ASSESSMENT VARIABILITY OF ANNUAL DAILY MAXIMUM RAINFALL OF TERENGGANU, MALAYSIA

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ABSTRACT

Recently, major cities in Terengganu have been affected by problems related to flooding incident. Meanwhile, extreme rainfall during northeast monsoon caused overflowing of Terengganu River and flooding, which cause a lot of destruction of house and property. The main objective of this study is to assess the variability of annual daily maximum rainfall. Tropical Rainfall Measuring Mission (TRMM) satellite-based rainfalls from public domain were used in this study. The daily satellite-based rainfall data for each major cities in Terengganu were retrieved using Geographical Information System (GIS) technique. Gumbel distribution functions were applied to estimate expected return period and probability of extreme rainfall event. For annual daily maximum, the maximum depth at Kemaman, Dungun, Marang, Hulu Terengganu, Kuala Terengganu, Setiu and Besut are 363.96mm, 477.54mm, 303.68mm, 347.85, 547.00mm and 398.44mm, respectively. For annual monthly maximum, the maximum depth at Kemaman, Dungun, Marang, Hulu Terengganu, Kuala Terengganu, Setiu and Besut are 926.89mm, 826.65mm, 969.77mm, 982.86mm, 1005.00mm, 1079.45mm and 1216.51mm, respectively. Meanwhile, for annual maximum rainfall, the maximum depth at Kemaman, Dungun, Marang, Kuala Terengganu, Kuala Terengganu, Setiu and Besut are 3767.97mm, 4642.43mm, 7065.96mm, 6733.18mm, 6342.88mm, 4707.01mm and 4187.03mm. From Gumble distribution, estimate extreme daily rainfall, probability and return period for 25 years in Kemaman, Dungun, Hulu Terengganu, Marang, Kuala Terengganu, Setiu and Besut are 546.52mm, 556.13mm, 475.4mm, 496.27mm, 551.10mm and 551.10mm. Meanwhile, the return period for 50 years in Kemaman, Dungun, Hulu Terengganu, Marang, Kuala Terengganu, Setiu and Besut are 632.93mm, 623.27mm, 5187.00mm, 545.93mm, 571.61mm, 635.28mm and 635.28mm. Lastly, the return period for 100 years in Kemaman, Dungun, Hulu Terengganu, Marang, Kuala Terengganu, Setiu and Besut are 179.33mm, 730.41mm, 10230.00mm, 616.46mm, 626.95mm, 719.45mm and 719.45mm. Based on the results acquired, every town has a daily estimate extreme rainfall; probability and return period are different. These results may help planning future development.
ABSTRAK

Baru-baru ini, bandar-bandar utama di Terengganu telah dipengaruhi oleh masalah yang berkaitan dengan kejadian banjir. Sementara itu, hujan yang melampau semasa monsun timur laut disebabkan limpahan Sungai Terengganu dan banjir, yang menyebabkan banyak kemusnahan rumah dan harta benda. Objektif utama kajian ini adalah untuk menilai kepelbagaian hujan maksimum harian tahunan. Mengukur Hujan Misi (TRMM) hujan berasaskan satelit tropika daripada domain awam telah digunakan dalam kajian ini. Harian data hujan berasaskan satelit untuk setiap bandar utama di Terengganu telah diambil menggunakan teknik Sistem Maklumat Geografi (GIS). Fungsi taburan Gumbel telah digunakan untuk menganggarkan tempoh pulangan dijangka dan kebarangkalian peristiwa hujan yang melampau. Untuk maksimum harian tahunan, kedalaman maksimum di Kemaman, Dungun, Marang, Hulu Terengganu, Kuala Terengganu, Setiu dan Besut adalah 363.96mm, 477.54mm, 332.45mm, 303.68mm, 347.85mm, 398.44mm, masing-masing. Untuk maksimum bulanan tahunan, kedalaman maksimum di Kemaman, Dungun, Marang, Hulu Terengganu, Kuala Terengganu, Setiu dan Besut adalah 926.89mm, 826.65mm, 969.77mm, 982.86mm, 1005.00mm, 1079.45mm dan 1216.51mm, masing-masing. Sementara itu, bagi hujan maksimum tahunan, kedalaman maksimum di Kemaman, Dungun, Marang, Hulu Terengganu, Kuala Terengganu, Setiu dan Besut adalah 3767.97mm, 4642.43mm, 7065.96mm, 6733.18mm, 6342.88mm, 4707.01mm dan 4187.03mm. Dari pengedaran Gumble, anggarkan hujan, kebarangkalian dan pulangan tempoh harian melampau selama 25 tahun di Kemaman, Dungun, Hulu Terengganu, Marang, Kuala Terengganu, Setiu dan Besut adalah 546.52mm, 556.13mm, 2666mm, 475.4mm, 496.27mm, 551.10mm dan 551.10mm. Sementara itu, tempoh masa selama 50 tahun di Kemaman, Dungun, Hulu Terengganu, Marang, Kuala Terengganu, Setiu dan Besut adalah 632.93mm, 623.27mm, 5187.00mm, 545.93mm, 571.61mm, 635.28mm dan 635.28mm. Akhir sekali, tempoh pulangan selama 100 tahun di Kemaman, Dungun, Hulu Terengganu, Marang, Kuala Terengganu, Setiu dan Besut adalah 179.33mm, 730.41mm, 10230.00mm, 616.46mm, 626.95mm, 719.45mm dan 719.45mm. Berdasarkan keputusan yang diperolehi, setiap bandar mempunyai hujan melampau anggaran harian; kebarangkalian dan tempoh pulangan adalah berbeza. Keputusan ini boleh membantu merancang pembangunan masa hadapan.
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LIST OF SYMBOLS

$X$  Annual daily maximum rainfall,
$M$  Mean of observed annual daily maximum rainfall,
$\sigma$  Standard deviation of observed annual daily maximum rainfall,
$F(x)$  Cumulative probability distribution
$P(x)$  Probability distribution,
$N$  Return periods of expected annual daily maximum rainfall.
yi  Each score
$\bar{y}$  The mean or average
$N$  The number of values
$\Sigma$  Means we sum across the values
# LIST OF ABBREVIATIONS

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<td>TRMM</td>
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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Most probably every year some part of Terengganu will expected of damage caused by the flooding. In January 2015, Kemaman was flooded again. Floods in low-lying areas in Kemaman following the heavy rain that fell in the high tides. In addition, many roads were submerged and cause a road closed. In November 2014, Jalan Pantai Batu Rakit in Kampung Pak Tuyu has suffered severe damage and the cause of the road in the Kampung Pak Tuyu to city was disconnected.

Meanwhile, in the news stated that Terengganu hit by worst floods in three decades. In December 2014, about 80 per cent of villages in Dungun had been flooded since the first wave of floods on December 15 when Sungai Dungun overflowed due to the high tide phenomenon.

The flood phenomenon has caused much damage and loss due to the rain that often occurs is due to the high intensity of rain. Many have lost their homes and possessions. Most of the people just left homeless after floods swept away all their possessions. Damage to property was estimated to reach hundreds of millions of dollars because of not only individuals, but also government agencies in the health sector such as hospitals, police stations and health clinics as well as in the plantations have suffered a loss. Floods that have caused a lot of damage has been caused flood victims is difficult to get aid and the relevant authorities are also difficult to provide assistance to flood victims.
Even though, injury and death are minimal, victim still suffered trauma and this is according to the eyewitnesses from those who did site investigation work after floods occurs. Most of the damaged houses were left without roofs and trees were uprooted and fell on some of the houses. Figure 1.1 and 1.2 show some of the flood damaged issues that happen recently in Terengganu.

![Figure 1.1](image1.jpg)

**Figure 1.1 ; Flood in Kemaman (Januari 2015)**

![Figure 1.2](image2.jpg)

**Figure 1.2 : Road damaged due to floods.(December 2014)**
1.2 PROBLEM STATEMENT

Recently, many infrastructure damage related to floods incident have been concerning in the community. While most infrastructure design (i.e. the main road) has taken into account the extreme rain information, there are still many roads were submerged by the flood. This may be due to climate change, which has an effect on the characteristics (i.e. depth, intensity, spatial and temporal variability) of the rainfall. Therefore, it is necessary to estimate extreme rainfall information by the latest rainfall information.

1.3 OBJECTIVE OF THE STUDY

The main objective of this study was to assess the variability of annual maximum rainfall of Terengganu, Malaysia. The specific objectives are:

(a) To obtain daily satellite base rainfall for study area.

(b) To analysis annual maximum rainfall, annual daily maximum and annual monthly maximum rainfall data.

1.4 SCOPE OF THE STUDY

In order to give a clear picture on how the study should be perform, the study has been specified into certain scope:

(a) This study focused on rainfall of Terengganu. (Kemaman, Dungun, Marang, Hulu Terengganu, Kuala Terengganu, Setiu and Besut).

(b) This study was conducted for period of 1998 – 2013.

(c) Data were collected from Tropical Rainfall Measuring Mission (TRMM) satellite base rainfall from public domain.

(d) Obtain and analyse all the data using Descriptive Statistical Analysis and Gumbel Distribution Function
1.5 **SIGNIFICANCE OF THE STUDY**

This study may give some benefits such as:

(a) Obtain the rainfall pattern in Terengganu and a different rainfall characteristic.

(b) The proposed return periods of annual daily maximum rainfall of this study can be used for upgrading such as the capacities of hydraulic structures of Terengganu and also will help the engineers in addressing the hydrology forecasting, development and flood control in future.

1.6 **THESIS STRUCTURE**

This thesis consists of five chapters. Chapter one presents an introduction of the thesis. It states the study background, problem statement, objectives of study and lastly scope of study. For chapter two, describe the study area of the research and comprises the literature review that related and suitable for these thesis. Chapter three explain 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 discussed from analysis. Finally, chapter five comprises the conclusion from the overall chapter and related some recommendation for future work on research field.
CHAPTER 2

LITERATURE REVIEW &
STUDY AREA

2.1 INTRODUCTION

Rainfall was possibly the first hydrological phenomenon to have been recorded by man as there are few simple rain gauges were found in India, China and Korea more than a thousand years ago. In 300 B.C, India used rain gauges to determine tax collections. Periods of high rainfall meant good crops and higher taxes; whereas low rainfall meant poor crops and a tax break from the government. The first recorded rainfall measurements and surface flow has been made by Perrault in the seventeenth century, who compared measures rainfall to the estimated flow of the Seine River to show that the two were related. In Malaysia, the first rainfall station was set up in Kuching, Sarawak, in 1876 while in Peninsular Malaysia, the first rainfall station was installed at Tanglin Hospital, Kuala Lumpur the following year. From this beginning, hydrology played an increasingly important role in the assessment and development of the country’s water resources. (Suhaila, 2014)

2.2 ACQUISITION OF PRECIPITATION DATA

2.2.1 Measurement of Precipitation Data

Precipitation is a primary sources of fresh water. The amount, intensity and spatial distribution of precipitation are important inputs in many hydrological studies.
Daily rainfall data of major cities in Terengganu (Kemaman, Dungun, Marang, Hulu Terengganu, Kuala Terengganu, Setiu and Besut) were collected from Tropical Rainfall Measuring Mission (TRMM) satellite base rainfall from public domain. The data from TRMM for each major cities in Terengganu were retrieves using Geographical Information System (GIS) technique.

2.2.2 Tropical Rainfall Measuring Mission (TRMM)

The Tropical Rainfall Measuring Mission (TRMM), is the first mission dedicated to measuring tropical and subtropical rainfall through microwave and visible infrared sensors, and includes the first space borne rain radar. Tropical rainfall comprises more than two-thirds of global rainfall. It is the primary distributor of heat through the circulation of the atmosphere. Understanding rainfall and its variability is crucial to understanding and predicting global climate change. Our current knowledge of rainfall is poor, especially over the oceans. By use of a low-altitude orbit of 217 miles (350 kilometres), TRMM's complement of state-of-the-art instruments will provide more accurate measurements. These new measurements will increase our knowledge of how rainfall releases heat energy to drive atmospheric circulation.

2.2.3 Descriptive Statistics

Descriptive statistical analysis for three types of data: i) annual rainfall, ii) annual daily maximum rainfall and iii) annual monthly maximum rainfall. Descriptive statistics deals with organization and summary of large scale data. It includes tables, graphs and numbers to present raw data (Ott and Longnecker, 2010). We applied descriptive statistics to rainfall data to examine its central tendency (mean, median and mode), variability (standard deviation), symmetry (skewness) and peakedness (kurtosis). (Ahammed, 2014)
2.2.4 Gumbel Distribution Function

Gumbel are commonly used for analysing return periods of annual daily maximum rainfall. The result of Gumbel Distribution can be used for upgrading such as the capacities of hydraulic structures. The famous statistician Emil Julius Gumbel (1941) was probably, the first person who dealt extreme values of hydrological data in organized way for conducting flood frequency analysis. Traditionally three extreme value distributions: Fréchet, Weibull and Gumbel are commonly used for analysing return periods of annual daily maximum rainfall. (Ahammed, 2014) The probability and return periods of annual daily maximum rainfall were estimated using Eqs. (1), (2) and (3) respectively:

\[ F(x) = \exp \left[ -\exp \left\{ -\frac{(x-\mu)}{\sigma} \right\} \right] \]  \hspace{1cm} (1)
\[ P(x) = 1 - F(x) \]  \hspace{1cm} (2)
\[ N = \frac{1}{P(x)} \]  \hspace{1cm} (3)

Where,
X = annual daily maximum rainfall,
M = mean of observed annual daily maximum rainfall,
\( \sigma \) = standard deviation of observed annual daily maximum rainfall,
F(x) = cumulative probability distribution,
P(x) = probability distribution,
N = return periods of expected annual daily maximum rainfall.

2.3 TERENGGANU

Terengganu is truly a tropical gateway. In the land where nature embraces heritage, it will truly revitalize your senses. Welcome to Terengganu and discover splendours of nature, the diversity of tradition and the fascination of heritage. There is absolutely no place like Terengganu. Terengganu is generally fairly hot and humid all year round, averaging from 28ºC to 30ºC in daytime and slightly cooler after sunset. Nevertheless, the sea breeze from South China Sea has somehow moderating the humidity in offshore areas while the altitude and lush forest trees and plant has cooled
the mountain and rural areas. Terengganu have seven main cities such as Kemaman, Dungun, Hulu Terengganu, Marang, Kuala Terengganu, Setiu and Besut.

Besides, Terengganu is a state in the east coast of Peninsular Malaysia that has never missed a flooding event, which occurs between October and March every year during the northeast monsoon period. The occurrence of flood at Dungun district Terengganu state was due to a combination of physical factors such as elevation and its close proximity to the sea apart from heavy rainfall experienced during monsoon period. More than 70% of Terengganu was categorized as low-lying coastal area with an altitude of less than 200 m altitude and 30% of the area was identified as vulnerable to flash flood. Heavy rainfall during the north east monsoon season between October and March resulted severe floods almost every year all over Terengganu, especially during the months of November and December. Environmental damages due to floods include the spread of diseases originating from dead rats and animals as well as contamination of floodwater from sewers, animal feedlots, etc. (Gasim, 2007)

2.3.1 Kemaman

Kemaman is a district in Terengganu, on the east coast of Malaysia facing the South China Sea. Kemaman district is bordered by Dungun district to the north and the state of Pahang to the south and west. It is the southern gateway to the state of Terengganu.

2.3.2 Dungun

Dungun is a coastal district of the Malaysian state of Terengganu. Kuala Dungun is the capital of the district. Dungun is made up of eleven ‘mukim’, or sub districts: Abang, Besol, Jengai, Jerangau, Kuala Dungun, Kuala Paka, Kumpal, Pasir Raja, Rasau, Sura, and Hulu Paka.
2.3.3 **Hulu Terengganu**

Hulu Terengganu is a rather remote area in the state of Terengganu but became known after the Kenyir Hydroelectric project. Now its man-made lake is well-known as a tourist destination.

2.3.4 **Marang**

Marang is a district in Terengganu, Malaysia. The district seat is the town of Marang. The districts that border Marang are Kuala Terengganu and Kuala Nerus to the north, Hulu Terengganu in the west, while Dungun is in the south. The eastern part of the district is a stretch of coastline facing the South China Sea.

2.3.5 **Kuala Terengganu**

Kuala Terengganu is the smallest in terms of area, but it has the largest population in Terengganu with a population of 406,317 in 2010. City status was awarded to Kuala Terengganu with the title ‘Bandaraya Warisan Pesisir Air’ (English: Coastal Heritage City) on 1 January 2008. Even though the city is not spared from modernity and development, Kuala Terengganu still retains strong Malay influences that are intermixed with other cultures from its long history as a port.

2.3.6 **Setiu**

Setiu is one of the districts in Terengganu, Malaysia. This district is bordered by Besut to the north, Hulu Terengganu to the west, and on the south, Kuala Nerus. Setiu is divided into seven mukim or sub district. The sub districts are Caluk, Gantung, Hulu Nerus, Hulu Setiu, Merang, beach and lakes.

2.3.7 **Besut**

Besut is the northernmost district in the Malaysian state of Terengganu. It is bordered by the state of Kelantan to the north and west and the South China Sea to the
east. It is the northern gateway to Terengganu. Kampung Raja is the district capital, though Jerteh is more developed. Another major town is the fishing port of Kuala Besut. There are other small towns and villages such as Jabi, Apal, and Tembil.

Figure 2.1 : Topography pattern of Terengganu

2.4 CONCLUSION

In previous literature review, researches already state about the rainfall characteristics, the method to use Descriptive Statistical and method to use Gumbel Distribution Function. Other than that, the elaboration of flood incident in Terengganu has been discussed in this chapter.
CHAPTER 3

METHODOLOGY

3.1 PROJECT METHODOLOGY

Figure 3.1: Flow Chart of project methodology
3.2 HYDRO CLIMATOLOGY

The term weather refers to the condition of the atmosphere at any particular time and place. Weather is always changing. The climate of a particular region is the composite of weather characteristics over many years. Climate reflects weather variations, including extremes as well as averages, Elements of weather and climate include precipitation, wind, temperature, humidity, air pressure and clouds. (Suhaila, 2014). The factors that produce weather and climate in any given location include:

(a) Altitude
(b) Prevailing winds
(c) Ocean currents
(d) Mountain barriers
(e) Distribution of land and water bodies
(f) Region of high and low atmospheric pressure

3.3 MEASUREMENT OF RAINFALL

3.3.1 Tropical Rainfall Measuring Mission (TRMM)

Daily rainfall data of major cities in Terengganu (Kemaman, Dungun, Marang, Hulu Terengganu, Kuala Terengganu, Setiu and Besut) were collected from Tropical Rainfall Measuring Mission (TRMM) satellite base rainfall from public domain. For TRMM observatory and instruments, GSFC designed, built and tested the observatory "in house" at its Greenbelt, Md., facility. At launch, the observatory weighed 7,920 lbs. (3,600 kg). It is about 17 feet tall (approximately 5 meters) and 12 feet (3.6 meters) in diameter. A gallium arsenide solar array/nickel cadmium battery power subsystem provides 1,100 watts of load power to the satellite. (Rui, Earth Observatory).

The TRMM Microwave Imager (TMI) is a multi-channel radiometer, whose signals in combination can measure rainfall quite accurately over oceans and somewhat less accurately over the land. The TMI and PR data, will yield the primary precipitation data sets. (Rui, Earth Observatory).
Figure 3.2: Webpage TRMM data

3.3.2 Descriptive Statistics

Descriptive statistical analysis for three types of data: i) annual rainfall, ii) annual daily maximum rainfall and iii) annual monthly maximum rainfall. Descriptive statistics deals with organization and summary of large scale data. It includes tables, graphs and numbers to present raw data (Ott and Longnecker, 2010). We applied descriptive statistics to rainfall data to examine its central tendency (mean, median and mode), variability (standard deviation), symmetry (skewness) and peakedness (kurtosis). (Ahammed, 2014) The various statistical moments used in this study are given below:

First moment (mean):

\[ \bar{y} = \frac{\sum y_i}{n} \]

Second moment (variance):

\[ s^2 = \frac{\sum (y_i - \bar{y})^2}{n - 1} \]

Third moment (skewness):

\[ g = \frac{n \sum (y_i - \bar{y})^3}{(n - 1)(n - 2)s^3} \]

Fourth moment (kurtosis):

\[ \gamma_2 = \left[ \frac{\mu_4}{(\mu_2)^2} \right] - 3 \]
3.2.3 **Gumbel Distribution Function**

The famous statistician Emil Julius Gumbel (1941) was probably, the first person who dealt extreme values of hydrological data in organized way for conducting flood frequency analysis. Traditionally three extreme value distributions: Fréchet, Weibull and Gumbel are commonly used for analysing return periods of annual daily maximum rainfall. (Ahammed, 2014). Hence, the Gumbel distribution function (1941) has been applied to predicting the return periods of expected extreme rainfall events. (Faisal, 2012). The probability and return periods of annual daily maximum rainfall were estimated using Eqs. (1), (2) and (3) respectively.

\[
F(x) = \exp\left\{-\exp\left\{-\left(\frac{x-\mu}{\sigma}\right)\right\}\right\} 
\]  
(1)

\[
P(x) = 1 - F(x) 
\]  
(2)

\[
N = \frac{1}{P(x)} 
\]  
(3)

Where,

\(X\) = annual daily maximum rainfall,
\(M\) = mean of observed annual daily maximum rainfall,
\(\sigma\) = standard deviation of observed annual daily maximum rainfall,
\(F(x)\) = cumulative probability distribution,
\(P(x)\) = probability distribution,
\(N\) = return periods of expected annual daily maximum rainfall

3.3 **CONCLUSION**

In this chapter, it slightly briefs the preparation of collecting data, preprocessing, processing and analysis the rainfall data into Gumbel Distribution Function. At the end of this chapter, result is successfully achieved and shown.