JOURNAL OF
ENVIRONMENTAL HYDROLOGY

The Electronic Journal of the International Association for Environmental Hydrology
On the World Wide Web at http://www.hydroweb.com

VOLUME 19 2011

ANNUAL RAINFALL ESTIMATION BASED ON TWO DIFFERENT METHODS

M.R. Sheriza[1]
N.A. Ainuddin[1,2]
A.H. Hazandy[1,2]
M.S. Helmi Zulhaidi[3]

[1]Institute of Tropical Forestry and Forest Products
[2]Faculty of Forestry
[3]Faculty of Engineering
Universiti Putra Malaysia, Selangor, Malaysia

Rainfall is frequently used as a climate index during prolonged dry seasons and extreme rainfall to determine changes in global climate. This study estimates average total rainfall for the study area based on arithmetic mean and the Thiessen polygon methods. The objective was to analyze rainfall variability based on statistical analysis of variance and to produce maps of rainfall variability using isohyetal contour techniques. Based on the two methods, results showed three distinctive rainfall patterns occurred for consecutive years within the study area.

INTRODUCTION

Water sources such as rainfall are vital for human and animal consumption as well as for agriculture and natural vegetation (Eltahir, 1992). It is important for water resources, and with low rainfall it affects agriculture activity, contributes to climate change, and natural hazards such as floods and droughts (Manfreda et al., 2002). In response to growing concerns about climate change issues, researchers have begun developing methods of assessing rainfall distribution and patterns from rainfall data. This is because rainfall was observed as a frequent indicator of climate change in determining changes in the study of global and local climate change. Rainfall analysis and variability assessment was reported as an indicator of drought analysis in Peninsular Malaysia (Department of Irrigation and Drainage Malaysia, 2005). Furthermore, spatial rainfall analysis is one of the methods available to map rainfall patterns based on annual rainfall data. There many types of techniques involved in estimating annual rainfall such as Isohyetal contour techniques. Isohyetal contour maps produced from this technique are one of the analyses carried out by most of the meteorological office (Shearman and Laster, 1975). Later, the technique was also implemented in another study by Fiedler (2003). Other techniques such as the Thiessen polygon method was used by Chidley and Key (1970), Sing and Birsoy (1975), and Bayrakter et al. (2005). Using annual rainfall data estimation, rainfall patterns can be predicted and monitored.

STUDY AREA

The study is conducted in Negeri Sembilan which is located in western Malaysia. Peninsular Malaysia climate is equatorial with annual averages of temperatures that are between 20.5^o and 36^o C. The important feature of equatorial climate is the small seasonal variation in incoming solar radiation, both in duration and intensity (Ainuddin, 1998). Negeri Sembilan has two distinctive rainfalls, polar which is moderately dry and moist. Negeri Sembilan received the lowest yearly rainfall for Peninsular Malaysia based on the analysis conducted by Shaharuddin and Noorazuan (2006) for 1987 - 1997. This finding was comparable to Perlis which is located at the Northern part of Peninsular Malaysia. Particularly, this region is facing dry conditions every year during West East Monsoon season. Again, based on research dry conditions were observed in Jelebu and Kuala Pilah. Subsequently, Negeri Sembilan experienced mean monthly relative humidity ranging 80.6% - 85.6% (1997 – 2006). Figure 1 illustrates the location of study area in Malaysia and Negeri Sembilan map. Also the map was presented the location rainfall stations Negeri Sembilan.

MATERIALS AND METHODS

Rainfall Data

Rainfall data was acquired from Malaysian Meteorological Department (Malaysia Meteorological Department, 2008). The location of the stations is shown in previously map in Figure 1. Rainfall data are collected over 24 hour period beginning 08:00 at Malaysia time which equal to 00:00 UTC time. Three rainfall stations are located at the west and east of Negeri Sembilan, respectively. One station is located at the southern part of Negeri Sembilan. In this study, total rainfall stations finalized for the analysis were seven. Stations was named regarding to the location of the station area namely in the valley, estate or plantation for example Ladang Batang Jelai rainfall station which is located at plantation area. Table 1 showed overall rainfall data and stations used for the analysis.

Data Analysis

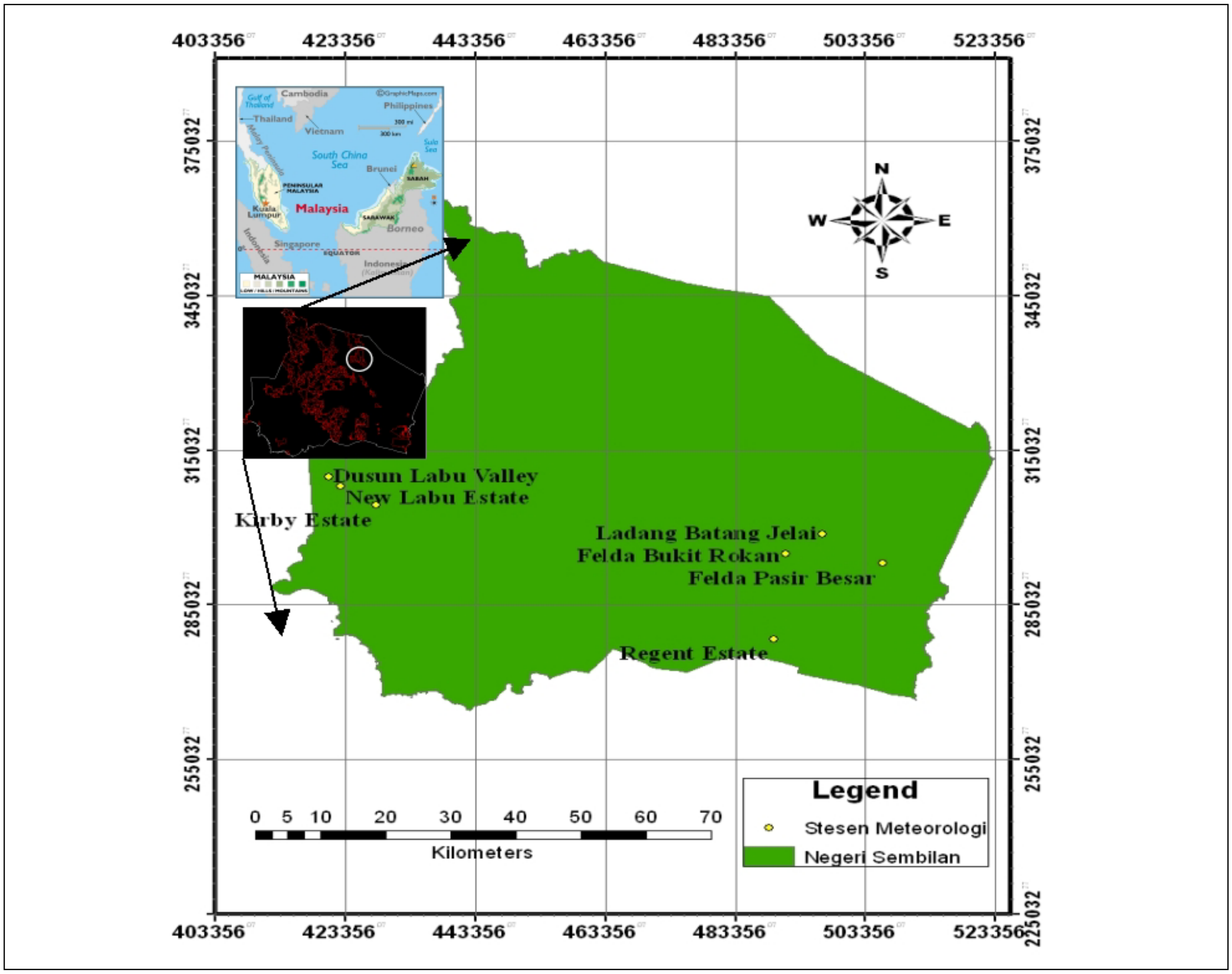

Figure 1. Location of the study area in Malaysia (blue) and Negeri Sembilan map (black) and the seven rainfall stations (green).

Data was analyzed based on the two different techniques which are Arithmetic mean and Thiessen Polygon. The techniques were using Spatial Analyst extension in ArcGIS 9.3.1 version software of Geographical Information System (GIS) for analyzing and mapping of the area. For Arithmetic methods, the data analysis was calculated as the amount of rainfall divided by the number of rainfall stations. This technique is simple but it was found least accurate for the area with uniformly distributed and the topography is flat (Grand Solution Manual, 2011). Thiessen Polygon is calculated based on this equation:

Table 1. Complete rainfall data for the stations.

Rainfall Station	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	TOTAL
Dusun Labu Valley	1527	1883	2204	2616	2379	1892	2628	1935	1719	2262	21044
Felda Bukit Rokan	1358	1404	1875	2020	1618	1701	1847	1656	1318	1951	16749
Felda Pasir Besar	2088	1306	1770	1978	1562	2257	2359	1591	1319	1857	18086
Kirby Estate	1877	1620	1546	3008	2501	2140	2593	1684	1414	1714	20097
Ladang Batang Jelai	1558	1318	1942	2191	1485	1808	2040	1510	1088	1559	16499
New Labu Estate	2225	2222	2346	2507	2071	1872	2498	1367	1382	2103	20592
Regent Estate	1284	1230	1571	1832	1334	1484	1774	1546	1161	1950	15166

$$P_{avg} = \sum_{i=1}^{n}\left(\left[\frac{A_i}{\sum A_i}\right] * P_i\right) \quad (1)$$

where A_i is the area of each polygon and P_i is the rainfall data at the centre of each polygon, and n is the total number of polygons. Finally, average rainfall over the basin is *Pavg*. In this study, all the rainfall stations were plotted on the map at an appropriate scale. After that, without crossing any lines straight lines were drawn in order to connect rainfall stations. Next, each connecting line is then bisected and a perpendicular is drawn through the connecting line. Later, the area of each polygon was measured and the total areas for each polygon were computed. Whereas, the isohyetal contour map was produced according to minimum and maximum value of the rainfall data. The process was conducted using Spatial Analyst tools. In this study, yearly contour map was also presented to represent variation of rainfall distribution for different years.

Statistical Analysis

In this study data was statistically analyzed using Analysis of Variance (ANOVA) and Tukey Honestly Significant Difference (HSD) using SPSS software package. The objective is to test significances of the rainfall data among the station and within rainfall years. The significance level was set at $p=0.05$.

RESULTS AND DISCUSSION

Annual Rainfall

Annual rainfall estimated from Arithmetic technique was 1839 mm. This study found the estimation was closed to a study conducted by Shaharuddin and Noorazuan (2006) with 1846 mm of rainfall. Shaharuddin and Noorazuan (2006) conducted the study from rainfall data of 1983 – 2008 (28 years). Whereas, an annual rainfall was estimated at 2018 mm with the application of Thiessen polygon techniques (as described in Table 2). This indicated an overestimation of average total rainfall from the arithmetic mean method. As the annual rainfall is representing the estimation of average total rainfall, this study was suggested Thiessen polygon as the best technique to estimate the annual rainfall for this study area. This is because the technique is capable to estimate average total rainfall as it manage to take into account of wide area rather than point source area or point location of the stations. Figure 2 illustrates the Thiessen polygon map for this study area.

Statistical Analysis

There were differences in rainfall values within the seven stations (as described in Table 3). Regent Estate showed significant differences with Dusun Labu Valley and New Labu Estate (p=0.01) and (p = 0.035). There were no significant differences among other rainfall stations such as Felda Bukit Rokan, Felda Pasir Besar, Kirby Estate and Ladang Batang Jelai. However, there

Table 2. Annual rainfall for each method.

Method	**Annual Rainfall** (mm)
Arithmetic method	1839
Thiessen Polygon method	2018

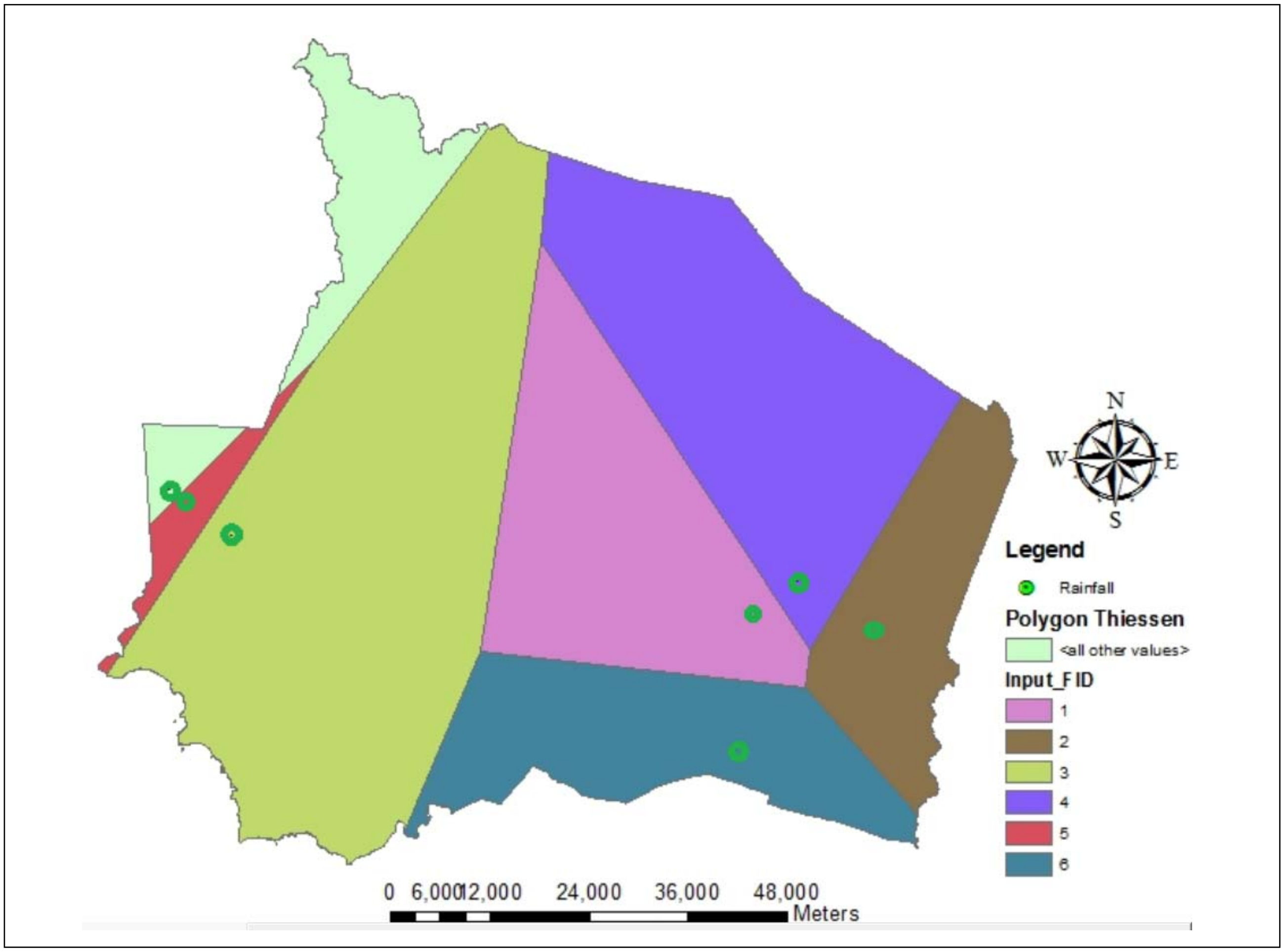

Figure 2. Thiessen Polygon for seven representative stations.

were differences within years tested (p= 0.000) as described in Table 4. In details, rainfall in 1997 was significantly difference with 2000 rainfall with negative relationship (p= 0.031). The 1998 were significantly difference with 2000 and 2003 rainfall (p= 0.003) and (p= 0.009) respectively. For 2000 there was significantly different with 2004 and 2005 rainfall (p= 0.007) and (p= 0.000). The 2003 rainfall were showed significant difference with 2004 and 2005 (p= 0.019) and (p= 0.000). This study found there were no significant differences within the 2006 and other years.

Rainfall Isohyetal Contour Map

The overall view of yearly rainfall distribution from Isohyetal contour map techniques is shown in Figure 3. The map presented the annual rainfall amount contour for the seven representative stations. Blue color, turquoise, yellow and red indicated rainfall as high, moderate, low and very low, respectively.

Rainfall distribution from yearly isohyetal contour map

From the contour map lowest annual rainfall were observed at eastern and southern part of the region. The areas experienced low rainfall value with the contour color was expanded the orange color area towards the section. As shown in Figure 4, 1997 to 2006 map showed red contour area which indicated low rainfall for the consecutive years. However, Regent estate and Felda Bukit Rokan showed the same contour colors which was indicated insignificant differences. The maps were also depicted the extreme distribution of blue color which indicated higher rainfall at western

Table 3. Results of the analysis of variance for rainfall stations.

Station	N	Mean	F	sig-F
Dusun Labu Valley	10	2140.80	3.560	0.004
Felda Bukit Rokan	9	1644.22		
Felda Pasir Besar	11	1821.55		
Kirby Estate	10	1977.00		
Ladang Batang Jelai	10	1649.90		
New Labu Estate	10	2059.20		
Regent Estate	10	1516.60		
Total	70	1827.29		

Table 4. Results of the analysis of variance for years.

Year	N	Mean	F	sig-F
1997	7	1702.51	5.708	0.000
1998	7	1568.97		
1999	7	1893.30		
2000	7	2307.47		
2001	7	1849.93		
2002	7	1879.10		
2003	7	2248.43		
2004	7	1612.66		
2005	7	1342.90		
2006	7	1913.64		
Total	70	1831.89		

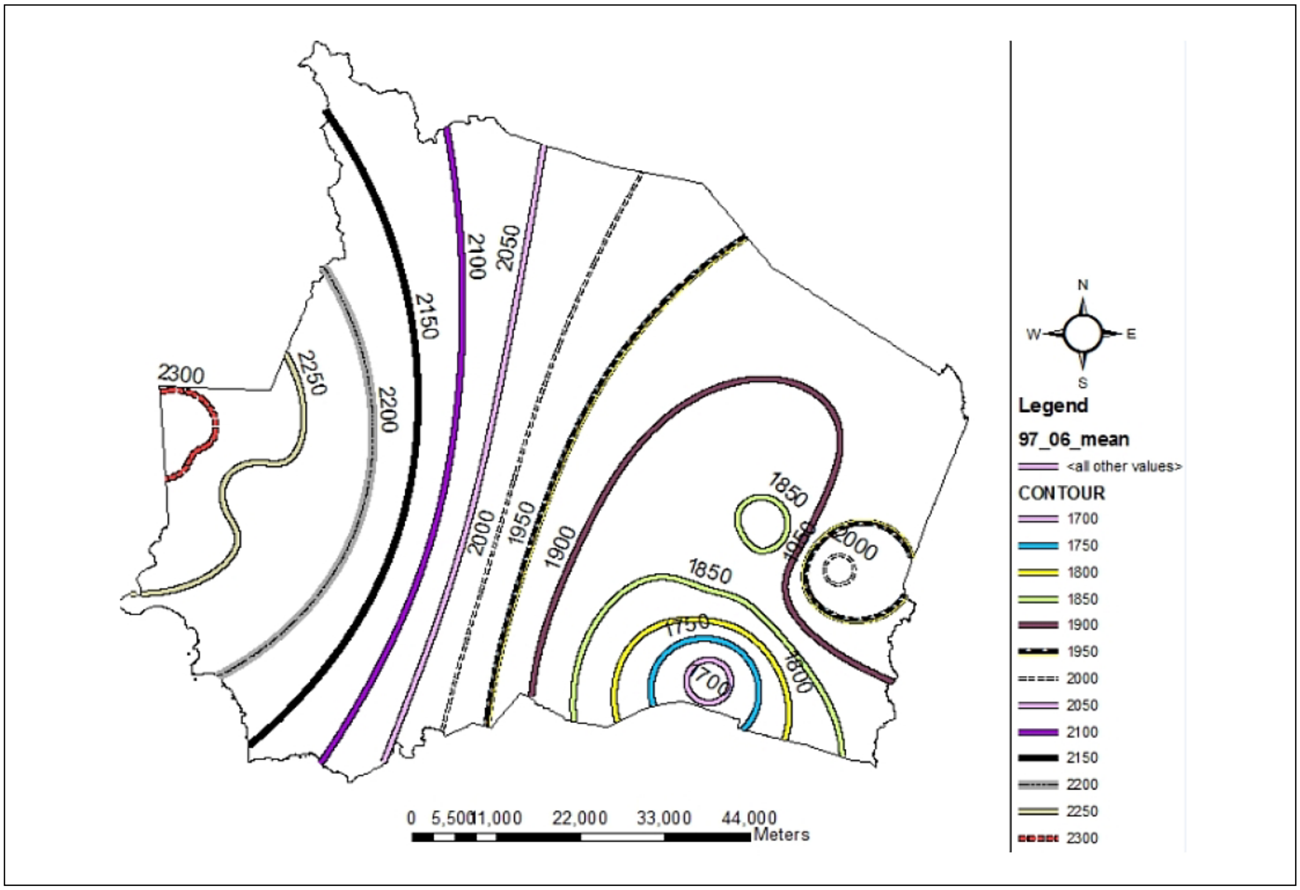

Figure 3. Isohyetal contour for the study area.

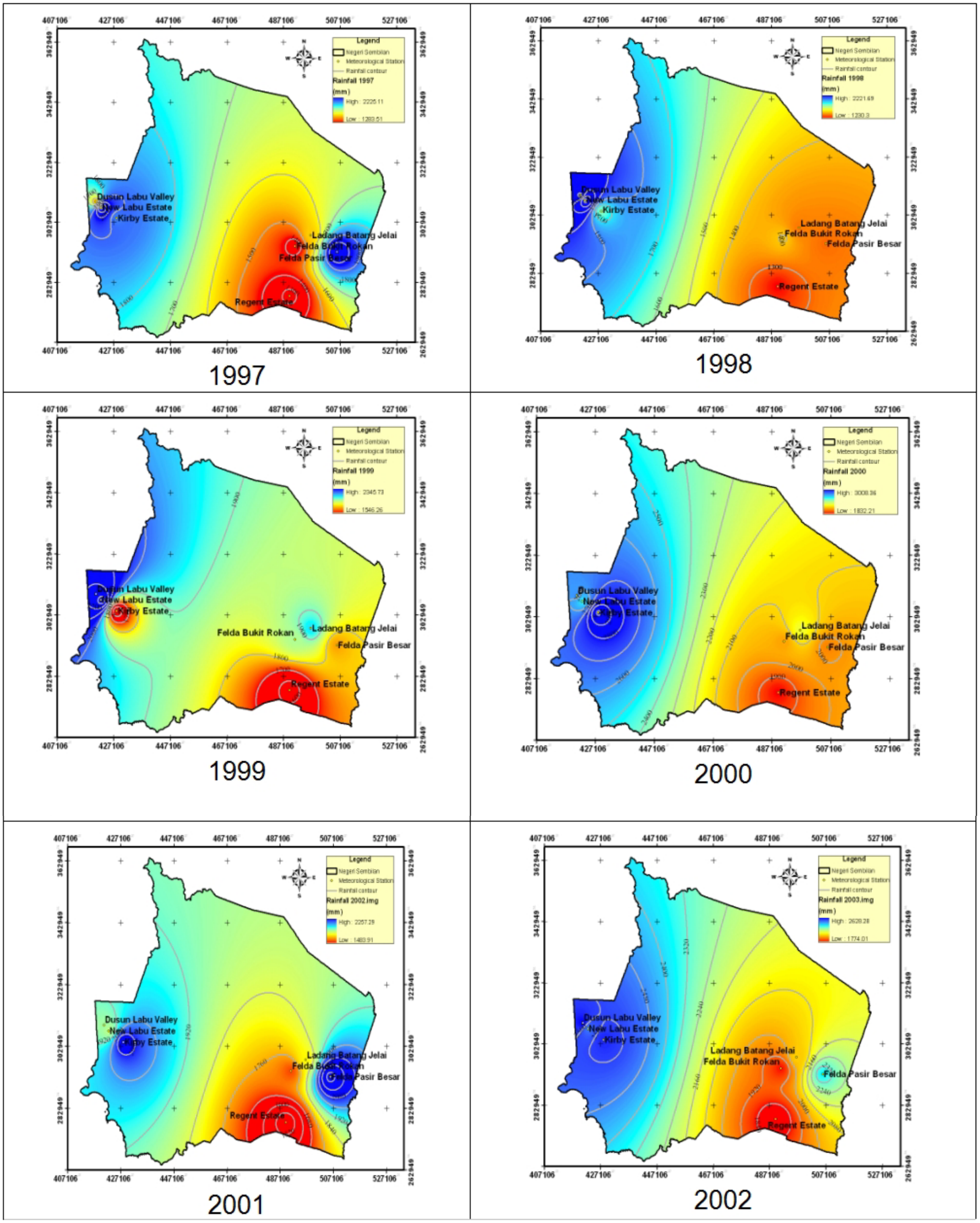

Figure 4. Isohyetal contour map for each year.

part of Negeri Sembilan as mentioned in Shaharuddin and Noorazuan (2006). As summarized, the contour colors distributed into two distinctive areas particularly in 1997 and 2001 maps. Low rainfall observed in 1997 and 1998 could be affected by prolonged dry season which severely affected Southeast Asian countries.

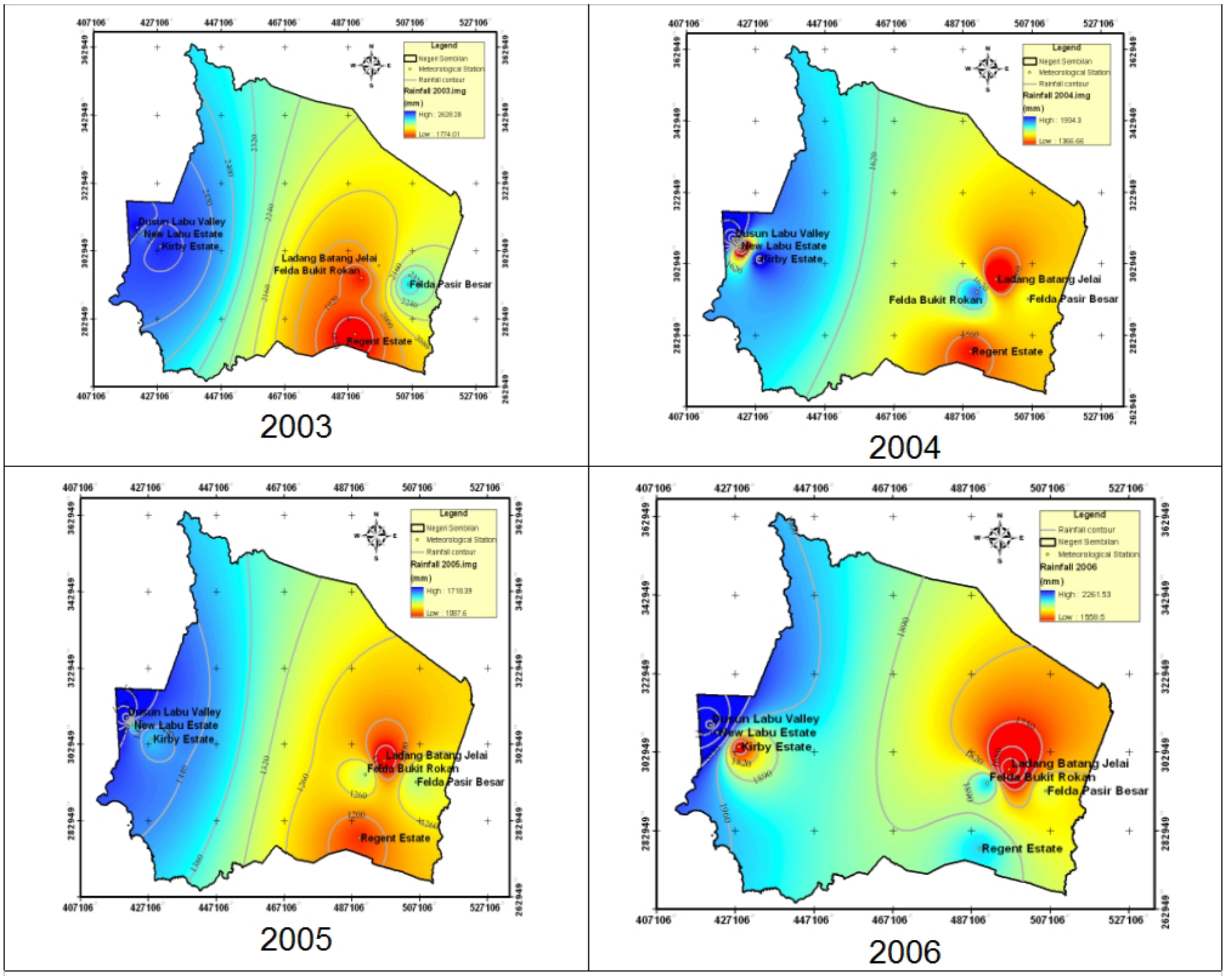

Figure 4 (continued). Isohyetal contour map for each year.

CONCLUSION

This study suggests Thiessen polygon techniques are suitable for estimation of annual rainfall for the study area. Statistical analysis conducted found there were significant differences in rainfall within the stations in Negeri Sembilan. The 2000 rainfall was significantly difference from 1997, 1998, 2003, 2004 and 2005. As a conclusion three distinctive rainfall contour patterns occurred within the region. Higher rainfall was attributed to western region of Negeri Sembilan. Whereas, the Regent Estate at the southern part of the region experienced the lowest rainfall for the whole year. This study found higher rainfall occurred near the coastal section due to receive more rain days. Rainfall distribution was clearly distinguished within the region although with shorter period of research conducted. This whole package of techniques can assist environmental and drainage management division for example Department of Irrigation and Drainage Management (DID) and Malaysia Meteorological Department (MET) of Malaysia. The departments are suggesting integrating this technique to implement in their forecasting and monitoring activities toward rainfall pattern particularly during dry season.

ACKNOWLEDGMENT

This study was funded by University Research Grant (91646-RUGS), Universiti Putra Malaysia. We would also like to thank the Malaysia Meteorological Department for sharing the rainfall data with users. This appreciation also goes to Dr. Khairun Anwar Uyup and Mrs. Marryanna Lion who have given full attention to reviewing this paper.

REFERENCES

Ainuddin, A.N. 1998. Forest Fire Management: An Overview. IFFNNo. 18, January, 1998. http://www.fire.uni-freiburg.de/iffn/country/my/my_1.htm. Accessed on 20 January 2000.

Bayraktar, H., F.Z. Turalioglu, and Z. Xen. 2005. The estimation of average areal rainfall by percentage weighting polygon method in Southeastern Anatolia Region, Turkey, Atmospheric Research, Vol. 73, pp. 149-160.

Chidley, T.R.E., and K.M. Keys. 1970. A Rapid Method of Computing Areal Rainfall, Journal of Hydrology, Vol. 12 (1970), pp. 15-24.

Department of Irrigation and Drainage Malaysia (DID). 2005. http:/ /infokemarau.water.gov.my/report/Drought%20ReporL_11Jul05.pdf, Accessed 20 September, 2011.

Fiedler, F.R. 2003. Simple, practical method for determining station weights using Thiessen polygons and isohyetal maps. J. Hydrol. Eng. Vol. 8(4), pp. 219– 221.

Grand Solution Manual. 2011. http://www.aboutcivil.com/Grand%20Solution%20Manual,%20GSM.html, Accessed on 20 September 2011.

Malaysian Meterological Department.Accessed on 11 November 2010

Manfreda, S., G. Di Santo, V. Iacobellis, and M. Fiorentino. 2002. A Regional Analysis of Rainfall Pattern in Southern Italy, Mediterranean Storms, Proceedings of the 4th EGS Plinius Conference held at Mallorca, Spain, October 2002), Universitat de les Illes Balears (Spain).

Shaharuddin A., and H. Noorazuan Md. 2006. Menganalisis poladan arah aliran hujan di Negeri Sembilan menggunakan kaedah GISpoligon Thiessen dan kontur Isoyet. School of Social, Development and Environmental Studies, Faculty of Social Sciences and Humanities, GEOGRAFIA Online, Malaysian Journal of Society and Space 2 (105 - 113).

Sherman, R.J., and P.M. Salter. 1975. Objective Rainfall Interpolation and Mapping Technique, Hydrological Science Bulletin, Vol. XX(3), pp. 9/1975.

Singh, V.J., and Y.K. Birsoy. 1975. Comparison of the methods of estimating mean areal rainfall, Nordic Hydrology, Vol. 6, pp. 222-241.

ADDRESS FOR CORRESPONDENCE
M.R. Sheriza
Institute of Tropical Forestry and Forest Products
Universiti Putra Malaysia (UPM)
43400 UPM, Serdang
Selangor, Malaysia

Email: sherizamohdrazali@yahoo.com