HOMOGENEITY TESTS AND TREND ANALYSIS FOR RAINFALL DATA IN THE SOUTHERN REGION OF PENINSULAR MALAYSIA

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DEDICATION

Specially dedicated to my beloved parents, Mohammad Zamri Zakaria and Zaimah Zainol Ariffin, my family, my supervisor Dr. Norazlina Ismail and to all my friends. Thank you for your love and support.

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ABSTRACT

This study focuses on performing homogeneity tests and trend analysis for rainfall data in the southern region of Peninsular Malaysia. Twelve rainfall stations throughout the state of Johor, Melaka and Negeri Sembilan with data from 1980 to 2016 were used in this study. Four absolute homogeneity tests namely standard normal homogeneity test, Buishand range test, Pettitt test and von Neumann ratio test are carried out to determine the homogeneity of the annual rainfall data. To evaluate the performance of the methods used, three different variables were used, which are annual total amount rainfall, annual mean and annual median. The results are categorized into three classes which are useful, doubtful and suspect depending on the *p-value* obtained from those absolute homogeneity tests. From the results of the three variables used, only one station is considered as inhomogeneous "labelled as suspect" while the other stations are considered homogeneous. Mann-Kendall test and Sen's slope estimator was used to study the trend analysis. Annual and seasonal rainfall indices (southwest monsoon and northeast monsoon season) with total amount of rainfall index are used to evaluate the trend analysis. From the Mann-Kendall test, *p-values* are obtained to determine the presence of a trend within a 5% significance level. Results for the annual period and northeast monsoon season shows that only one station has a significant increasing trend. However, during the southwest monsoon season, all of the station did not have a significant trend. To conclude the trend analysis, more than half of the stations indicated an increasing trend, although it is not statistically significant. Sen's slope estimator is carried out to estimate the magnitude of the trend. The positive/negative value in the magnitude of the trend corresponds to the *tau value* in the Mann-Kendall test. Most of the rainfall stations shows a positive magnitude in slope in all criteria of the annual and seasonal rainfall indices.

ABSTRAK

Kajian ini bertujuan untuk melaksanakan ujian "homogeneity" dan analisis "trend" untuk data hujan di seluruh kawasan selatan Semenanjung Malaysia. Dua belas stesen hujan di seluruh negeri Johor, Melaka dan Negeri Sembilan dengan data dari tahun 1980 hingga 2016 telah digunakan dalam kajian ini. Empat ujian "absolute homogeneity" iaitu ujian "standard normal homogeneity", ujian "Buishand range", ujian "Pettitt" dan ujian "von Neumann ratio" dilaksanakan untuk menguji "homogeneity" data tahunan hujan. Untuk menilai prestasi uijian yang digunakan, tiga pembolehubah yang berbeza digunakan, iaitu jumlah keseluruhan hujan tahunan, "mean" tahunan dan "median" tahunan. Hasilnya dikategorikan kepada tiga kelas iaitu "useful", "doubtful" dan "suspect" bergantung kepada nilai p yang diperoleh dari ujian "homogeneity". Dari hasil tiga pembolehubah yang digunakan, hanya satu stesen yang dianggap sebagai "inhomogeneous", dilabel sebagai "suspect" manakala stesen-stesen lain dianggap "homogeneous". Ujian "Mann-Kendall" dan "Sen's slope estimator" digunakan untuk mengkaji analisis "trend". Indeks hujan tahunan dan bermusim (musim monsun barat daya dan musim monsun timur laut) dengan indeks jumlah hujan digunakan untuk menilai analisis "trend". Dari ujian "Mann-Kendall", *nilai p* diperolehi untuk menentukan kehadiran "trend" dalam 5% "significance level". Keputusan untuk tempoh tahunan dan musim monsun timur laut menunjukkan bahawa hanya satu stesen mempunyai peningkatan "trend" yang ketara. Walau bagaimanapun, semasa musim monsun barat daya, semua stesen tidak mempunyai "trend" yang ketara. Untuk menyimpulkan analisis "trend", lebih daripada separuh stesen menunjukkan arah "trend" yang meningkat, walaupun tidak begitu ketara. Ujian "Sen's slope estimator" dilakukan untuk menganggarkan magnitud "trend". Nilai positif/negatif dalam magnitud "trend" sepadan dengan *nilai tau* dalam ujian "Mann-Kendall". Kebanyakan stesen hujan menunjukkan magnitud positif dalam semua kriteria indeks hujan tahunan dan bermusim.

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LIST OF ABBREVIATIONS

IPCC	-	Intergovernmental Panel on Climate Change
DID	-	Department of Irrigation and Drainage Malaysia
MetMalaysia	-	Malaysian Meteorological Department
SWM	-	Southwest Monsoon
NEM	-	Northeast Monsoon
MK	-	Mann-Kendall
TAR	-	Total Amount Rainfall
SNHT	-	Standard Normal Homogeneity Test
BRT	-	Buishand Range Test
VNR	-	Von Neumann Ratio
CV	-	Coefficient of Variation
VAR	-	Variance

LIST OF SYMBOLS

μ	-	Mean
σ	-	Standard deviation
y	-	Skewness
k	-	Kurtosis
$T(k)$	-	Standard normal homogeneity test statistic
S_k*	-	Buishand range test statistic
X_k	-	Pettitt test statistic
N	-	Von Neumann ratio statistic
S	-	Kendall's statistic
Q	-	Sen's slope statistic
τ	-	Tau value

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CHAPTER 1

INTRODUCTION

1.1 Background Of Study

Statistical methods are commonly applied to evaluate the trend of rainfall data series. Rainfall is one of the most important climatic element which has influence on both the spatial and temporal water availability. Climate change has a high impact on the environment which one of the main cause is severe flooding. Over the past few years in the 21st century, Peninsular Malaysia has experienced a few number of serious flooding that is primarily caused by climate change. Therefore it is necessary to study the shift in rainfall trends. Rainfall behavior should be evaluated and integrated in design guidelines.

One of the most discussed issue over the past few years is about climate change and its threat towards the environment. Referring to IPCC (2014), pollutions from human activity and natural factors contribute towards climate change. For example, air pollutions caused by oil and gas industry has a big impact on climate change and also harms the public health. IPCC (2007) stated that in the years from 1995 to 2006, the warmest years has been experienced worldwide in the history of global surface temperature since in the year 1850. The variation of temperature anomalies which indicated an increasing trend beyond year 1995 can be seen in Figure 1.1.

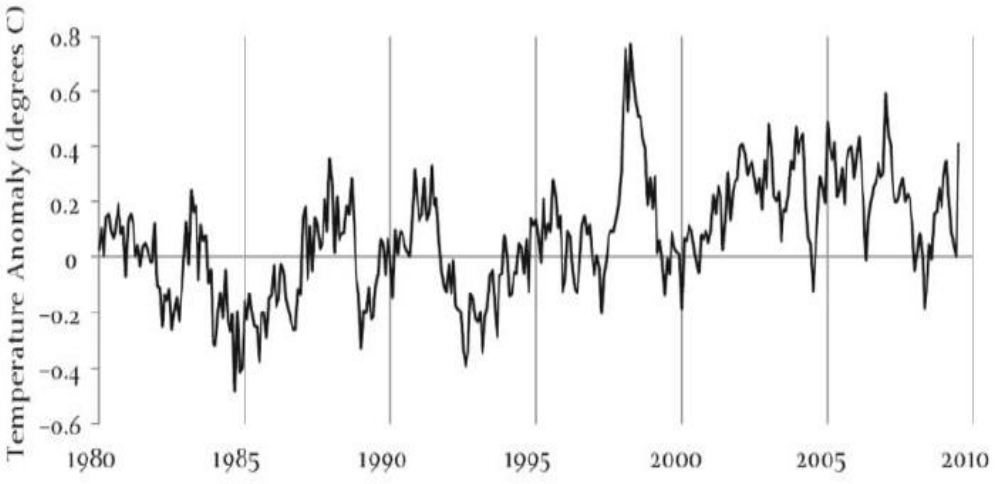

Figure 1.1 Global surface temperature from 1980 to 2010

Climate change is arguably to have an impact on the global surface temperature on a global scale. The increase in temperature around 0.3 to 0.6˚C is expected to have an impact on the rainfall activity to increase by 0.5% to 1.8% (Nicholls, 2007). More water can be held by the warmer air thus the increase in temperature can influence the amount of precipitation. Moreover, the consequences of climate change is observable to cause the increase occurrence of flooding as a result of changes in rainfall patterns (Trenberth, 2010).

For Peninsular Malaysia, records of rainfall data from the Department of Irrigation and Drainage (DID) Malaysia indicated that the rainfall intensity has increased. The rainfall intensity which are categorized into one-hour, three-hour and six-hour rainfall intensities from 1970 to 1980 and 2000 to 2007 in Kuala Lumpur indicated a rising trend by 17%, 29% and 31% respectively (Ministry of Natural Resources and Environment Malaysia, 2010). The community living along the shoreline also noticed a shift in rainfall intensity. Interviewees (fisherman) agrees and states that global warming has led to unpredictable rainfall activity and more frequent rainfall events occurred at the east coast of Peninsular Malaysia (Mohamed Shaffril, 2011).

1.2 Problem Statement

Due to unpredictable rainfall trend, it is crucial to study the rainfall activities to avoid the formation of floods and under design of hydraulic structure. Formation of floods are mainly influenced by heavy rainfall where there are more rains that the drainage system can take. Other than that, floods can also be caused by an overflow in the rivers bank. This event may occur when there are more water upstream than usual, and as it flows downstream to the low-lying areas, a high burst of water may flood the area.

The occurrence of floods in Malaysia are very common as it happens nearly every year during the monsoon seasons. Recent floods occurred in the northern and eastern states of Kelantan, Terengganu, Pahang, Perak and Perlis on December 2014 (contributors, 2017). One of the major floods in Peninsular Malaysia occurred throughout December 2006 and January 2007. The states affected by the major flood consist of Johor, Melaka, Pahang and Negeri Sembilan which cost over $ 395 million in property damage which is equivalent to over RM 1.5 billion (contributors, 2018).

Various studies concerning rainfall activities has been carried out, for instance assessing the changes in rainfall trend (Suhaila et al., 2010, Chun Kiat Chang, 2017, Che Ros et al., 2016). However, these studies was carried out to assess the changes of rainfall trend for Peninsular Malaysia and a specific river basin. Major flood in Peninsular Malaysia occurred in the southern region of the country which is the main focus of this study. There is a lack of studies combining homogeneity testing and trend analysis for the southern region of Peninsular Malaysia.

1.3 Objectives

The objectives of this study are:

1. To investigate the homogeneity of the annual rainfall data by using four absolute homogeneity tests which are the Standard normal homogeneity test, Pettitt test, Buishand range test and von Neumann ratio test.

2. To determine the changes in the annual and seasonal rainfall trend by applying Mann-Kendall trend test. Sen's slope estimator will be applied to measure the magnitude of the trend.

1.4 Scope of Study

Statistical analysis are carried out to assess the statistics of rainfall trend and evaluate the occurrence of hydrologic events based on the records. Homogeneity tests are carried out to detect the variability of the data. Results from the homogeneity tests will determine if a set of data can be used for further analysis. Additionally, the Mann-Kendall test is carried out to investigate the trend of the rainfall data and furthermore the Sen's slope estimator are used to estimate the magnitude of the trend. Various researches has been done and it is a norm to study the behavior of the rainfall trend and changes in hydrologic time series to support an understanding in the event of a climate change (Chew Hung, 2011). The Mann-Kendall trend test is a popular method among all of the other statistical tests available to detect a trend (Tomozeiu et al., 2000).

1.5 Significance of the Study

Rainfall frequency analysis is crucial in hydrologic and economic evaluation of water resource managements. It plays an important role to estimate the return periods and their interrelated event magnitudes which would suggest a proper design criteria of hydraulic structures. To fully understand the rainfall behavior and its anticipated impact, an extensive investigations of trends and variability in the extreme precipitation data should be carried out. Therefore, this study is very important as the study area which is the southern region of Peninsular Malaysia, is anticipated to have a large spatial and temporal changes in rainfall activity.

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