ASSESSMENT VARIABILITY OF ANNUAL DAILY MAXIMUM RAINFALL

OF KELANTAN, MALAYSIA

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ABSTRACT

Kelantan is one of the areas in Peninsular Malaysia that often vulnerable with a big flood and affected all local mains road. This situation prevents the help and rescue to get the flooding area. The main objectives of this study were to assess variability of annual daily maximum rainfall, to analysis annual rainfall, annual monthly maximum rainfall and annual daily maximum rainfall and to estimate expected return periods of extreme rainfall events of Kelantan, Malaysia for the period of 1998 to 2013. This study uses rainfall data derived from Tropical Rainfall Measuring Mission (TRMM) satellite-based rainfall data. The rainfall data from TRMM satellite-based for each major city in Kelantan were retrieved using Geographical Information System (GIS) technique. This study was focus on rainfall characteristics of major cities in Kelantan (Gua Musang, Kuala Krai, Jeli, Pasir Puteh, Bachok, Kota Bharu, Tumpat, Machang, Pasir Mas and Tanah Merah). Descriptive statistical analysis was conducted on annual rainfall, annual monthly and daily maximum rainfall. Gumbel distribution function was applied to estimate return periods of extreme rainfall events. It was found that annual daily maximum rainfall for Pasir Putih, Kelantan is 616.13 mm which had a return period of 100 years was the highest maximum annual daily rainfall estimated. For future, the result from this study could be used as a guideline in planning and designing any infrastructure in Kelantan, Malaysia.
ABSTRAK

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

The weather in Malaysia is characterised by two monsoon regimes, namely, the Southwest Monsoon from late May to September, and the Northeast Monsoon from November to March. The Northeast Monsoon brings heavy rainfall, particularly to the east coast states of Peninsular Malaysia (Kelantan, Terengganu, Pahang and East Johor) and western Sarawak, whereas the Southwest Monsoon normally signifies relatively drier weather. The transition period in between the monsoons is known as the intermonsoon period.

The 2014–2015 Malaysia floods hit Malaysia from 15 December 2014 – 3 January 2015. More than 200,000 people affected while 21 killed on the floods (www.thestar.com). This flood has been described as the worst floods in decades. Kelantan were the worst recorded. Due to its geographical characteristics which are in east coast state, unplanned urbanization, and proximity to the South China Sea, Kota Bharu has become extremely vulnerable monsoon floods every year. The water level of Sungai Kelantan at Tambatan DiRaja, which has a danger level of 25 metres, reached 34.17 metres in December, 2014 compared to 29.70 metres in 2004 and 33.61 metres in 1967. The levels at Tangga Krai, which has a danger level of 5 metres, reached 7.03 metres compared to 6.70 metres in 2004 and 6.22 metres in 1967 (Richard Devis, 2015)

The floods had covered the main roads to Kelantan and make it difficult for the help and rescue process. Apart from that, the government's losses from floods in several states across Malaysia are estimated to cost up to RM2 billion that comprise damaged
public infrastructure such as roads and bridges. The recent floods also give a huge damage to Keretapi Tanah Melayu Berhad (KTMB) railway infrastructure which includes damage to railway quarters, signalling, tracks, locomotives, machinery, and rolling stock (www.thestar.com). This is because all infrastructures were designed based on the 50 years back probability rainfall pattern data. The uncertain climate changes cause the maximum rainfall increase then more water would flow to rivers. That is when the rivers overflow; causing major flood that resulted in millions in damages, not to mention lost lives and destroyed homes.

1.2 PROBLEM STATEMENT

The flood in 2014 occurred in Kelantan was the worst in Malaysia and have destroyed and damaged almost all the infrastructure such as bridges, road and drainages. Most major routes have been planned and designed by the intensity of extreme rainfall historical data. Due to global climate change, characteristics of rainfall (intensity, depth, spatial and temporal) change. Therefore, this study aim to come out with the latest estimated extreme rainfall data for each major city in Kelantan so that it can be used in future infrastructure design.

1.3 OBJECTIVES OF STUDY

The study main focus was to assess variability of annual daily maximum rainfall of Kelantan Malaysia, for the period of 16 years (Jan 1998 - Dec 2013). The specific of this study are as follows:

1. To analysis annual rainfall, annual monthly maximum rainfall and annual daily maximum rainfall
2. To estimate expected return periods of extreme rainfall events
1.4 SCOPE OF STUDY

This study was limited to rainfall data for 16 years starting from January 1998 until December 2013 of main cities in Kelantan, Malaysia (Fig.1.1). This study uses rainfall data derived from satellite image data Tropical Rainfall Measuring Mission (TRMM). Literature review found that many previous researches using such data, and easily obtained from the public domain. Method uses for data analysis are Descriptive Statistical Analysis and Gumbel Distribution Function to obtain the return periods.

Figure 1.1: Kelantan Study Area
Source: www.malaysia-today.net

1.5 SIGNIFICANT OF STUDY

The return period and probability of expected extreme daily rainfall provides appropriate information for engineer to design any structure that can accommodate with high rainfall intensity.
1.6  THESIS STRUCTURE

This report consists of five chapters. Chapter one comprises the introduction section. Background of study, problem statement, objectives of study, scope of study and lastly significant of study are included. In chapter two, it comprises related and suitable literature reviews for the research. Chapter three will explained the research methodology used to collect rainfall data from satellite-based data. The data will then be analysed to get the maximum value and the annual value. The result obtained is presented and discussed in chapter 4. Finally, chapter five comprises the conclusion of the overall chapter and relates some recommendation for future work in the research field.
CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The hydrological cycle is a balance process among precipitation, evaporation, and all the steps in between. This process powered by energy from the sun, continuous exchange of moisture between the oceans, the atmosphere and the land. Evaporation is the process by which water changes from a liquid to a gas whether it is from oceans, seas, and other bodies of water (lake, rivers, streams) provides nearly 90% of the moisture in atmosphere. Another 10% remaining is released by plants through transpiration. In addition, a very small portion of water vapor enters the atmosphere through sublimation, the process by which water changes directly from a solid (ice or snow) to a gas. The gradual shrinking of snow banks in cases when the temperature remains below freezing results from sublimation. Together, evaporation, transpiration, and sublimation, plus volcanic emissions, account for almost all the water vapor in the atmosphere that is not inserted through human activities. While evaporation from the oceans is the primary vehicle for driving the surface-to-atmosphere portion of the hydrologic cycle, transpiration is also significant. For example, a cornfield 1 acre in size can transpire as much as 4,000 gallons of water every day. Then the water vapor will condensed and produced precipitation such as rain, snow, sleet and hail which are the primary mechanism for transporting water from atmosphere back to the Earth’s surface (Fig 2.1).
However, changes in the amount of rain falling during storms provide evidence that the water cycle is already being affected. Over the past 50 years, the amount of rain falling during the most intense 1 percent of storms increased by almost 20 percent. Warmer winter temperatures cause more precipitation to fall as rain rather than snow. Furthermore, rising temperatures cause snow to begin melting earlier in the year and rising the sea level which causes for flood. Changes in global atmospheric circulation patterns accompany La Niña and are responsible for weather extremes in various parts of the world that are typically opposite to those associated with El Niño. These patterns result from colder than normal ocean temperatures inhibiting the formation of rain-producing clouds over the eastern equatorial Pacific region while at the same time enhancing rainfall over the western equatorial Pacific region (Indonesia, Malaysia and northern Australia.) These patterns affect the position and intensity (weakening) of jet streams and the behaviour of storms outside of the tropics in both the Northern and Southern hemispheres.

As most people are well aware, the immediate impacts of flooding include loss of human life, damage to property, destruction of crops, loss of livestock, and deterioration of health conditions owing to waterborne diseases. As communication links and infrastructure such as power plants, roads and bridges are damaged and disrupted, some economic activities may come to a standstill, people are forced to leave their homes and normal life is disrupted.
Damage to infrastructure causes long-term impacts, such as disruptions to supplies of clean water, wastewater treatment, electricity, transport, communication, education and health care. Loss of livelihoods, reduction in purchasing power and loss of land value in the floodplains can leave communities economically vulnerable.

2.2 STUDY AREA

2.2.1 Location

Kelantan is located at east coast of peninsular Malaysia with latitude of 06°10’N and longitude of 102°20’E. The study area include main cities in Kelantan which are Gua Musang, Kuala Krai, Jeli, Pasir Puteh, Bachok, Kota Bharu, Tumpat, Machang, Pasir Mas and Tanah Merah Kota Bharu is one of the main districts in Kelantan and become the capital city of Kelantan which was the main location of commercial centre and state management office. Kelantan River Basin is selected as a pilot area because it represents typical basins and flood plains that are prone to annual monsoon floods in Malaysia. Kelantan River is the major river in Kelantan state and emerges at the confluence of the Galas river and Lebir river near Kuala Krai and meanders over the coastal plain until it finally reached into the South China Sea, about 12 km north of Kota Bahru. The main reach of the Kelantan River has some further larger tributaries downstream. The basin covers 85 percent of the state’s surface area. The river only drops 10 meters from the coast up to Guillemard Bridge with the distance of 60 km. The main river comprises of seven major Subcatchments (Kota Bahru, Gullimard, Pergau, Kuala Krai, Galas, Lebir and Nenggiri) that covers a drainage area of 13,170 km. Four major cities are located along the river are Kota Bahru, Pasir Mas, Tumpat and Kuala Krai.

2.2.2 Climate

Kelantan has a tropical climate, with temperatures from 21 to 32 °C and intermittent rain throughout the year. The wet season is the east-coast monsoon season from November to March which develops in conjunction with cold air outbreaks from Siberia produce heavy rains which often cause severe floods along the east coast states
of Kelantan, Terengganu, Pahang and East Johor in Peninsular Malaysia, and in the state of Sarawak in East Malaysia. During this season, most states experience monthly rainfall minimum (typically 100 - 150 mm). This is attributed to relatively stable atmospheric conditions in the equatorial region. In particular, the dry condition in Peninsular Malaysia is accentuated by the rain shadow effect of the Sumatran mountain range.

2.3  FLOOD EVENTS IN STUDY AREA

2.3.1  Historical Flood Events

Floods in the study area are mainly caused by heavy rainfall brought by the monsoon and categorize as annual flood as it occurs every year during the monsoon season. The study area faces Northeast monsoon from November to March every year. The Northeast monsoon brings heavy rain to east coast states of Peninsular Malaysia and western Sarawak, whereas the Southwest monsoon normally signifies relatively drier weather. Due to its geographical characteristics, unplanned urbanization and proximity to the South China Sea, Kota Bharu has become extremely vulnerable to monsoon flood every year. Severe flooding occurred in 1926 and 1967. In the 1967 floods 84% of the Kelantan population (537,000 people) were badly affected. Some 125,000 people were evacuated and 38 drowned. Some of other recorded flood experiences in study area occur in 1983, 1986, 1988, 1993, 2001, 2003, and 2004. The unprecedented in November 2004 which was triggered by monsoon, has been described as one of the worst natural flood in the history of Kota Bharu other than the latest flood in 2015 with more than people 200,000 affected while 21 killed on the floods.

The highest number of deaths was recorded as 21 in recent event 2015 with the number of evacuees of 200,000 causing monetary loss of US$ 5.27 million. The second highest monetary damage occurred in 1993 with value of US$ 2.22 million. The recorded historical floods, that the number of evacuees was always 100 or above which implies that those floods were severe. According to the past records intensive precipitations have become more frequent and more severe which cause frequent floods. Thus, a flood early warning system is essential to provide sufficient time for the authorities to evacuate the downstream communities to safer places and take necessary measures to protect physical properties in vulnerable areas.
2.4 HYDROLOGY DATA FOR INFRASTRUCTURE DESIGN

2.4.1 Rainfall Characteristics

Three main characteristics of rainfall are its amount, frequency and intensity, the values of which vary from place to place, day to day, month to month and also year to year. Precise knowledge of these three main characteristics is essential for planning its full utilization. A soil has a definite and limited water intake rate and moisture holding capacity. Hence greater quantities as well as intensities of rainfall normally reduce the effective fraction, increasing run-off and lessening infiltration. Similarly, uneven distribution decreases the extent of effective rainfall while an even spread enhances it. A well distributed rainfall in frequent light showers is more conducive to crop growth than heavy downpours. For example, annual rainfall is lower than 100 mm in the Middle Eastern desert countries, so it may all become effective. In countries like India and Pakistan, intensity, frequency and amount are high during July and August and hence the effective fraction is very low. From November to April, however, most of the rainfall is effective in these countries due to its low intensity, frequency and amount.

Moreover, this rainfall characteristic analysis can also be used by engineers and planner to design infrastructures, roads and bridges to specification that will maintain their accessibility and longevity. Knowing the historical size of floods and frequencies helps governments plan where to put business, hospitals, homes and dams for flood mitigation needs. The infrastructure is designed based on the intensity and the frequency of historical hydrology data. The existing infrastructure may not be able to withstand the extreme flood and collapse or damage due to climate changes.

2.4.2 Return Periods

A return period or also known as a recurrence is an estimate of the likelihood of an event, such as an earthquake, flood or a river discharge flow to occur. It is a statistical measurement typically based on historic data denoting the average recurrence interval over an extended period of time, and is usually used for risk analysis. For example is to decide whether a project should be allowed to go forward in a zone of a certain risk, or to design structures to withstand an event with a certain return period.
The following analysis assumes that the probability of the event occurring does not vary over time and is independent of past events. When dealing with structure design expectations, the return period is useful in calculating the riskiness of the structure. The probability of at least one event that exceeds design limits during the expected life of the structure is the complement of the probability that no events occur which exceed design limits.

2.5 DETERMINATION OF RAINFALL BY USING SATELLITE IMAGE DATA.

The study focuses on the needs of developing a technique which can be used to determine the quantity of rainfall with the right information and cheaper cost to retrieve. Since 1970s, much effort was made to determine the data from satellite image data (Barrett, 1993). The main importance of estimating data by using satellite image data is to provide information regarding to events, the number and data distribution for the field of meteorological, climatological, hydrological and hydrological sciences (Levzzani et al., 2001). The ability of satellite image for estimating data depends on the position of the satellite and the type of sensor used.

Generally, the distribution of information and the number of data from satellite image data can be obtained by either indirectly or directly from the sources (Arkin and Ardanuy, 1989; Barrett, 1993; Levzzani et al., 2002). The observation is done directly by using passive sensors. Rain particle is the main factor of the decreased in upwelling at passive micro frequency wave. Passive sensor traced the microwave energy absorbed and dispersed by the rain particle and changes the information to estimated rate of particles by comparing with the level of radiation from the surface of the Earth. Passive microwave sensor mounted on low satellite orbit caused the derived rainfall information to have scarcity in temporal and spatial resolution; although the information given is reliable (Barrett, 1993). Indirect observation is done by using empirical relationships of temporal and spatial variability between the covered clouds that has a value of lower temperature threshold and rainfall particle. The surface temperature of cloud is obtained
by infra-red radiation emitted by the clouds (Levzzani et al., 2002 and Dingman, 2002). An infra-red wave sensor which installed on geostationary satellites at high orbital position, giving a good temporal resolution of rainfall distribution, but the information about rainfall distribution is less effective (Barrett, 1993)
CHAPTER 3

RESEARCH METHODOLOGY

3.1 INTRODUCTION

This chapter describes the phases involved in achieving the study objectives. There were FOUR (4) phases, namely; i) Data collecting, ii) Pre-processing of Data, iii) Processing, and iv) Result and analysis (Fig 3.1). The first part will be explaining about how all the data needed being collected. The second part, pre-processing performed on the data obtained before processing data can be applied. As for the third part, explained how to publish the Descriptive Statistical Analysis and Gumbel Distribution Function analysis. While the results and analyses are described in CHAPTER 4.
3.2 DATA COLLECTING

The rainfall data is collected from satellite-based TRMM daily for 16 years (Jan 1998 – Dec 2013). Satellite-based rainfall data is the main source for this study. The data is about all around the world including the study area.

3.2.1 TRMM Satellite Image Data

Satellite-based TRMM rainfall data were obtained from public domain archives (NASA). This archive database has provided a wide range of rainfall data products processed with various types of algorithms in form of the distribution of daily rainfall data, monthly and rainfall rates at intervals of three hours, since 1998 until present. To complete this study, the TRMM satellite image data derived by 3B42 V7 algorithm or also known as TRMM Multi-Satellite Precipitation (TMPA) were used (Figure 3.2).
TMPA satellite image rainfall data provided by the archive database was in the form of raster data model. The data series can be obtained with only downloading cost for the user. For the purpose of this study, there were 1,860 data files downloaded for study period July 2009 to June 2014. It is known to be the best standard product (Huffman et al., 2007). However, calibration and validation process need to be done.

![Satellite Data Image in TIFF Format including the Study Area](image1)

3.2.2 Map of Study Area

Figure 3-3 shows a map of the study area which is the main cities in Kelantan, Malaysia.

![Study Area](image2)
3.3 PRE-PROCESSING

Pre-processing of data was done before all the data can be used in the processing process.

3.4 PREPARATION OF SATELLITE DATABASE IMAGE

To carry out the analysis, variability of annual daily maximum rainfall of Kelantan, satellite-based data need to be converted into GIS-ready data. All respective 16 years daily data are exported into raster data to enable it for processing with Geographical Information System (GIS) software.

Figure 3.4 : Satellite-based Data Exported into Raster Image by Using Software
3.5 PROCESSING

The following data will then be transferred to ArcGis software for duplication and manipulation techniques.

Figure 3.5: ArcGis Satellite-based Data in Raster Image
The following data were then clipped for the limited study area.

Figure 3.6 : Clipped ArcGis Satellite-based Data in Raster Image.