International Journal of Advances in Engineering and Management (IJAEM)
Volume 5, Issue 12 Dec 2023, pp: 186-196 www.ijaem.net ISSN: 2395-5252

Using of normal ratio and double mass analysis methods in estimate and adjust the missing precipitation data of Georgetown, Penang, Malaysia

Eng.Abdulkarim Taher Mohamed Annejjar[1], Eng. Adel Mohammed Abdulnasir Ateeyah[2]

1(Technical college of Civil Aviation and Meteorology Tripoli – Libya
Department : Meteorology Department
2(Technical college of Civil Aviation and Meteorology Tripoli – Libya
Department : Meteorology Department

Date of Submission: 10-12-2023 Date of Acceptance: 20-12-2023

ABSTRACT

In a general sense, many countries rely on rainwater as a source of water for various purposes. The rainfall is an important source for irrigation and supplying the water bodies for sizeable quantities of water. The quality and accuracy rainfall data is often poor and reliable data records are obtainable at coarse periods such as hourly, daily, monthly, and annually. The collection of this data for long periods of time relativity must correct prior to use in hydrological analysis and modeling. Rainfall collection gauges by several factors affected, as the existence of close barriers, the wind, and others, this is can affect the validity and accuracy of the data collection. This study is attempt to analyze and adjust the data of the annual trends of rainfall in Georgetown, Penang state based on the recorded rainfall data from the three main (Butterworth, Prai and Bayan Lepas) observation stations in 2004 to 2015. The data were analyzed to calculate and adjust the missing amount of rainwater in three stations by using the normal ratio and double mass analysis methods. The study relies on Microsoft Excel software to analyze the data statistically and assess and adjust the missing in the rainfall data. The adjustment of the raw date was by using of the Double Mass Analysis (DMA) technique. The precipitation data from three gauges stations were used to present the curve. The estimating of the missing data was by using the Normal Ratio Analysis (NRA) technique. The precipitation data from three gauges stations were used to present the curves. The results show that the Bayan Lepas station got the greatest effect between the whole stations. The study believes the missing in the recorded data was because of disturbances of theAir traffic of Penang International Airport.

Keywords: Normal ratio analysis, Double mass crave, Bayan Lepas, Rainfall, Penang.

I. INTRODUCTION

Water is the first requirement for survival and one of the vital natural resources (1). The shortage of water is growing faster than the population in two times (2). According to United Nations in (2014), 1.8 billion people in many regions of the world expect to face the drinking water shortage by the year of 2025. The rapid growth of the population, the enormous development in the industry and increasing demand for water contributes significantly to the growth of this dilemma. The alternative sources of water such as RF are a good way to deal with cases of water shortage. The sustainable management of water sources can be a support of the economic and social development of the nation (3),(4). In many countries around the world, the rainfall water is a principal source of water for industries, agricultures and domestic purposes (5). Since long time ago, the setup of the projects to collect rainwater were spreading in many regions worldwide that lack of surface water and even in rich water sources countries as an optimal way of water management for the purpose of providing water and fill the shortage of drinking water. Rainfall plays a major

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role in supporting water resources in large quantities of water annually.

Tropics characterized by large amounts of semi-equal heavy Rainfall annually with the absence of snow (6). Malaysia's ranking as one of the most important tropical regions around the world, receiving a huge inheritance, and plenty of rain annually. The weather is classified by two main types of monsoons. The period from May to September is the Southwest Monsoon. While from November to March is the Northeast Monsoon with a heavy density of RF. These amounts RF constitute a good source of many of the activities and a mainstay of surface water and rivers. According to WWF in Malaysia, it is estimated that water bodies receive about 3,000 mm annually from the RF events. It contributes to providing about 900 billion cubic meters per year, Fig (1). Emits the importance of the study of rainfall in determining the characteristics of rainfall, temporal and spatial variation, solve flooding and drought problems and statistical modeling and forecasting of rainfall.

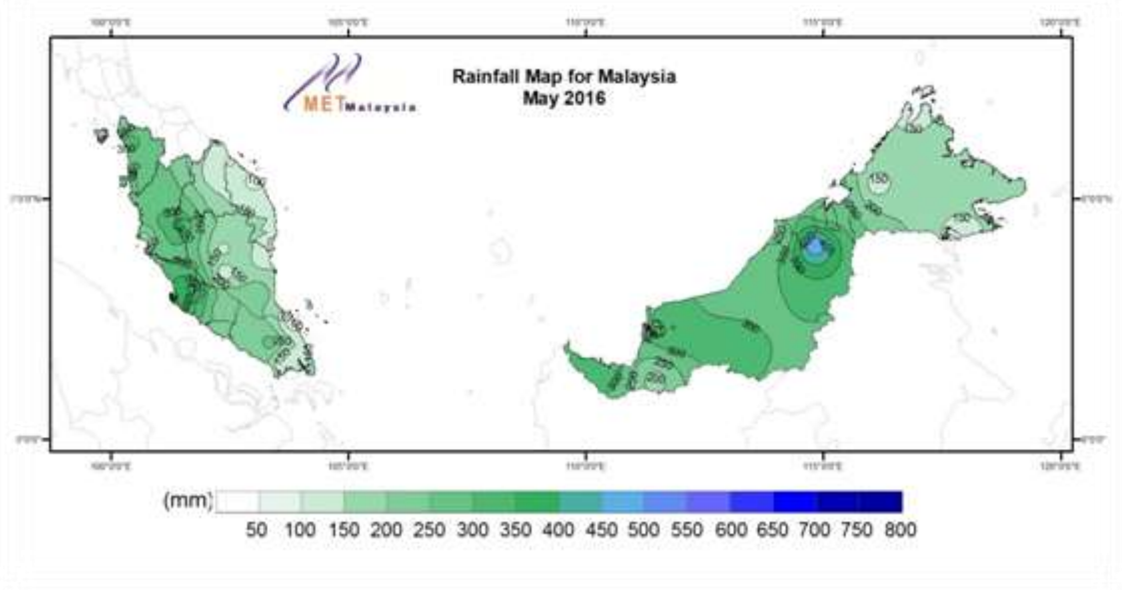

Figure 1: the amount of rainfall (mm) in May 2016 in Malaysia. Source: DOM, 2016.

II. METHODOLOGY

2.1 Sampling and data collection

The annual rainfall data for twelve years, from January 2004 to December 2015 which collected by using tipping bucket rain gage, for three rain gauging stations (Butterworth, Prai and Bayan Lepas) at Penang State, Malaysia were selected to use in this study.The sampling of the secondary data was collected from the Department of Meteorology-Malaysia (DOM) for three stations in mm.

The raw data from Department of Metrology had completed detailed gauges survey for these selected precipitation gauges (Butterworth, Prai and Bayan Lepas) which also included temporary point's inspection, rainfall monitoring at a key location within the rainfall data collection system.

2.2 sit survey

According to the previous studies and literature review, Penang state is a part of peninsular of Malaysia which located on the northwest coast (7). The state is consisting of two main parts, SeberangPerai and Penang Island, Georgetown Island. The state bordered from the north and east by the state of Kedah and on the south by the state of Perak. According to National Higher Education Research Institute report in 2010, the population in Penang state was about 1.5 million people. The weather condition of Penang state follows the weather of peninsular of Malaysia, a tropical climate with heavy rain usually (8). The climate affected often by the sea and smog or chemical fog that emitted from forest fires in Sumatra, Indonesia (6). According to DOM in 2011, this phenomenon of smog knows as a haze, namely. The average range of temperatures is between 26-27 °C and the total rainy days, 146 days per year. Bayan Lepas, Butterworth and Prai are

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the stations located in the state of Penang as regional meteorological stations in northern Peninsular Malaysia.Fig(2). These three stations founded in 1951, 1985 and 1984, respectively. They are working on a recording rainfall data periodically and regularly.

Figure 2: the rainfall stations within Penang state.

Furthermore, Bayan Lepas station located in Georgetown Island, while the stations of Butterworth and Prai located in the other part of Penang state. This location of Bayan Lepas station can be affected by the air traffic and aircraft landing and takeoff. In addition to that, the station established in 1951 as a main metrological recorder station for northern part of Malaysia, the data at that certain period were collect by simple equipments and not accurate 100 % comparing with the much recent stations, Butterworth and Prai in 1985 and 1984. For this reason the accuracy of the data need to test before use it in hydrological analysis or other activities.

Table 1: The locations of rainfall stations within the study area

	Stations	Geographic coordinate		Description
		latitude	longitude	
1	Bayan Lepas	5°17'50.78"North	100°16'50.3"East	Located in Pulau Pinang/ Penang Island.
2	Butterworth	5°24'6.67"North	100°22'1.47" East	Located in the main state of Penang / Seberang Perai.
3	Prai	5°22'15.16"North	100°23'49.57" East	Located in the main state of Penang / Seberang Perai.

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2.3Normal Ration Method (NRM) technique

The normal ratio method or Simple Proportion is clarified by the normal simple ratio between more than two stations, based on two sober or solid data for two stations to estimate the missing in the amount of rainfall for the third station. The Annual Average Rainfall (AAR) is the most important values for all stations including the missing one when the precipitation (P_N) for two stations also required for the finding of the missing amount of rainfall.

In 2006, Raghunath, H. M. (13),modified another simpler and easier form of the normal ratio method or Simple Proportion method:

$PC = \frac{1}{n}\left[\frac{PA}{AA} \times AC + \frac{PB}{AB} \times AC\right]$ ….. (Equation 3.2)

n: refers to the number of stations without the missing one, n = 2 for this study.
PA: refers to the total rainfall in station A.
PB: refers to the total rainfall in station B.
PC: refers to the total rainfall in station C as a missing point.
AA: refers to the Annual Average Rainfall (A.A.R) for station A.
AB: refers to the Annual Average Rainfall (A.A.R) for station B.
AC: refers to the Annual Average Rainfall (A.A.R) for station C.

2.4 The Double Mass Curve (DMC)

Adjust and examine the recorded data is necessary before use the rainfall data to ensure the validity of it for different purposes. The Double mass Curve analysis technique is one of the easier methods to adjust and correct the shifting in the recorded data. The change in the surrounding environmental conditions of a station, coming of a new building, fence, deforestations or planting of trees may affect the catch of the gauge due to change in the wind pattern or exposure. The using of Double Mass curve Analysis technique is to correct and adjust of the recorded data. The adjustment of the data is by multiplying by the ratio of the slope $^{m_2}/_{m_1}$.

In this study, the adjustment of the raw data was conducted by depended on the recorded data for three gauges for interval of twelve years (2004-2015). The curves of application data for the three provide the information of the missing data and adjust the data. The results of the correlation analysis and the double mass curve analysis were checked in order to contrast both series and to use them alternatively when a segment of anyone of the series was missing (9).

III. RESULT AND DISCUSSION

Briefly, after developed the research hypothesis, selected the methods for estimating, adjustment and analyze the data statistically by Microsoft Excel software, will show the results in simple and clear way, to be in easy form for the reader to understand and absorbed through the figures and curves that showing the steps to conduct of the research.

The gathered data from the Department of Metrology (DOM) for the period of twelve years (2004-2015) for three stations showed a variation between Bayan Lepas rainfall station and the others two stations, Butterworth and Prai. The following some tables and figures refer to the raw data that collected from the Malaysian department of Metrology.

2004												
Stations	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
BAYAN L.	92.4	37.8	139.6	165	140.6	208.6	140.1	259.4	229.8	373.6	158.4	36.4
BUTTER.	88.5	65.9	150.6	295.9	99.2	217.4	139.6	222.9	248.9	228.4	376.7	19.3
PARI	84.3	130	66.5	306.3	98.1	200.7	170.2	235.1	269.8	286.8	202.7	84.5

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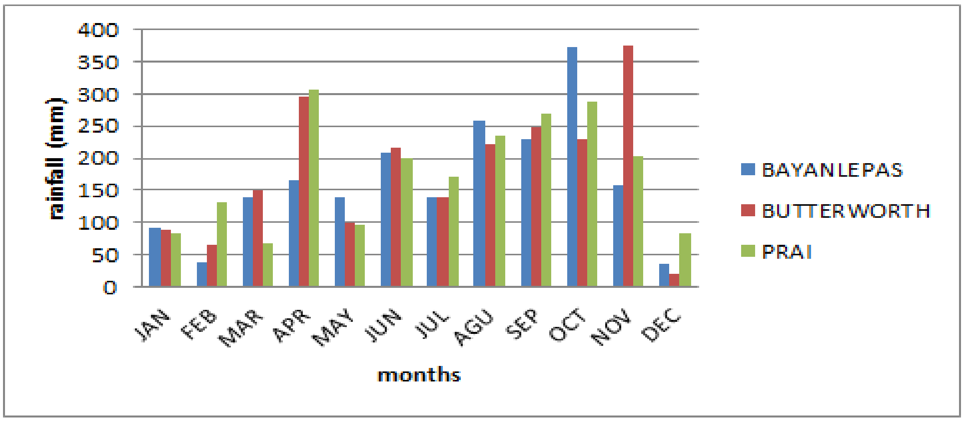

Figure 3: the annual rainfall amounts for three stations in 2004.

2005												
Stations	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
BAYAN L.	94.6	76.2	86.4	140.6	349.6	128	209.4	121.6	164.2	241	312.4	147.6
BUTTER.	5.6	95.8	47.9	115.8	399.3	14.4	225.2	156.4	104.4	381.2	298.8	138.2
PARI	41.1	65.1	47.5	221.2	158.2	28.6	211.2	184.4	157.8	290.4	187.4	71.6

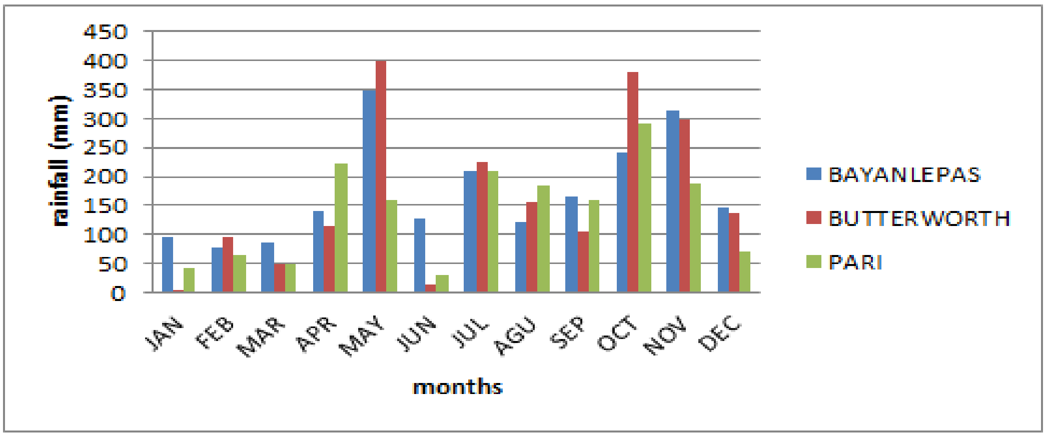

Figure4: the annual rainfall amounts for three stations in 2005.

2006												
Stations	JAN	FEB	MAR	APR	MAY	JUN	JUL	AGU	SEP	OCT	NOV	DEC
BAYAN L.	47.4	97.4	189.5	70.8	380.7	218.6	189.4	129.6	167.4	212.8	212.6	140.8
BUTTER.	43.8	44.8	77	174.8	257.8	155.2	309.4	141.8	258.2	382.8	380.6	136
PARI	167.6	70.7	143.2	129.6	74.8	187.6	91.4	104.4	199.8	432.2	375	208.4

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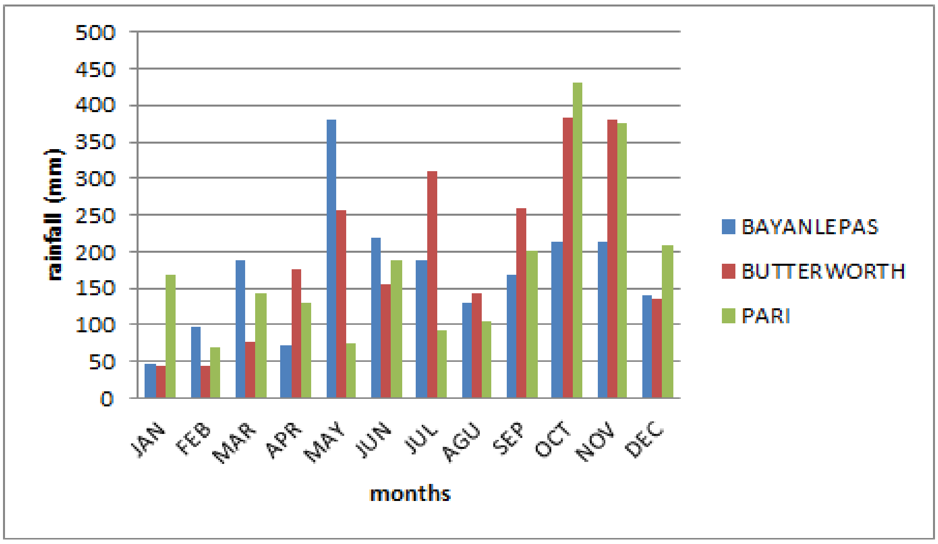

Figure5: the annual rainfall amounts for three stations in 2006.

						2007						
Stations	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AGU**	**SEP**	**OCT**	**NOV**	**DEC**
BAYAN L.	127.6	39.8	125.2	279.2	144.4	133.4	228.6	183.2	480.2	300	145.6	138.8
BUTTER.	77.2	31.6	58.6	155.8	143.2	224	208.6	127.4	344.4	321.4	144.4	169
PARI	130	33.6	205.6	299.6	153.4	196.6	295.3	154.8	361	374.5	96.2	171

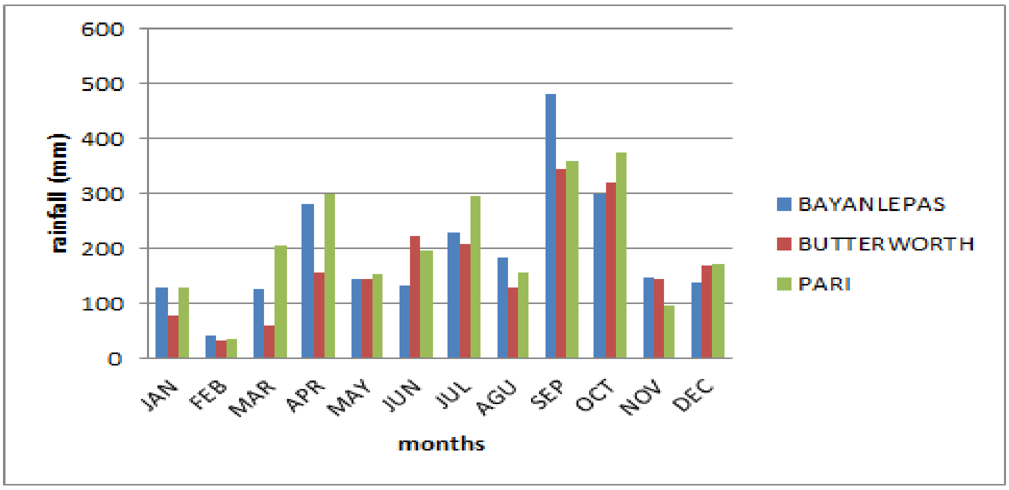

Figure6: the annual rainfall amounts for three stations in 2007

The analysis of the raw data that gathered in 2004 shows that the highest recorded of rainfall amounts was in November within Butterworth station, while the minimum amounts was in December for the same station. In 2005, the data showed that there was increased in the values of rainfall in May within Butterworth station, when it was recognized the decreased in the rainfall to reach the minimum amount in January for the same station as well. Furthermore, the period of 2006 to 2010 showed increase in the amount of the rainfall for the months from October to December and April to June, other than that its identified that there was decreased in the mass of rain in January to March.

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3.1Estimating the missing rainfall data by using Normal Ratio Method

The estimating of the missing rainfall data was done by using Normal Ratio Method (NRM). The calculations were conducting by Microsoft Excel software for the three gauges within the state of Penang, Malaysia. As mentioned above, this gauge is effecting by the Penang airport and the air traffic movements. The following some tables and figures show the results of using the Normal Ratio Analysis for the missing data of Bayan Lepas station at Georgetown Island.

2004												
Stations	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
BAYAN L.	79.84	90.78	100.1	278.2	91.16	193.1	143.2	211.6	239.7	238.2	267.4	48.1
BUTTER.	88.5	65.9	150.6	295.9	99.2	217.4	139.6	222.9	248.9	228.4	376.7	19.3
PARI	84.3	130.3	66.5	306.3	98.1	200.7	170.2	235.1	269.8	286.8	202.7	84.5

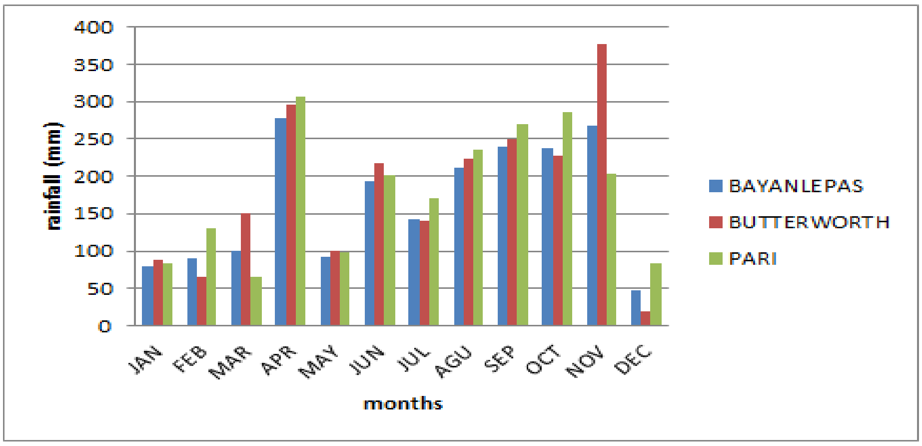

Figure7: the annual rainfall amounts for three stations in 2004 after using NRM.

2005												
Stations	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
BAYAN L.	28.50	90.55	54.57	198.1	307.0	25.3	249.05	196.4	152.7	379.8	272.69	116.7
BUTTER.	5.6	95.8	47.9	115.8	399.3	14.4	225.2	156.4	104.4	381.2	298.8	138.2
PARI	41.1	65.1	47.5	221.2	158.2	28.6	211.2	184.4	157.8	290.4	187.4	71.6

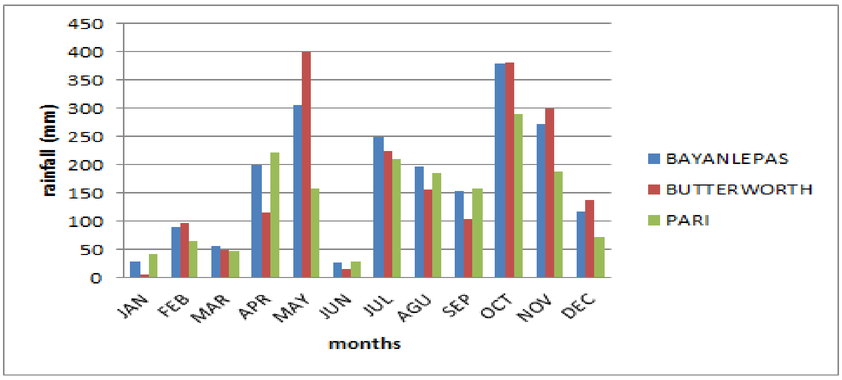

Figure8: the annual rainfall amounts for three stations in 2005 after using NRM.

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2006												
Stations	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
BAYAN L.	97.97	52.78	100.9	137.1	147.4	155.8	177.7	110.8	206.480	370.1	342.2	157.3
BUTTER.	43.8	44.8	77	174.8	257.8	155.2	309.4	141.8	258.2	382.8	380.6	136
PARI	167.6	70.7	143.2	129.6	74.8	187.6	91.4	104.4	199.8	432.2	375	208.4

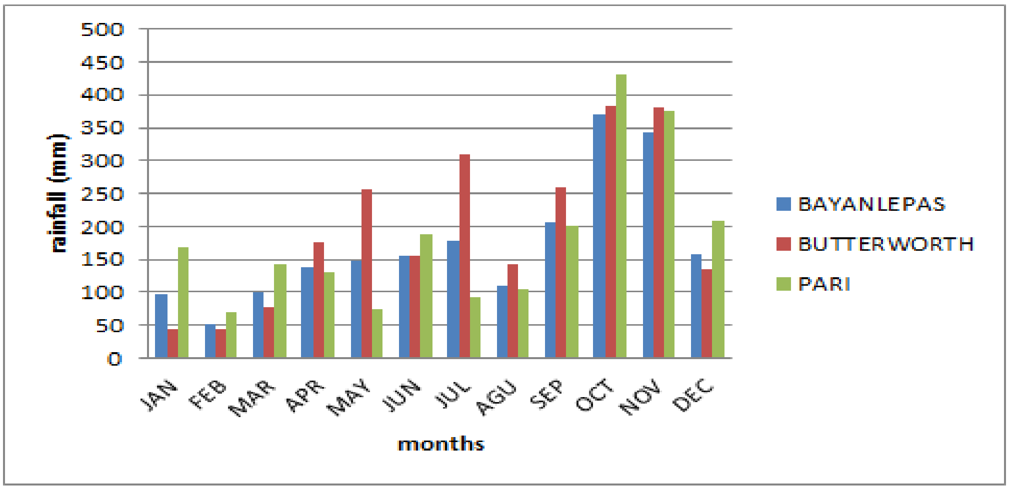

Figure9: the annual rainfall amounts for three stations in 2006 after using NRM.

2007												
Stations	JAN	FEB	MAR	APR	MAY	JUN	JUL	AGU	SEP	OCT	NOV	DEC
BAYAN L.	105.9	34.13	130.7	231.3	155.2	222.4	259.9	146.7	369.5	362.5	129.0	178.4
BUTTER.	77.2	31.6	58.6	155.8	143.2	224	208.6	127.4	344.4	321.4	144.4	169
PARI	130	33.6	205.6	299.6	153.4	196.6	295.3	154.8	361	374.5	96.2	171

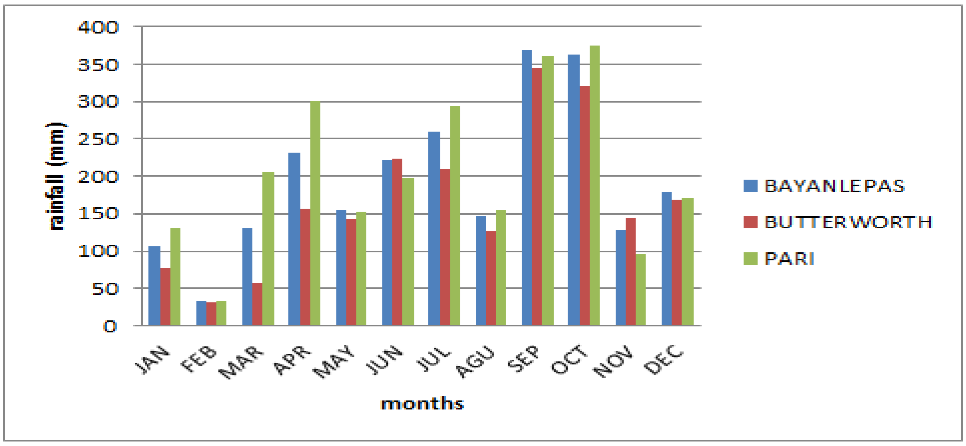

Figure10: the annual rainfall amounts for three stations in 2007 after using NRM.

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The Normal Ratio Method (NRM) is one of the best methods that use in estimating the missing rainfall data (14). The method is based on analyzing the recorded data for more than two rainfall stations. This method was showed a sufficient accuracy in estimated the missing amounts of rainfall within the stations of the study site. The results were conducted based on the data of the stations that there are increasing in the mass of rain within the station of Bayan Lepas and this increase refers to the missing of the rainfall during the rain storms.

The results showed that the amounts of the rainfall were changed to thereal values, this change in the data for Bayan Lepas is logical and explain of the change in the environment and surrounding conditions, such as the new barriers, brake down of the devises and gauges and other factors that affect directly on the tends of rain.

3.2 The adjustment of the rainfall data by using the Double Mass Curve (DMC)

The using of Double Mass Curve analysis technique is to adjust and correct the the mass and the amount of rainfall according to the recorded data for the previous years for more than two rainfall gauges. This study was rely on the data of three main stations at Penang state to draw the rainfall curve. The results show that there is missing in the volume of precipitation for Bayan Lepas gauge and adjust it by find the correlation amoung the three stations.

In order to adjust the rainfall data by using Double Mass Curve analysis technique, requied to calculate the avarage of the total annual rainfall and the annual cumulative for the three stations. From the annual cumulative for the stations easy to find the avarage annual cumulative for all of them.

To sum up, by applied the amount of the average cumulative rainfall for the three station on the curve can easily recognize the shifting in the rainfall amounts, as shown in Fig. (11). It can be clearly identified that there is a distinct change in curve between the years 2010 to 2015, which indicates that a change in system (exposure) has occurred in the year 2010. To deal with this dilemma and correct the records in more accurate form by calculate the ratio of (m_1/m_2), were m_1 is refer to the first slope and m_2 refers to the second slope ($slope_1$ /$slope_2$). The following calculations are the simple way to achieve that:

Cumulative rainfall (2011 to 2015) = 26409.3 – 16042.1 = 10367.2 mm

Slope 1= 2.4/2.9 = 0.82758621

Slope 2= 1.8/2.9 = 0.62068966

Adjustment for environmental changed = 16042.1 × Slope 1 / Slope 2

= 16042.1 × (0.73086286/1.049129901)

= 11175.52277 mm

Cumulative rainfall (2004 to 2015) = 10367.2 + 11175.52277 = 21542.72277 mm

(For the current environment)

A.A.R adjusted for the current regime = 21542.72277 / 12 = 1795.226897

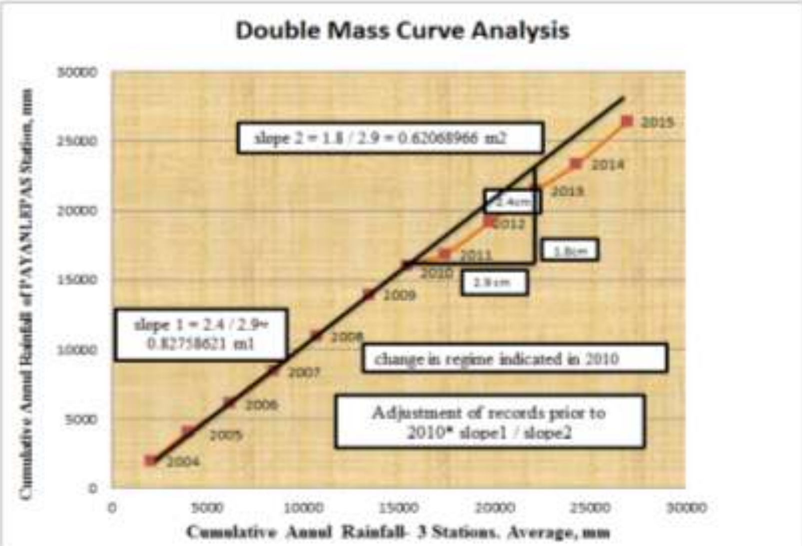

Figure 11: the Double mass curve analysis for three stations.

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IV. CONCLUSION

To sum up, the shortage of water is growing faster than the population in two times (2). Many countries worldwide rely on the rainfall in irrigate the crops, industries and other uses. The rapid growth of the population, the enormous development in the industry and increasing demand for water contributes significantly to the growth of this dilemma. Rainfall plays a significant role in providing water for various activities. The alternative sources of water such as rainfall are a good way to deal with cases of water shortage (10). The sustainable management of water sources can be a support of the economic and social development of the nation (3),(4). Emits the importance of the study of rainfall in determining the characteristics of rainfall, temporal and spatial variation, solve flooding and drought problems and statistical modeling and forecasting of rainfall for agricultural purposes.

Furthermore, it’s easy to recognize the variation in the recorded data between Bayan Lepas station and the others two stations in the raw data. The results showed that there are huge degradations in the amounts of the rainfall for the Bayan Lepas rainfall gauge comparing with the other two gauges. These degradations or changes in the precipitation data of Bayan Lepas rainfall station came from many external distributions. It is expected that the effect of the airport and the air traffic movements were the main purposes of lost huge amounts of rainfall during the record. The effect of the wind storms, sea and others disturbances were also could take place and affect the accuracy of the rainfall data. These differences in the rainfall values push the attention to find a way to adjust and estimating the missing rainfall within this station by using easier methods and software to present the curves and figures of the lost amounts.

The Normal ratio and the Double mass curve analysis techniques were the simple and easiest methods that used since 1950th to estimate and adjust the precipitation values (12),(14). As results of using the Normal ratio and the Double mass curve analysis techniques were showed logical increases and explain the change in the data to a real one. In addition to that, these increased in the data explain the effect of the environment and surrounding conditions and factors which affect directly on tends of rain. The adjustment of the rainfall data by using Double Mass Curve analysis technique showed that there is a distinct change in the curve between the years 2010 to 2015, which indicates that a change in the system (exposure) has occurred in the year 2010. This shifting in the data indicates that the accuracy of the recorded data must adjust and correct before use it in the hydrological analysis and other purposes.

Recommendations

Penang state is one of the tourist areas in the peninsular of Malaysia. This area has a high precipitation annually and defines as a first station to record the rainfall mass in Malaysia. The change in the surrounding conditions and environment affect directly on the characterizations of the data. This study recommends the following points:

- The quality of the data must be examined from time to time to ensure the accuracy of recorded values of precipitation.
- Must take in the considerations the change in the vicinity of the stations, environmental conditions and obstacles that surround the stations to ensure good quality of the recorded data.
- Conducting statistical analyzes and data modification and adjustment of the rainfall before use in hydrological analysis and other operations.
- Reduce the smoke from forest fires in Sumatra, Indonesia, which is very large impact on the amount of rainfall and high temperatures and the growing phenomenon of nanotechnology by the contracts and agreements and achieve the cooperation efforts between the Asian countries.
- Supporting and activating the role of organizations and research institutions that specializing in the study of climate change and rain.
- Choosing new areas to estimate the amount of rainfall stations which locate far from the influence of human and natural activities which contribute effectively to give a clear and real picture of the amount of rain for the area.

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