ANALISIS CURAH HUJAN DENGAN MODEL LINIER DAN BILINIER

RAINFALL ANALYSIS USING LINEAR AND BILINEAR MODELS

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Abstrak

Negara dengan iklim tropis seperti Malaysia tergantung pada curah hujan yang terkonsentrasi pada durasi waktu yang pendek selama beberapa bulan dalam setahun. Curah hujan yang besar tersebut memberikan peningkatan pada tingginya runoff (aliran air) dengan debit puncak yang terjadi dalam durasi singkat yang dapat membawa pada terjadinya banjir secara cepat. Sebuah model yang dapat memprediksikan curah hujan secara efektif adalah penting untuk dapat mengeliminasi kerusakan akibat banjir. Akurasi, kehandalan, dan spot waktu adalah elemen-elemen yang dibutuhkan untuk prediksi secara akurat. Paper ini menyajikan analisis diagnostic pada data curah hujan menggunakan model linear dan bilinear. Analisis ini menyatakan bahwa Akaike's Information Criterion (AIC), Akaike's Bayesian Information Criteria (BIC), SBIC dan varian residu untuk model Bilinear (BL) adalah lebih kecil dibandingkan dengan model ARIMA (Autoregressive integrated Moving Average). Hal ini menunjukkan bahwa model bilinear cocok dan sesuai dengan curah hujan. Untuk itu, penemuan ini dapat mengarahkan kepada pengembangan model yang lebih akurat untuk memprediksikan banjir.

Kata kunci : bilinier, curah hujan, linier, Malaysia

Abstract

Countries with tropical climate like Malaysia are subjected to heavy rainfall concentrated in a short duration of time during certain months in a year. Such heavy rainfalls give rise to high runoff with peak flow occurring within a short duration leading to the occurrence of flash flood. A model that forecasts rainfall effectively is imperative as this helps to eliminate damages in the event of flood. Accuracy, reliability and timeliness are the elements required for an accurate forecast. This paper presents diagnostic analysis on the rainfall data using linear and bilinear models. The analysis confirmed that the Akaike's Information Criterion (AIC), Akaike's Bayesian Information Criteria (BIC), SBIC and the residual variances for Bilinear (BL) model is smaller than that of ARIMA (Autoregressive Integrated Moving Average) model. This suggests that the bilinear model fits the rainfall better. Thus, the finding may lead to the development of a more accurate model for flood forecasting.

Keywords : bilinear, linear, Malaysia, rainfall

1. INTRODUCTION

Malaysia has an equatorial climate with high temperature and relative humidity. It is subjected to the North-East and South-West monsoon between the months of November-February and May-August respectively. Average annual rainfall for Peninsular Malaysia is about 2.400 mm with more rain in the East coast 2.600 mm in Sabah and up to 3.800 mm in Sarawak (Malaysian Water Association, 2003).

During the North-East monsoon, heavy and prolonged rainfall result in floods, inundating extensive areas for several weeks, especially areas in the East coast of peninsular Malaysia, North of Sabah and South of Sarawak. The west coast of peninsular Malaysia, however, is often affected by the South-West monsoon wind that does not bring as much rain. Occasional conventional thunderstorms characterized by high intensity and short duration rainfall mark the transitional periods between the two monsoons. In such cases, fast water level responses usually lead to flash floods could last for several hours.

High flows coupled with high tides may flood the lower reaches. Inland flooding, on the other hand, is usually due to inadequate drainage either insufficiently provided or choked by silt or rubbish. Rapid land development, land-use changes either from forest to agriculture or industries has not been properly controlled resulting in the increase in surface runoff, erosion and sedimentation, with the capacity of channels reduced, flash flooding is more frequent. (Abdul Talib et al, 1994).

The time occurrence of excessive rainfall and the resultant flash flood is rather short and most often the authorities are unable to issue the warnings in advance.

A model that is able to forecast rainfall effectively is imperative as this helps to eliminate damages in the event of flood. Accuracy, reliability, and timeliness are the elements required for an accurate forecast. These form the basis of specific flood warning and facilitate the water resources managers to take responsive actions to mitigate flood damage.

On the other hand, inaccurate forecasts may do more damage than good. Inaccurate forecast will lead to either a false alarm or no alarm at all. Un-der such circumstances, it may be preferable not to make a forecast than to do so erroneously.

The impact of missing data may vary, depending upon the origin of the missing data. If rainfall is highly variable, then malfunctioning of one of the strategic rain gages will have adverse effect on flood forecasting. Likewise, if stages or discharges of a highly variable upstream tributary are used as inputs, then missing observation of this tributary will have detrimental effect on the forecast.

The introduction of a rainfall predictive model that is capable of allowing for such missing data reduc-es the error significantly. Thus, the missing dis-charge can be predicted using the data observed in the previous time interval and the lead time for flood forecasting can be increased.

2. STUDY AREA

The study area consists of the Sg. Selangor basin located within the State of Selangor Darul Ehsan. It is approximately 70 km long and 30 km wide and stretches from the slopes of the mountainous Titiwangsa ranges at Bukit Fraser in the northeast to the Straits of Malacca in the West (Ariffin & Abdul Talib, 2000).

With a catchment area of 1.820 sq.km, the general flow of Sg. Selangor is in a South-Westerly direction traversing a total distance of approximately 110 km before discharging into the Straits of Malacca at the town of Kuala Selangor. (DOE, 1994). The catchment is subjected to two monsoonal periods: the Northeast Monsoon (October to January) and the Southwest monsoon (May to September). Rainfall peaks during the monsoons with a larger peak in October-December. February and July-August which are inter-monsoonal periods have the least rainfall.

Average annual rainfall ranges from 2.000 mm to 3.500 mm. Mean annual evaporation ranges from 1.200 to 1.650 mm while mean annual runoff ranges from 800 mm to 1.850 mm (DOE). Daily rainfall data from 12 stations amounting to 363 data are used in the analysis.

3. RESULTS AND DISCUSSION

Figure 1 illustrates the rainfall hydrograph of Sg Selangor. From the analysis on 363 rainfall data, it is evident that data is non-stationary. The ACF (Autocorrelation function) plot in Figure 2 shows a very slow decrease in the ACF values whereas the PACF (Partial autocorrelation function) value at lag 1 is very large as given in Figure 3. These further confirmed that the data is non-stationary.

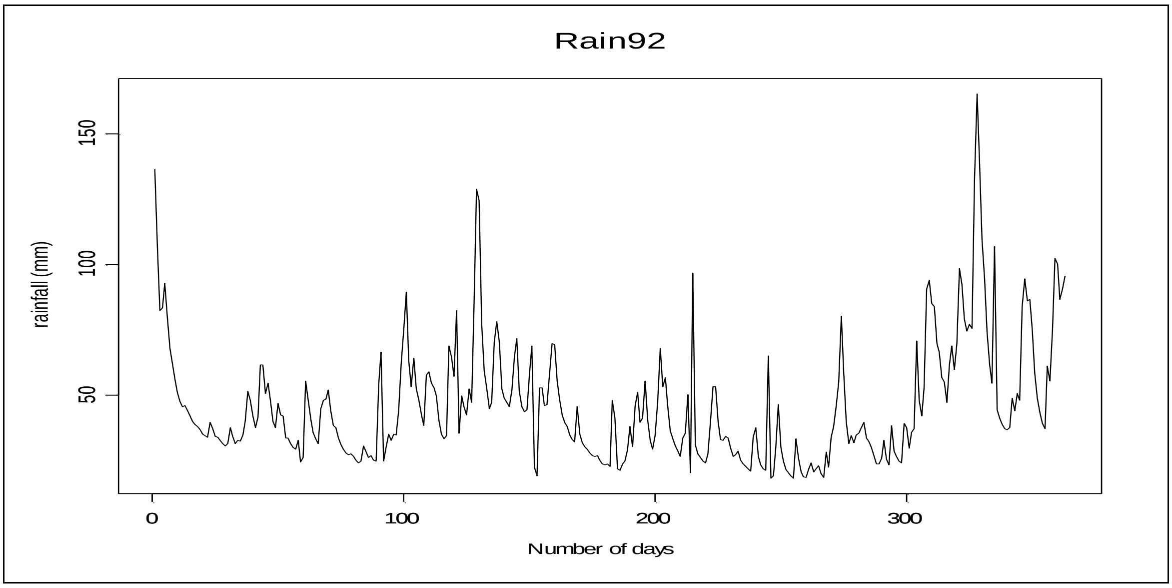

Figure 1. Rainfall Hydrograph

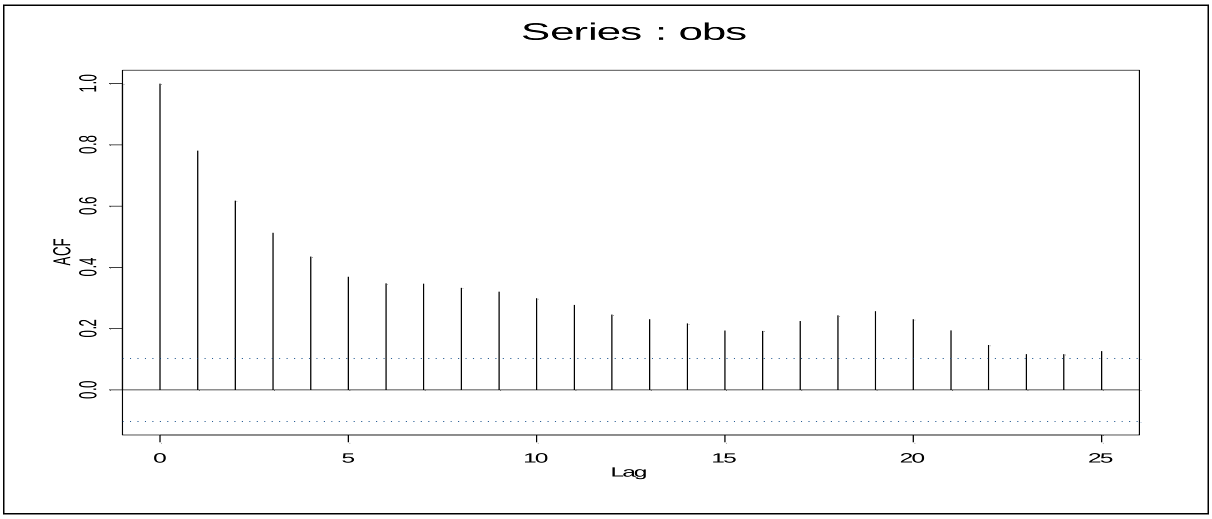

Figure 2. ACF Plot

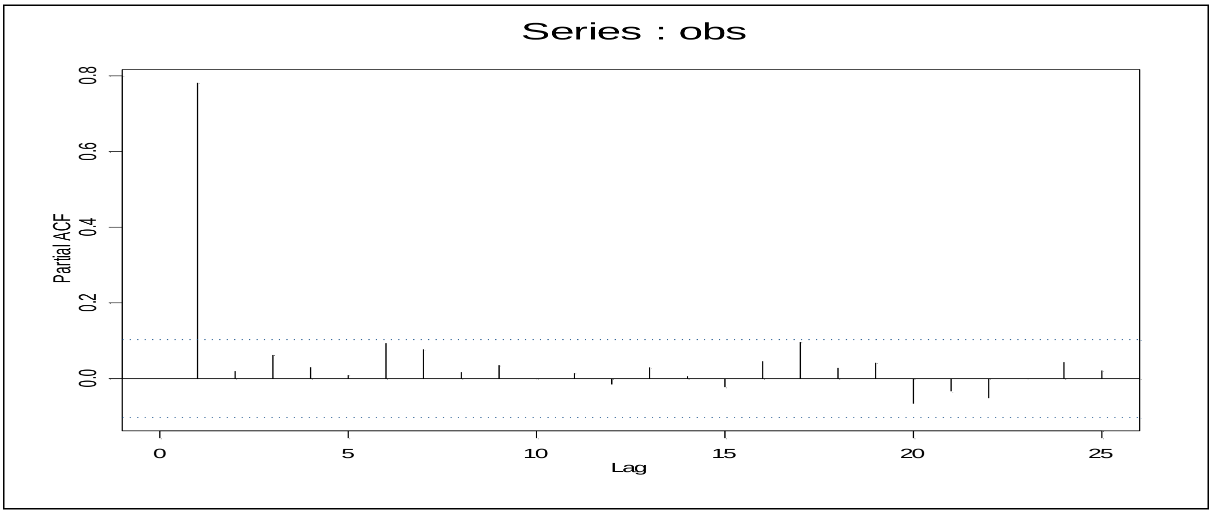

Figure 3. PACF Value at Lag 1

The effect of differencing the data should be explored. The first differenced data are shown respectively in Figure 4 and Figure 5. It can be seen that differencing of order unity and two reduce the original data to be stationary in mean. However, the differencing of order unity produces data with smaller magnitude of spikes, which means that it is closer to achieve stationary in variance. A moving average model of order two seems to be appropriate. Hence, ARIMA(0,1,2) is a possible candidate for the data.

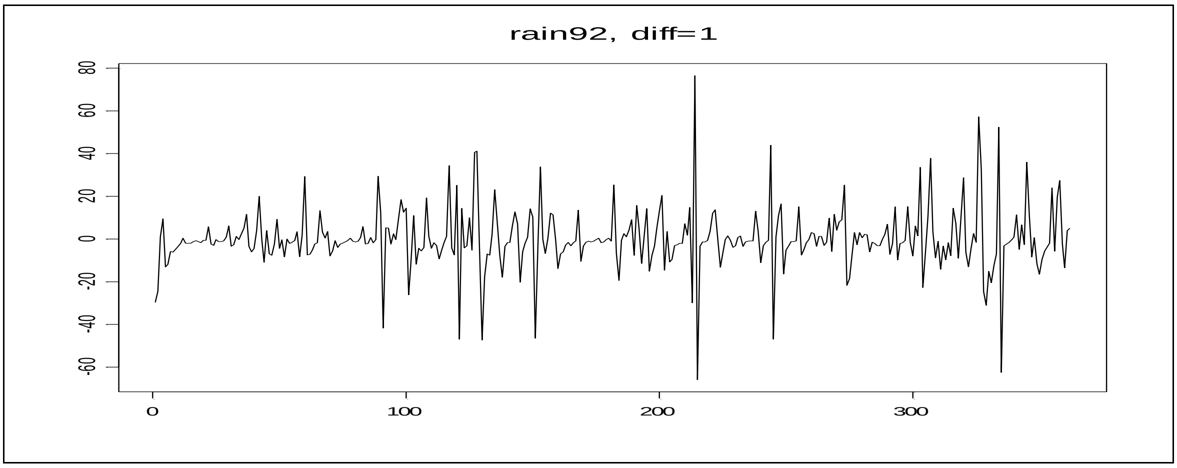

Figure 4. Plot of First Differenced Data

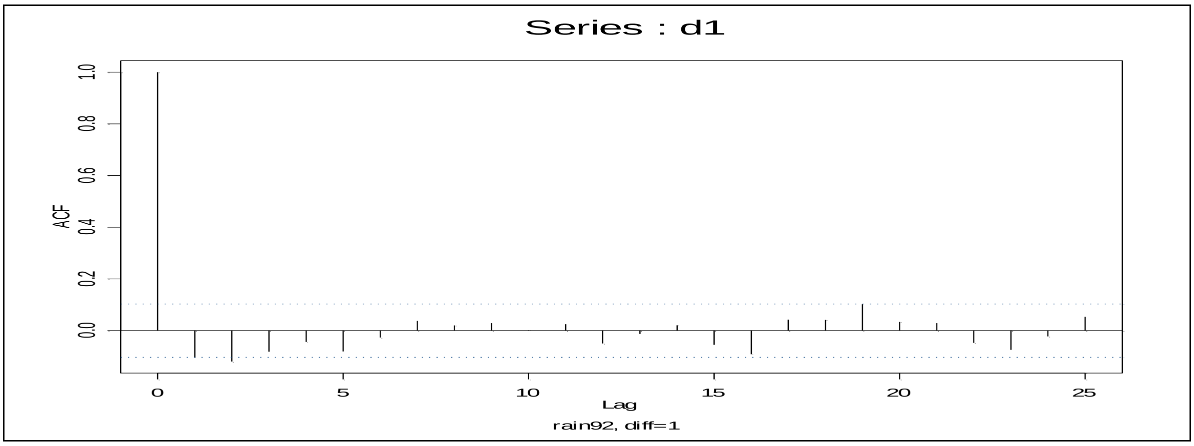

Figure 5. Plot of ACF of the First Differenced Data

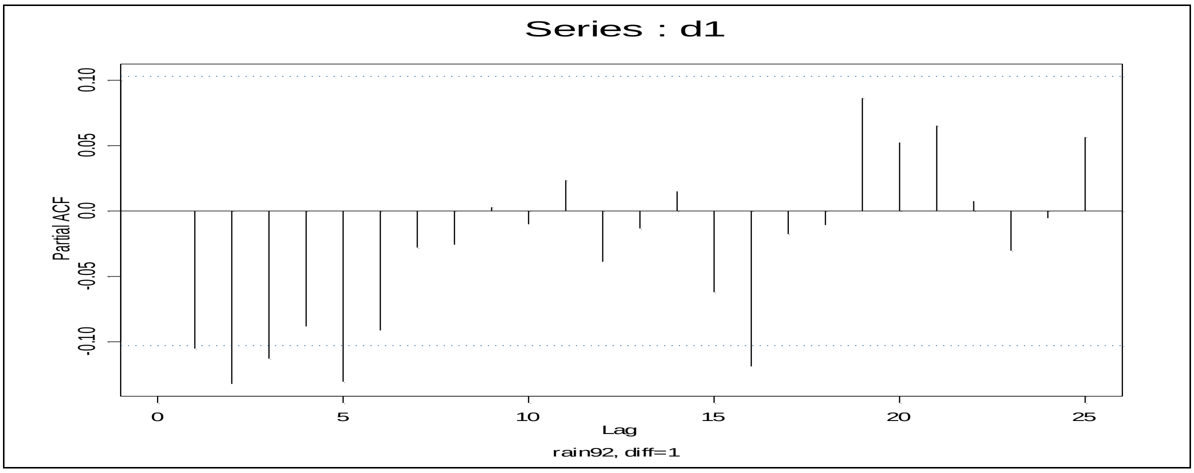

Figure 6. Plot of PACF of the First Differenced Data

When ARIMA (0,1,2) is fitted, the parameter estimates are θ_{11} = 0.199 and θ_{21} = 0.217. The t-test values for the parameter estimates are 3.876 and 4.224 respectively, which suggest that both are significant at 10% significance level. The goodness-of-fit of the model is then investigated. The Ljung-Box statistics at lags 12 and 24 are 14.680 and 35.156 respectively whereas the 5% critical values based on the chi-square distribution with 11 and 23 degrees of freedom are 23.209 and 40.289 respectively. Hence, the Ljung-Box statistics are not significant at 5% significant level and there is no strong reason to reject the model. Investigation on the ACF and PACF plots of the standardized residuals reveals that not a single significant spike is observed as shown in Figure 7 and 8. Results suggest that the residuals are white noise. The correlation between the residuals and normal scores is 0.935. The Durbin-Watson statistic takes the value 1.910 which suggests that the residuals are white noise.

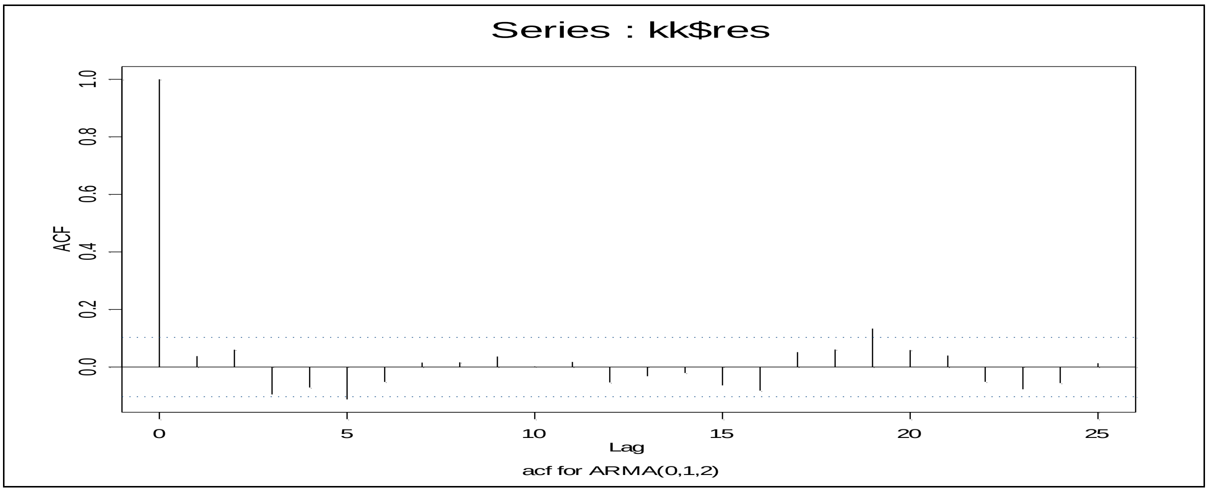

Figure 7. The ACF Plot of the Residuals for ARIMA(0,1,2)

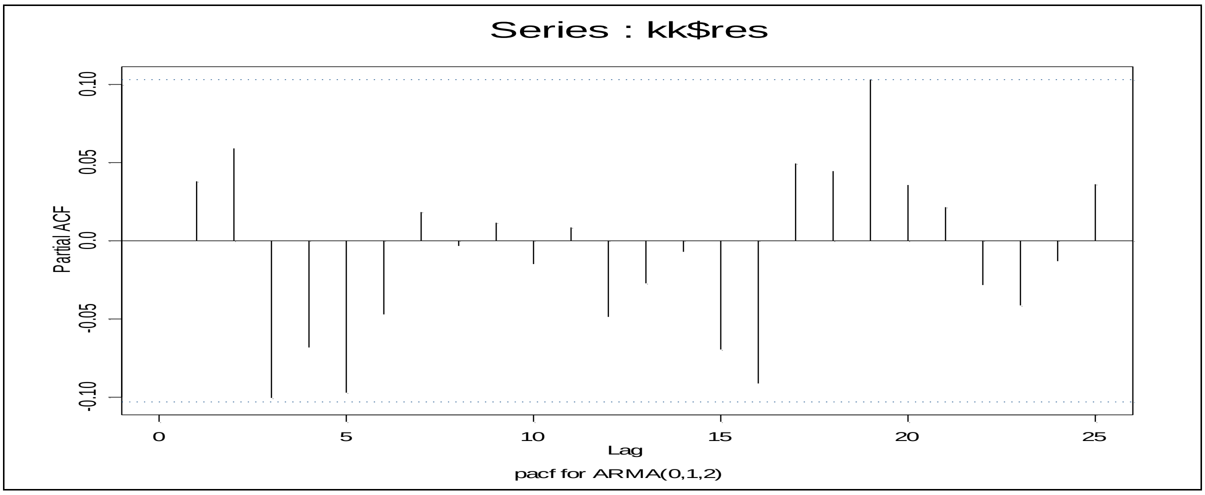

Figure 8. The PACF Plot of the Residuals for ARIMA(0,1,2)

Other linear models are investigated. The diagnostic results are given in Table 1. Other models are considered but fail to improve the modeling. It is obvious that the AIC, BIC and SBIC values for ARIMA(0,1,2) are the lowest. The same is observed for the residual variance. The correlation values and the Durbin-Watson values do not differ much. Hence, ARIMA(0,1,2) can be taken as the best fitted linear model on the rainfall data.

Table 1. Linear ARIMA Models

Model	AIC	BIC	SBIC
ARIMA(0,2,1)	2962.39	1937.14	1936.14
ARIMA(0,2,2)	2960.26	1939.90	1937.90
ARIMA(0,1,2)	2943.38	1923.02	1921.02

The possibility of fitting non-linear model on the rainfall data is investigated. Non-linearity tests are applied on the data. The F-test suggests that the rainfall data is non-linear with p-value 0.014 whereas the Keenan's test suggests otherwise with p-value of 0,869. Hence, we have reason to investigate whether fitting bilinear model can improve the modeling. Four different bilinear models are considered; BL(1,0,1,1), BL(2,0,1,1), BL(3,0,1,1) and BL(1,1,1,1). The results of the analysis are shown in Table 2. In general, the results are almost similar for the models. Based on parsimony principle, BL(1,0,1,1) is selected, as the number of parameters considered is the smallest. The parameter estimates are ϕ_1 = 0,7830 and β_{11} = 0,0004.

Table 2. The Results for Fitted Bilinear Models

Model	AIC	BIC	SBIC
BL(1,0,1,1)	2.916,347	1.895,987	1.893,987
BL(2,0,1,1)	2.918,397	1.902,930	1.899,930
BL(3,0,1,1)	2.918,611	1.908,039	1.904,039
BL(1,1,1,1)	2.918,055	1.902,589	1.899,589

Table 3 summarizes the diagnostic results for linear and bilinear models considered. It is obvious that the values of AIC, BIC and SBIC for BL(1,0,1,1) is smaller than that of ARIMA(0,1,2). These suggest that BL(1,0,1,1) fits the rainfall data better.

Table 3. Summary of Diagnostic Results for the Rainfall Data

Model	AIC	BIC	SBIC
ARIMA(0,1,2)	2943.38	1923.02	1921.02
BL(1,0,1,1)	2916.347	1895.987	1893.987

4. CONCLUSIONS

The analysis on the highly variable rainfall data of Sg Selangor catchment using both linear and non-linear models have been investigated. Diagnostic results of the analysis conclude that the Bilinear model (1,0,1,1) fits the rainfall better with smaller values of AIC, BIC, and SBIC compared to ARIMA model. It is believed that the finding will lead to the development of a flood forecasting model that is more accurate and reliable with longer lead time.

REFERENCES

Abdul-Talib, S. (1994). **Effects of Urbanisation on the Maintenance of Drainage System: A Case Study at ITM Campus, Shah Alam Selangor Darul Ehsan,** Buletin Jurutera, Vol. 94, No.1.

Ariffin, J., Abdul Talib, S. (2000). **A Pilot Study on Flood Forecasting for Selangor River Basin**. Seminar Hasil Penyelidikan 2000 UiTM.

Department of Environment (DOE), Ministry of Science, Technology and the Environment of Malaysia(1998). **A Final Report on Development of Water Quality Criteria as Standard in Malaysia (Phase iv – River Classification)**, Vol.3.

Malaysian Water Association (2003). **Malaysia Water Industry Guide 2003**, Malaysian Water Association, Kuala Lumpur.