular Malaysia, area of 35,965 km² that include the highest peak of the main range (the Titiwangsa Range), GunungTahan (2,187 m) while Perlis is only 795 km², as the smallest state.The main range forms as backbone of Peninsular Malaysia, separated eastern part (facing South China Sea) from the western part (facing Straits of Malacca and Indian Ocean). Due to humid tropical climate, the weather of Peninsular Malaysia is warm and humid all year with temperature ranging from 21°C to 32°C (Wong *et al.*, 2009). Based from chapter 2 (in 2.3.1 topography and monsoon), the rainfall patterns in the study area can be decided.