Open Journal of Modern Hydrology, 2011, 1, 11-22
doi:10.4236/ojmh.2011.12002 Published Online October 2011 (http://www.SciRP.org/journal/ojmh)

Introducing the Mixed Distribution in Fitting Rainfall Data

Jamaludin Suhaila, Kong Ching-Yee, Yusof Fadhilah, Foo Hui-Mean
Department of Mathematics, Faculty of Science, University Teknologi Malaysia, Johor Bahru, Malaysia
E-mail: suhailasj@utm.my
Received July 26, 2011; *revised August* 29, 2011; *accepted September* 27, 2011

Abstract

Several types of mixed distribution are proposed and tested in order to determine the best model in describing daily rainfall amount in Peninsular Malaysia for the time period of 33 years. A mixed distribution is a mixture of discrete and continuous daily rainfall which included the dry days. The mixed distributions tested in this study were exponential distribution, gamma distribution, weibull distribution and lognormal distribution. The model will be selected based on the Akaike Information Criterion (AIC). In general, the mixed lognormal distribution has been selected as the best model for most of the rain gauge stations in Peninsular Malaysia. However, these results are greatly influenced by the topographical, geographical and climatic changes of the rain gauge stations.

Keywords: Mixed distribution, Akaike Information Criterion (AIC), Maximum Likelihood Estimator (MLE), Mixed Lognormal

1. Introduction

Flood and drought are the calamity that can cause by imbalance amount of rainfall and amount of runoff in the certain area. Flood happen when the amount of rainfall is greater than the outflow of water, while drought is vice versa. Both these disasters will give great impact to agriculture sector and cause death if the disaster is seriously befallen. Hence, by studying the characteristic of the rainfall, preparations to overcome these disasters can be done earlier in order to reduce any lose that occur. Hence, continuous researches interested on the distribution of hydrology have been carried out [1-4].

Modelling rainfall data can be distinguished into two parts: rainfall occurrence and rainfall amount. A model of rainfall occurrence is a model that provides a sequence of dry and wet days, while a model of rainfall amounts simulates the amount of rainfall occurring on each wet days [5]. Markov chain models are often used to fit the rainfall occurrence [6,7]. On the other hand, two parameters gamma distribution, exponential distribution, weibull and lognormal are among the theoretical distribution used to fit the rainfall attribute [8-13]. However, gamma distribution only models the amount of rainfall in wet days [14].

In Peninsular Malaysia, studies on finding the best model for rainfall data had been carried out by several researchers. Mixed-exponential is the best fit distribution for hourly rainfall data among exponential, gamma and weibull [15]. While mixed lognormal is the most appropriate distribution for describing the daily rainfall amount compare to lognormal and skew normal [16]. Based on these studies, the mixed distribution is seemed more suitable in describing rainfall data in Peninsular Malaysia. Hence, mixed distributions are more suitable for Peninsular Malaysia [17,18].

However, past studies that have been conducted in Malaysia, only considered rainfall amount on wet days, which does not following the nature of rainfall where there are days that do not rain at all. The importance of included the zeros (dry days) is the characterization of daily rain rate, drought, or climate change effects can by analyze [19]. To the best of author knowledge, the mixtures of two distributions which include the rainfall data for dry days and wet days have not yet been done in Malaysia. Hence the study proposes to investigate the concept of mixture of these rainfall data.

2. Study Area

Malaysia is located in Southeast Asia which has two land mass which separated by South China Sea. The land mass that on the Asian mainland is called Peninsular Malaysia and the other is East Malaysia with two states Sarawak and Sabah which located on the island of Borneo. The area of Malaysia is approximately 330,000 square kilometres and share border with Thailand (in the north), Singapore, Indonesia (in the south), Brunei and the Philippines (in the east). The weather in Malaysia is generally hot and humid due to its location which near to the equator. The climate between the east and west coasts are different due to two monsoon seasons that annually strike in Malaysia. The southwest monsoon occurs from May to August while the occurrence of northeast monsoon is during November to February. The periods between these two monsoons are named as inter monsoon seasons. Northeast monsoon usually bring heavy rain to east coast of Peninsular Malaysia. Compared to the northeast monsoon, the southwest monsoon is much drier throughout Peninsular Malaysia due to the Peninsular Malaysia is protected by Sumatran (Indonesia) mountain range. During the inter monsoons seasons, the west coast of Peninsular Malaysia will reach the maximum monthly mean rainfall. Generally, the annual rainfall in Malaysia is between the ranges of 2000 to 4000 mm with uniform temperature which ranged from 25.5˚C to 32˚C throughout the country.

3. Rainfall Data

The daily rainfall data used in this study were obtained from the Malaysian Meteorological Department and Drainage and Irrigation Department which contain the period of 33 years (1975-2007). Seventy rain gauge stations were chosen for this study. The quality of rainfall data was checked through the homogeneity test, which are the standard normal homogeneity test, Buishand range test, the Pettitt test and the Von Neumann ratio test [20]. The stations chosen were scatter around in the area of Peninsular Malaysia. The details about the stations are shown in **Table 1** and **Figure 1**.

4. Methodology

4.1. Modeling Rainfall Amount

Most of the data are either discrete or continuous. The characteristic of rainfall data is neither continuous component nor discrete component, but it is a mixture of both components. However, the rainfall data were often assumed as continuous values in which zero rainfall values were ignored. A mixed distribution was suggested by combining the discrete and continuous components [21]. For mixed distribution, given a random sample X_1, $X_2,\cdots,X_n$ that containing $n-m$ zeroes (dry days), the likelihood of the random sample with parameter; p and θ is as follows:

$$L(p,\theta \mid x) = p^m (1-p)^{n-m} f(x_1,\theta)\cdots f(x_m,\theta) \quad (1)$$

where m is the total of wet days, and f is a parametric family distribution. Equation (1) does not represent the true likelihood if the data are dependent. The MLE of p is given as $\hat{p} = m/n$.

In this study, four mixed distribution model were used to determine the appropriate model for rainfall characteristic in Peninsular Malaysia. The probability density function and the logarithm of the likelihood function of the four distributions will be described with X as the random sample for each distribution.

- Exponential distribution is given as

$$f(x;\lambda) = \begin{cases} \lambda e^{-\lambda x}, & x \ge 0 \\ 0, & x < 0 \end{cases} \quad (2)$$

where $\lambda > 0$ is named as rate parameter or the scale parameter which determined the variation of rainfall amount series. By using (1), the likelihood of exponenttial distribution is shown below:

$$L(p,\lambda \mid x) = p^m (1-p)^{n-m} \prod_{i=1}^{m} \lambda e^{-\lambda x_i} \quad (3)$$

Then, solve the log likelihood function and the MLE for $\hat{\lambda}$ is given as $\hat{\lambda} = 1/\bar{x}$. The same method is applied for others distribution in order to find their log likelihood function and MLE.

- Use e The weibull distribution with two parameters is described as follows:

$$f(x;\alpha,\beta) = \begin{cases} (\alpha/\beta)(x/\beta)^{\alpha-1} e^{-(x/\beta)^{\alpha}}, & x \ge 0 \\ 0, & x < 0 \end{cases} \quad (4)$$

where $\alpha > 0$ is the shape parameter and $\beta > 0$ is the scale parameter. Shape parameter represents the shape of the distribution and scale parameter determines the variation of rainfall amount series.

The logarithm of the likelihood function of mixed weibull is given as below

$$\begin{aligned} \ln L(p,\alpha,\beta \mid x_i) &= m\ln p + (n-m)\ln(1-p) \\ &\quad + m\ln\alpha - m\alpha\ln\beta + (\alpha-1)\sum_{i=1}^{m}\ln x_i \\ &\quad - \sum_{i=1}^{m}(x_i/\beta)^{\alpha} \end{aligned} \quad (5)$$

To solve the nonlinear equation, the method known as Simple Iterative Procedure is employed [22].

- The probability density function for gamma distribution can be written as

$$f(x;\alpha,\beta) = \left(\beta^{-\alpha} x^{\alpha-1}/\Gamma(\alpha)\right) e^{-x/\beta} \quad \text{for} \quad x > 0 \quad (6)$$

Table 1. The latitude and longitude of the chosen 70 stations.

Code	Station Name	Latitude	Longitude
E01	Kota Bharu	6°10'12"N	102°16'48"E
E02	To' Uban	5°58'12"N	102°08'24"E
E03	Sek. Keb. Kg. Jabi	5°40'48"N	102°33'36"E
E04	Kg. Merang, Setiu	5°31'48"N	102°57'00"E
E05	Stor JPS Kuala Trengganu	5°19'12"N	103°07'48"E
E06	Kg. Menerong	4°56'24"N	103°03'36"E
E07	Klinik Bidan, Jambu Bongkok	4°56'24"N	103°21'00"E
E08	Sek.Men. Sultan Omar, Dungun	4°45'36"N	103°25'12"E
E09	Sek. Keb. Kemasek	4°25'48"N	103°27'00"E
E10	JPS Kemaman	4°13'48"N	103°25'12"E
E11	Kuantan	3°46'48"N	103°13'12"E
E12	Rumah Pam Pahang Tua, Pekan	3°33'36"N	103°21'36"E
E13	Endau	2°35'24"N	103°40'12"E
E14	Mersing	2°27'00"N	103°49'48"E
NW01	Abi Kg. Bahru	6°30'36"N	100°10'48"E
NW02	Guar Nangka	6°28'48"N	100°16'48"E
NW03	Padang Katong ,Kangar	6°27'00"N	100°11'24"E
NW04	Arau	6°25'48"N	100°16'12"E
NW05	Kodiang	6°22'12"N	100°18'00"E
NW06	Alor Star	6°12'00"N	100°24'00"E
NW07	Ampang Pedu	6°14'24"N	100°46'12"E
NW08	Pendang	5°59'24"N	100°28'48"E
NW09	SIK	5°48'36"N	100°43'48"E
NW10	Dispensari Kroh	5°42'36"N	101°00'00"E
NW11	Rumah Pam Bumbong Lima	5°33'36"N	100°26'24"E
NW12	Bkt Berapit	5°22'48"N	100°28'48"E
NW13	Ldg. Batu Kawan	5°15'36"N	100°25'48"E
NW14	Klinik Bkt. Bendera	5°25'12"N	100°16'12"E
NW15	Kolam Takongan Air Itam	5°24'00"N	100°16'12"E
NW16	Pintu A.Bagan, Air Itam	5°21'00"N	100°12'00"E
NW17	Rumah Penjaga JPS. Parit Nibong	5°07'48"N	100°30'36"E
SW01	Jam. Sg. Simpangn, Jln. Empat	2°26'24"N	102°11'24"E
SW02	Malacca	2°16'12"N	102°15'00"E
SW03	Pekan Merlimau	2°09'00"N	102°25'48"E

SW04	Ldg. Bkt. Asahan	2°23'24"N	102°33'00"E
SW05	Tangkak	2°15'00"N	102°34'12"E
SW06	Pintu Kawalan Separap Batu Pahat	1°55'12"N	102°52'48"E
SW07	Pintu Kawalan Sembrong	1°52'48"N	103°03'00"E
SW08	Sek.Men.Inggeris Batu Pahat	1°52'12"N	102°58'48"E
SW09	Ldg. Kian Hoe, Kluang	2°01'48"N	103°16'12"E
SW10	Kluang	2°01'12"N	103°19'12"E
SW11	Ldg. Benut, Rengam	1°50'24"N	103°21'00"E
SW12	Ibu Bekalan Kahang, Kluang	2°13'48"N	103°36'00"E
SW13	Sek.Men.Bkt Besar di Kota Tinggi	1°45'36"N	103°43'12"E
SW14	Senai	1°37'48"N	103°40'12"E
SW15	Ldg. Getah Kukup, Pontian	1°21'00"N	103°27'36"E
SW16	Stor JPS Johor Bahru	1°28'12"N	103°45'00"E
W01	Stn. Pemereksaan Hutan, Lawin	5°18'00"N	101°03'36"E
W02	Selama	5°08'24"N	100°42'00"E
W03	Rumah JPS, Alor Pongsu	5°03'00"N	100°35'24"E
W04	Pusat Kesihatan Bt.Kurau	4°58'48"N	100°48'00"E
W05	Gua Musang	4°52'48"N	101°58'12"E
W06	Ipoh	4°34'12"N	101°06'00"E
W07	Ldg Boh	4°27'00"N	101°25'48"E
W08	S. K. Kg. Aur Gading	4°21'00"N	101°55'12"E
W09	Sitiawan	4°13'12"N	100°42'00"E
W10	Rumah Kerajaan JPS, Chui Chak	4°03'00"N	101°10'12"E
W11	Rumah Pam Paya Kangsar	3°54'00"N	102°25'48"E
W12	Ibu Bekalan Sg. Bernam	3°42'00"N	101°21'00"E
W13	Kg. Sg. Tua	3°16'12"N	101°41'24"E
W14	Gombak	3°16'12”N	101°43'48”E
W15	Empangan Genting Kelang	3°14'24"N	101°45'00"E
W16	JPS. Wilayah Persekutu	3°09'36"N	101°40'48"E
W17	Genting Sempah	3°22'12"N	101°46'12"E
W18	Janda Baik	3°19'48"N	101°51'36"E
W19	Sg.Lui Halt	3°04'48"N	102°22'12"E
W20	Ldg. Sg. Sabaling	2°51'00"N	102°29'24"E
W21	Setor JPS Sikamat Seremban	2°44'24"N	101°57'36"E
W22	Hospital Port Dickson	2°31'48"N	101°48'00"E
W23	Ldg. Sengkang	2°25'48"N	101°57'36"E

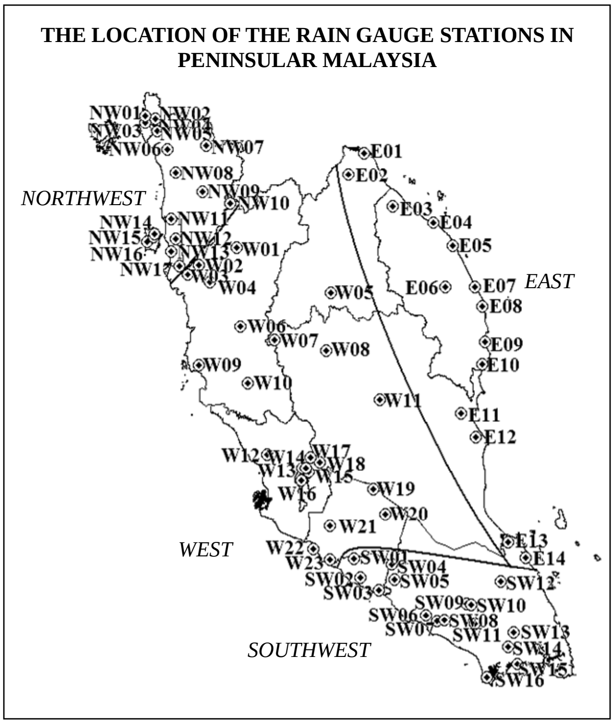

Figure 1. The location of the 70 rain gauge stations in Peninsular Malaysia.

where $\alpha > 0$ is the shape parameter and $\beta > 0$ is the scale parameter for gamma distribution.

The logarithm of the likelihood function of mixed gamma is given as

$$\begin{aligned}\ln L\left(p,\alpha,\beta \middle| x_i\right) &= m\ln p + \left(n-m\right)\ln\left(1-p\right) \\ &+ \left(\alpha-1\right)\sum\nolimits_{i=1}^{m}\ln x_i - m\alpha\ln\beta \\ &- m\ln\Gamma\left(\alpha\right) - \left(1/\beta\right)\sum\nolimits_{i=1}^{m} x_i\end{aligned} \quad (7)$$

where the MLE for $\hat{\beta}$ is $\hat{\beta} = \overline{x}/\hat{\alpha}$ while the MLE for $\hat{\alpha}$ is $\psi\left(\alpha\right) = \left(\sum\nolimits_{i=1}^{m}\ln x_i \big/ m\right) - \ln\beta$ which $\psi\left(\alpha\right) = \Gamma'\left(\alpha\right)/\Gamma\left(\alpha\right)$ is the digamma function.

- The probability density function for lognormal distribution is

$$f\left(x;\mu,\sigma\right) = \left(1\big/x\sigma\sqrt{2\pi}\right)\mathrm{e}^{\left[-\left(\ln x-\mu\right)^2/2\sigma^2\right]} \quad \text{for} \quad x > 0 \quad (8)$$

where μ and σ are the location and scale parameters respectively.

4.2. Goodness-of-Fit Tests (GOF)

GOF is used to determine the best model among the distributions tested in rain characteristic. In this study, AIC was used to select the best model. The model that attains the lowest AIC will be the best model among the competitive distribution. The result of AIC is directly dependent with the sample size of observation [23]. AIC is asymptotically effective and unbiased since the test is based on the maximum likelihood function and if the sample size is sufficiently larger than 30, the test will yield fairly accurate result [24]. The sample size of this study is greater than 30, hence AIC can be applied to determine the best model. The formula for AIC is given as

$$AIC = -2\ln L + 2k \quad (9)$$

where $\ln L$ is the logarithm of the likelihood function of the propose model and k is the number of parameters.

5. Result and Discussion

This section is divided into two main sub-sections. The descriptive statistics for each of the seventy rain gauge stations will be discussed in the first sub-section followed by a discussion on fitting distributions in the second sub-sections.

5.1. Descriptive Statistics

The descriptive statistics in terms of mean, standard deviation, coefficient of variations (CV), skewness, the maximum amount of rainfall and number of wet days of the annual rainfall amount for each seventy rain gauge stations are summarized in **Table 2**. Based on the values of descriptive statistics, the five highest mean rainfall amounts among the stations are Chui Chak (W10), followed by Kg Menerong (E06), Endau (E13), Selama (W02) and Pusat Kesihatan Bt. Kurau (W04). Due to the geographical locations of Selama, Chui Chak and Bt. Kurau stations which full of limestone bedrock, granitic hills and mine waste deposits (e.g. slime, tailings and mining ponds) [25].

Lake is an indicator of high level climate and mountain also can affect the climate in the area [26]. These situations somehow contribute to the increase in total amount of rainfall in those areas. Lawin (W01), Ldg. Sg.Sabaling (W20), Raya Kangsar (W11), Guar Nangka (NW02) and Sitiawan (W09) are among the stations that received the lowest mean rainfall. Most of these stations are at the inland areas of Peninsular Malaysia in which the climate at these areas is less affected by the monsoons. The climate for most of the inland stations is relatively dry [27].

In terms of CV, three of the stations (W12, W10 and SW09 stations) attain the highest CV among the other stations which in the range of 28% to 45%. These results the irregularity of the daily rainfall received by the stations. On the other hand, the value of skewness is affect

Table 2. Statistic of annual rainfall amount for seventy rain gauge stations.

Code Station	Mean	CV (%)	Skewness	Maximum amount of rainfall (mm)	Number of Wet Days
E01	2514.17	23.74	5.99	591.5	4378
E02	2711.21	26.72	4.95	409	4632
E03	2782.36	17.83	3.93	329.5	4487
E04	2740.71	20.13	3.97	365.5	3884
E05	2574.25	16.63	5.33	520.4	4623
E06	3572.57	22.77	6.67	676	6245
E07	2491.53	13.6	8.49	790	3814
E08	2492.8	18.43	5.02	572	4599
E09	2610.47	15.78	4.21	330	4365
E10	2662.02	13.7	4.88	434	4796
E11	2910.43	18.71	4.99	527.5	4947
E12	2522.35	16.49	5.04	444.8	4447
E13	3192.49	17.28	3.98	353.5	5313
E14	2624.81	23.22	4.91	383.3	4890
NW01	1891.97	16.77	2.63	125.5	4522
NW02	1741.53	15.86	3.15	218.5	4274
NW03	1895.09	17.4	2.6	150.1	4482
NW04	1967.99	20.17	2.51	180	4389
NW05	1902.01	20.08	2.66	163	4531
NW06	1971.59	16.28	2.56	172.1	4493
NW07	2018.02	26.46	2.79	211.5	4665
NW08	2222.72	21.89	3.12	261	4865
NW09	2594.84	23.61	2.71	220.5	5043
NW10	2062.3	18.37	2.6	175	5084
NW11	2139.28	21.67	3.32	275	4339
NW12	2182.73	26.49	3.79	295	4650
NW13	1837.35	14.96	2.67	206	3872
NW14	2764.42	13.96	4.35	484.8	5199
NW15	2258.85	18.72	3.67	308.5	4917
NW16	2506.14	20.88	2.59	245.5	4270
NW17	2187.5	15.13	2.75	230	3584
SW01	2371.15	23.61	2.44	217.5	4990
SW02	1980.71	17.73	2.86	275.2	4428
SW03	1964.88	14.51	3.22	272.5	4168

SW04	1769.56	13.27	2.3	172	3550
SW05	1895.45	19.86	2.29	152.7	4366
SW06	1910.17	14.28	2.33	137.5	3963
SW07	2146.75	17.92	3.64	320	4811
SW08	2222.21	18.83	2.86	200.5	4623
SW09	1929.68	29.96	2.27	210	3087
SW10	2116.02	22.68	4.82	433.4	4767
SW11	2199.05	19.49	2.87	210	4550
SW12	2760.32	12.71	4.31	372	5395
SW13	2076.83	22.13	3.64	271.5	5012
SW14	2447.37	11.5	4.21	364.4	5369
SW15	2467.35	20.55	3.39	260	4797
SW16	2407.34	15.92	3.3	313.6	5132
W01	1682.42	14.76	2.82	159	4586
W02	3165.87	13.75	2.01	176	5400
W03	2417.88	17.95	2.52	170	5187
W04	3151.77	16.42	2.21	193	6435
W05	2331.09	22.48	2.57	154.5	5544
W06	2487.51	14.74	2.08	135.4	5248
W07	2187.79	12.55	2.27	110	6481
W08	2315.17	15.07	2.1	130	4077
W09	1760.24	18.42	2.67	178.7	4251
W10	3590.15	31.11	1.36	160.5	4926
W11	1733.74	10.85	3.58	259.8	4314
W12	2548.82	44.89	2.29	173.6	5274
W13	2386.12	20.17	2.39	173.5	5317
W14	2421.35	15.89	2.13	139	5297
W15	2354.28	14.87	2.22	162.5	5233
W16	2577.83	17.34	2.66	289	5425
W17	2483.4	13.88	16.46	800.5	6018
W18	1863.52	24.28	3.47	210	5044
W19	2182.01	20.9	2.3	215	3111
W20	1722.8	13.58	3.19	226	3936
W21	1974.31	16.71	2.37	144.5	4674
W22	1997.41	18.88	2.77	200	4209
W23	2148.78	14.36	4.8	500	3922

by maximum amount of rainfall received by the stations. For example, the Genting Sempah (W17) station has the both highest maximum amount and skewness value. While in terms of number of wet days, rain always occurred at these areas. In addition, there is study indicated that the landslide often occur at area of Genting Sempah which had caused numbers of deaths and injuries [28]. Hence, some studies had been carried out to predict the landslide hazard [29] and debris flow [30] in Genting Sempah.

Due to the effect of northeast monsoon, the stations (E01, E02, E03, E04, E05, E06, E07, E08, E09, E10, E12, E13, E14, SW12 and W22 stations) that are at the east coast of Peninsular Malaysia receive high mean rainfall amount which are more than 2490 mm. Besides, the stations (NW14, NW15 and NW16 stations) located in island take in more rainfall amount than the stations (NW11, NW12 and NW13 stations) in mainland although the location of these stations are in the same neighborhood. Not only that, the stations (W12, W13, W14, W15 and W16 stations) situated in urban area also receive high rainfall amount. Hence, rainfall amount can be varying according to the surrounding of the area and monsoons.

5.2. Fitting Distribution Based on AIC Criterion

The results of AIC values are displayed in **Table 3** with the bolded values indicated the lowest AIC. The best fit distribution of the rain gauge stations are shown in **Figure 2**. The mixed lognormal distribution is dominating other distributions as the best fitting distribution among the studied stations. 48 stations attained the lowest AIC values for mixed lognormal followed by 20 stations chosen for mixed gamma to describe their rainfall data. On the other hand, only 2 stations chose mixed weibull as the best fitting distribution. Of all distributions, the mixed exponential was never selected by any of the stations.

Most of the stations that are located at the east coast obtain mixed gamma distribution as their best model. It is possible that the distributions of rainfall data at these stations are influenced by the northeast monsoon flow.

Meanwhile the Chui Chak station (W10) and Sg. Lui Halt station (W19) are the only two stations acquired mixed weibull distribution as the most appropriate fitted distribution. These stations are located at the foot of the mountain and recorded relatively high mean rainfall amount, high in coefficient variation, low in skewness and low in maximum amount of rainfall. These characteristics of rainfall data may possibly suitable for the chosen fitted distribution.

In general, the distinction of elevation and the exposure of the stations towards southwest and northeast monsoons could give impact in the result of the fitting of the distribution. The geographical sites, climatic changes and topographical of the stations also will be strongly affect the result.

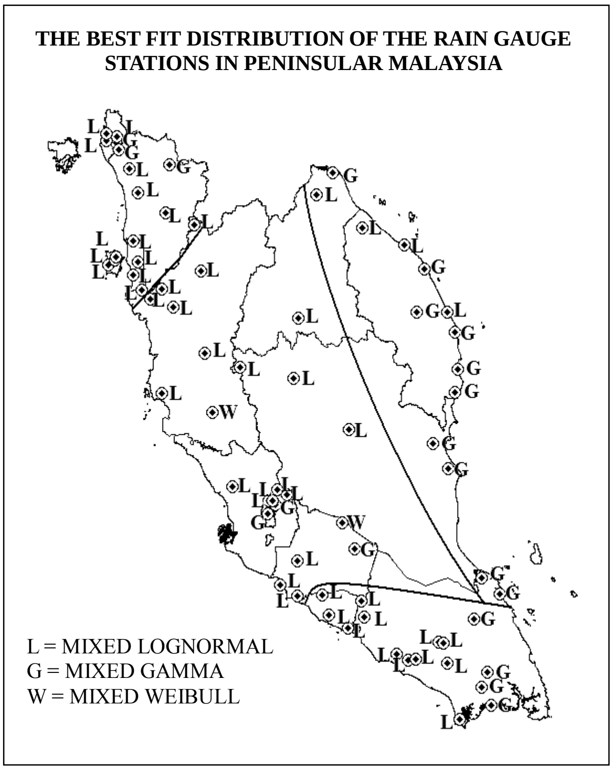

Figure 2. The best fit distribution of the 70 rain gauge stations in Peninsular Malaysia.

6. Conclusions

The urge in finding the most appropriate fitting distribution for daily rainfall amount in Peninsular Malaysia is always the main interest in particular studies. The concept of included zero values into rainfall data for attain the best fit distribution in Peninsular Malaysia still commence among researchers in Malaysia. Several distributions have been tested and compare in this study to find the best fitting distribution. The distributions tested are mixed exponential, mixed gamma, mixed weibull and mixed lognormal distributions.

The mixed lognormal distribution was the preferred best fitted distribution for the majority of the stations in Peninsular Malaysia which determined by Akaike Information Criterion. Mixed gamma distribution was the second favoured distribution followed by mixed weibull distribution. A big number of the stations in the east coast of Peninsular Malaysia were identifying mixed gamma distribution as the most appropriate distribution.

Table 3. The AIC Values of each of the seventy rain gauge stations.

Code Station	Mixed Lognormal	Mixed Exponential	Mixed Weibull	Mixed Gamma
E01	1780.2	1836.12	1819.75	**1776.57**
E02	**1935.18**	1966.82	1966.66	1965.91
E03	**1859.61**	1875.44	1875.71	1903.17
E04	**2026.01**	2088.15	2077.12	2052.49
E05	2192.14	2302.2	2245.2	**2147.35**
E06	3618.95	3719.17	3687.61	**3591.95**
E07	**2180.86**	2219.33	2221.1	2238.46
E08	2500.94	2590.35	2561.57	**2490.82**
E09	2531.7	2627.46	2592.58	**2523.7**
E10	2920.32	3042.57	2992.85	**2889.33**
E11	3000.91	3085.3	3058.61	**2981.49**
E12	2804.99	2915.33	2871.41	**2778.78**
E13	3187.37	3287.68	3246.43	**3140.35**
E14	2525.02	2586.52	2567.61	**2511.59**
NW01	**1195.13**	1221.16	1221.71	1224.53
NW02	**1163.38**	1194.62	1188.05	1168.29
NW03	**1116.84**	1126.51	1127.13	1120.45
NW04	1149.66	1172.35	1168.25	**1148.9**
NW05	1163.8	1182.11	1178.05	**1156.64**
NW06	**1042.91**	1051.43	1052.91	1052.21
NW07	1037.51	1048.67	1047.9	**1036.71**
NW08	**1296.41**	1313.28	1312.91	1304.15
NW09	**1648.16**	1676.94	1677.45	1679.63
NW10	**2147.8**	2178.05	2178.58	2179.74
NW11	**1886.3**	1896.38	1898.38	1910.33
NW12	**2612.54**	2639.22	2639.25	2635.19
NW13	**2374.93**	2378.72	2380.04	2404.06
NW14	**2028.27**	2053.87	2052.09	2037.62
NW15	**2063.86**	2095.01	2093.17	2078.96
NW16	**1785.7**	1798.41	1800.39	1815.03
NW17	**2528.99**	2558.74	2559.3	2594.77
SW01	**2721.3**	2739.43	2741.09	2750.8
SW02	**2671.64**	2705.31	2705.67	2705.72
SW03	**2455.27**	2465.63	2467.24	2492.7

SW04	**2473.73**	2486.84	2488.7	2497.16
SW05	**2441.66**	2473.87	2474.51	2476.97
SW06	**2921.51**	2931.74	2931.54	2970.96
SW07	**3207.96**	3240.12	3241.3	3249.62
SW08	**3623.89**	3640.73	3642.52	3624.41
SW09	**1936.21**	1950.77	1951.47	1949.19
SW10	**2713.08**	2750.38	2745.72	2720.64
SW11	**2782.9**	2804.38	2806.36	2829.98
SW12	3096.57	3143.79	3125.71	**3053.59**
SW13	2727.8	2771.99	2757.7	**2697.99**
SW14	3098.69	3128.57	3124.44	**3092.5**
SW15	**3407.23**	3429.43	3428.52	3480.96
SW16	3181.77	3203.63	3200.96	**3174.26**
W01	**2211.82**	2243.58	2244.1	2247.44
W02	**3745.16**	3770.63	3772.11	3813.83
W03	**3319.98**	3361.06	3357.32	3335.01
W04	**4038.2**	4047.06	4048.97	4076.01
W05	**2801.42**	2832.51	2834.45	2857.5
W06	**3637.63**	3657.88	3659.5	3669.78
W07	**3612.07**	3642.85	3644.75	3680.64
W08	**2894.37**	2920.65	2913.8	2965.79
W09	**2617.55**	2657.16	2656.14	2649.82
W10	2968.49	2990.87	**2960.74**	2996.41
W11	**2842.54**	2871.85	2873.85	2900.59
W12	**3673.74**	3700.92	3699.17	3683.17
W13	**3130.36**	3166.75	3165.12	3153.22
W14	**2785.77**	2817.34	2816.9	2809.3
W15	2886.01	2944.01	2930.3	**2878.02**
W16	3686.22	3731.25	3720.09	**3659.66**
W17	**3458.86**	3485.79	3487.67	3520.3
W18	**3022.74**	3054.46	3051.82	3105.33
W19	2298.48	2303.94	**2279.13**	2306.98
W20	2528.13	2557.14	2552.91	**2524.27**
W21	**2660.66**	2700.23	2694.04	2662.35
W22	**2237.97**	2261.93	2263.43	2270.58
W23	**2236.53**	2253.76	2254.63	2253.97

These stations are greatly influenced by northeast monsoon. Mixed exponential distribution is the only distribution that has not been selected by any of the stations in describing the rainfall distribution. In conclusion, the rain gauge stations in Peninsular Malaysia are greatly swayed by their topographical, geographical sites and climatic changes which give great disparity on the rainfall distribution.

7. Acknowledgements

Authors are faithfully appreciate the generously of the staff of Malaysian Meteorological Department and Drainage and Irrigation Department for providing the daily rainfall data for the usage of this paper. The work is financed by Zamalah Scholarship provided by Universiti Teknologi Malaysia and FRGS vote 4F024 from the Ministry of Higher Education of Malaysia.

8. References

[1] V. P. Singh, "On Application of the Weibull Distribution in Hydrology," *Water Resources Management*, Vol. 1, No. 1, 1987, pp. 33-43. doi:10.1007/BF00421796

[2] R. T. Clarke, "Estimating Trends in Data from the Weibull and a Generalized Extreme Value Distribution," *Water Resources Research*, Vol. 38, No. 6, 2002, 1089. doi:10.1029/2001WR000575

[3] P. K. Bhunya, R. Berndtsson, C. S. P. Ojha and S. K. Mishra, "Suitability of Gamma, Chi-Square, Weibull, and Beta distributions as Synthetic Unit Hydrographs," *Journal of Hydrology*, Vol. 334, No. 1-2, 2007, pp. 28-38. doi:10.1016/j.jhydrol.2006.09.022

[4] P. K. Swamee, "Near Lognormal Distribution," *Journal of Hydrologic Engineering*, Vol. 7, No. 6, 2002, pp. 441-444. doi:10.1061/(ASCE)1084-0699(2002)7:6(441)

[5] T. G. Chapman, "Stochastic Models for Daily Rainfall in the Western Pacific," *Mathematics and Computers in Simulation*, Vol. 43, No. 3-6, 1997, pp. 351-358. doi:10.1016/S0378-4754(97)00019-0

[6] S. Deni, A. Jemain and K. Ibrahim, "Fitting Optimum Order of Markov Chain Models for Daily Rainfall Occur-Rences in Peninsular Malaysia," *Theoretical and Applied Climatology*, Vol. 97, No. 1, 2009, pp. 109-121. doi:10.1007/s00704-008-0051-3

[7] R. D. Stern and R. Coe, "A Model Fitting Analysis of Daily Rainfall Data," *Journal of the Royal Statistical Society. Series A* (*General*), Vol. 147, No. 1, 1984, pp. 1-34. doi:10.2307/2981736

[8] N. T. Ison, A. M. Feyerherm and L. Dean Bark, "Wet Period Precipitation and the Gamma Distribution," *Journal of Applied Meteorology*, Vol. 10, No. 4, 1971, pp. 658-665. doi:10.1175/1520-0450(1971)010<0658:WPPATG>2.0.CO;2

[9] T. A. Buishand, "Some Remarks on the Use of Daily Rain-Fall Models," *Journal of Hydrology*, Vol. 36, No. 3-4, 1978, pp. 295-308. doi:10.1016/0022-1694(78)90150-6

[10] W. May, "Variability and Extremes of Daily Rainfall during the Indian Summer Monsoon in the Period 1901-1989," *Global and Planetary Change*, Vol. 44, No. 1-4, 2004, pp. 83-105. doi:10.1016/j.gloplacha.2004.06.007

[11] H. K. Cho, K. P. Bowman and G. R. North, "A Comparison of Gamma and Lognormal Distributions for Characterizing Satellite Rain Rates from the Tropical Rainfall Measuring Mission," *Journal of Applied Mete- orology*, Vol. 43, No. 11, 2004, pp. 1586-1597. doi:10.1175/JAM2165.1

[12] S. R. Bhakar, A. K. Bansal, N. Chhajed and R. C. Purohit, "Frequency Analysis of Consecutive Days Maximum Rain-Fall at Banswara, Rajasthan, India," *ARPN Journal of Engineering and Applied Sciences*, Vol. 1, No. 3, 2006, pp. 64-67.

[13] D. A. Mooley, "Gamma Distribution Probability Model for Asian Summer Monsoon Monthly Rainfall," *Monthly Weather Review*, Vol. 101, No. 2, 1973, pp. 160-176. doi:10.1175/1520-0493(1973)101<0160:GDPMFA>2.3.CO;2

[14] H. Aksoy, "Use of Gamma Distribution in Hydrological Analysis," *Turkish Journal of Engineering and Environmental Sciences*, Vol. 24, No. 6, 2000, pp. 419-428.

[15] Y. Fadhilah, M. Zalina, V. T. V. Nguyen, S. Suhaila and Y. Zulkifli, "Fitting the Best-Fit Distribution for the Hourly Rainfall Amount in the Wilayah Persekutuan," *Jurnal Teknologi*, Vol. 46, No. C, 2007, pp. 49-58.

[16] J. Suhaila and A. A. Jemain, "Fitting Daily Rainfall Amount in Malaysia Using the Normal Transform Distribution," *Journal of Applied Sciences*, Vol. 7, No. 14, 2007, pp. 1800-1886.

[17] J. Suhaila and A. A. Jemain, "Fitting Daily Rainfall Amount in Peninsular Malaysia Using Several Types of Exponential Distributions," *Journal of Applied Sciences Research*, Vol. 3, No. 10, 2007, pp. 1027-1036.

[18] J. Suhaila and A. A. Jemain, "Fitting the Statistical Distribution for Daily Rainfall in Peninsular Malaysia Based on AIC Criterion," *Journal of Applied Sciences Research*, Vol. 4, No. 12, 2008, pp. 1846-1857.

[19] E. Ha and C. Yoo, "Use of Mixed Bivariate Distributions for Deriving Inter-Station Correlation Coefficients of Rain Rate," *Hydrological Processes*, Vol. 21, No. 22, 2007, pp. 3078-3086. doi:10.1002/hyp.6526

[20] J. B. Wijngaard, A. M. G. K. Tank and G. P. K. Nnen, "Homogeneity of 20th Century European Daily Temperature and Precipitation Series," *International Journal of Climatology*, Vol. 23, No. 6, 2003, pp. 679-692. doi:10.1002/joc.906

[21] B. Kedem, L. S. Chiu and G. R. North, "Estimation of Mean Rain Rate Application to Satellite Observations," *Journal of Geophysical Research*, Vol. 95, No. D2, 1990, pp. 1965-1972. doi:10.1029/JD095iD02p01965

[22] H. Qiao and C. P. Tsokos, "Parameter Estimation of the

Weibull Probability Distribution," *Mathematics and Computers in Simulation*, Vol. 37, No. 1, 1994, pp. 47-55. doi:10.1016/0378-4754(94)90058-2

[23] R. P. McDonald, "An Index of Goodness-of-Fit Based on Noncentrality," *Journal of Classification*, Vol. 6, No. 1, 1989, pp. 97-103. doi:10.1007/BF01908590

[24] F. M. Mutua, "The Use of the Akaike Information Criterion in the Identification of an Optimum Flood Frequency Model," *Hydrological Sciences Journal*, Vol. 39, No. 3, 1994, pp. 235-244. doi:10.1080/02626669409492740

[25] B. K. Tan, "Urban Geology of Kuala Lumpur and Ipoh, Malaysia," *International Association of Engineering Geology* (*IAEG*2006), The Geological Society of London, London, 2006, pp. 1-7.

[26] C. E. Vincent, T. D. Davies and A. K. C. Beresford, "Recent Changes in the Level of Lake Naivasha, Kenya, As an Indicator of Equatorial Westerlies over East Africa," *Climatic Change*, Vol. 2, No. 2, 1979, pp. 175-189. doi:10.1007/BF00133223

[27] W. L. Dale, "The Rainfall of Malaya, Part II," *Journal of Tropical Geography*, Vol. 14, 1960, pp.11-28.

[28] Z. A. Roslan and A. H. Zulkifli, "'ROM Scale for Forecasting Erosion Induced Landslide Risk on Hilly Terrain," In: Kyoji Sassa, Ed., *Landslides*: *Risk Analysis and Sustainable Disaster Management*: *Proceedings of the Fist General Assembly of the International Consortium on Landslides*, *Part* 3, International Consortium on Landslides, Springer, Berlin Heidelberg, 2005, pp. 197-202.

[29] S. Ahmad, M. I. S. Mohd and M. Hashim, "Application of Remote Sensing Techniques for Prediction of Landslide Hazard Areas in Malaysia," 14*th United Nations*/*International Astronomical Federation Workshop on* "*Capacity Building in Space Technology for the Benefit of Developing Countries*," *with an Emphasis on Natural Disaster Management*, Vancouver, 2-3 October 2004.

[30] B. K. Tan and W. H. Ting, "Some Case Studies on Debris Flow in Peninsular Malaysia," In: H. Liu, A. Deng, and J. Chu, Eds., *Geotechnical Engineering for Disaster Mitigation and Rehabilitation*, Springer, Berlin, 2008, pp. 231-235. doi:10.1007/978-3-540-79846-0_20