

Application of Geographic Information Systems (GIS) in Analysing Rainfall Distribution Patterns in Batu Pahat District

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Abstract: Rainfall forecasting reports are crucial to provide information and warnings to the population in a particular location. The Malaysian Meteorology Department (MMD) is a department that plays an important role in monitoring the situation and issued the statement of changes in weather and provides services such as weather advisories and gives warnings when the situation requires. Uncertain weather situations normally have created panic situation, especially in big cities because of flash floods due to poor drainage management. Usually, local authorities provided rainfall data in tables, and it is difficult to analyse to acquire the rainfall trend. Therefore, Geographic Information System (GIS) applications are commonly used to generate rainfall patterns in visual formation with a combination of characteristics of rainfall data and then can be used by stakeholders to facilitate the process of analysis and forecasting rainfall. The objective of this study is to determine the pattern of rainfall distribution using GIS applications in Batu Pahat district to assist interested parties to understand and easy to analyse the rainfall data in visual form or mapping form. Rainfall data for a period of 10 years (2004-2013) and monthly data (Dec 2006 – Feb 2007) are provided by the Department of Irrigation and Drainage (DID) for 12 stations in the district of Batu Pahat, and rainfall maps in each year was obtained using the interpolation Inverse Distance Weighted (IDW) method was used in this research. The rainfall map was then analyzed to identify the highest rainfall that was received during the period of study. For the conclusion, this study has proved that rainfall analysis using GIS application is efficient to be used in gaining information of rainfall patterns as the results show that the highest rainfall occurred in 2006 and 2007, and it were the years of major floods occurrence in Batu Pahat district.

Keywords: Geographic information system (GIS), inverse distance weighted (idw), rainfall distribution.



1. Introduction

Malaysian climate condition has a uniform temperature, high humidity and abundant of rainfall. Therefore, climate forecasts can help certain parties in future planning involving agriculture industry, fishing industry, flood prediction and many more [1]. In addition, rain forecast may also help to identify specific locations, areas or regions in a country that receives the highest annual rainfall. Furthermore, weather forecasting plays an important role to give information about the weather and can provide early warning of the possibility of severe weather phenomena, high winds and rough seas. Together with these warnings, information will be disseminating through the mass media. It is intend to inform the public as soon as possible about the adverse weather conditions and sea conditions that were forecasted [2].

Traditionally, rainfall data were obtained from local authorities at meteorological stations (rain gauges data collection). Using Thiessen Polygons or Inverse Distance Weighting (IDW) data in each rain gauge was measured to gain its total volume of rainfall on the area. How accurate the rain gauge in predicting rainfall volume is depends on how consistent the gauge estimates where it is actually represent the rainfall distribution between each gauge. It is hardly to get the accurate results using rain gauge alone, therefore it was not surprising that many hydrologic analysis frequently exhibit large uncertainties [3]. Thus, the usage of GIS applications to produces the rainfall patterns in the form of visual and combined with the attribute data of rainfall can be used by stakeholders to facilitate the process of analysis and forecasting rain. Consequently, would help to solve the problems associated with rainfall data. IDW function should be used when a set of points is dense enough to capture the extent of surface area to which area that need to be analysed. This method gives more accuracy in interpolation results because it gives values close to the minimum and maximum values of the sample data. In this study, IDW function was chosen because the set of rainfall stations is dense enough to capture all the surface in Batu Pahat district.

This study focused on the district of Batu Pahat. This study aims to determine the pattern of 10 years rainfall distribution using GIS applications between 2004 and 2013 which includes 12 rainfall stations. The main data used were the rainfall data. In this study, the rainfall data was obtained from the Department of Irrigation and Drainage (DID). The map of the area in Batu Pahat district was also used in this study. The aim of this study was to determine the pattern of rainfall in the area of Batu Pahat in the form of mapping based on information and criteria required in the use of GIS applications. GIS application effectiveness is determined by using the analysis result of the rainfall distribution pattern based on cause and effect of the highest rainfall identified during the review period.

1.1. Rainfall Intensities

Rainfall is a form of precipitation that fell to earth as one of the processes to complete the cycle of the earth. According to [4], rain is one of the precipitation in liquid form where the diameter particulars is more than 0.5 mm. Effectiveness or impact of the rain on a system is dependent on the intensity. Rainfall intensity may be influenced by a number of internal factors such as the saturation of water molecules, latent heat of fusion, the rate of evaporation, cloud formation process, the initial coverage rate and external factors such as the position of latitude, the movement of the monsoons and the diverse landscape of earth [5].

In general, monthly and annual rainfall received throughout Malaysia is greatly influenced by the monsoon. The influence of monsoon forming a cycle of rain based on the northeast monsoon, the southwest monsoon and two transition periods [6]. Previous studies show that at the beginning of the season northeast monsoon, normally throughout the whole of Peninsular Malaysia was sluggish, particularly in the east coast. However, at the end of that season, many areas began to experience dry conditions [7].

1.2. GIS Application and IDW

A GIS is a computer system for capturing, storing, checking, and displaying data related to positions on Earth's surface. GIS can shows many different kinds of data on one map. This enables people to more easily see, analyse, and understand patterns and relationships. With GIS technology, people can compare the locations of different things in order to discover how they relate to each other [8].

Interpolation is the procedure used to predict cell value for location that lack sample points. The method of IDW should be used when the set of points is dense enough to capture the extent of local surface variation needed for surface. IDW determines cell values using a linear-weighted combination set of sample points. The weight assigned is a function of the distance of an output cell location. The greater the distance, the less influence the cell has on the output value [9].

2. Methodology

In this study, the Batu Pahat rainfall data, map of Batu Pahat District and GPS coordinates for rainfall stations were used (Figure 1). Analysis of rainfall data was based on the analysis of space and time. For the analysis of space, location of rainfall stations was plotted by using GPS, then the amount of annual rainfall was plotted by each rainfall station. After that, the isohyet maps that represented the annual rainfall for each year was predicted by using the interpolation of IDW method in GIS software. This interpolation is the procedure used to predict cell value for location that lack of sample points. The aim of isohyet map development using GIS was to identify the distribution of rainfall patterns and to compare the rainfall distribution between years. In addition, the changing patterns of rainfall from year to year can also be analysed. Other than that, the analysis of changes in rainfall per year was analysed by using the graph changes in rainfall for each station. The analysis was then performed to identify the highest rainfall received during the review period and then the causes and effects of the highest rainfall were identified. From this analysis, the average rainfall during this past decade can be determined. Furthermore, extreme phenomena that occurred during the ten years can also be identified.

3. Result and Discussion

The analysis has also been made based on rainfall stations where the rainfall patterns has shown in graphical form between 2004 and 2013 (Figure 2). It indicates that the darker the colour show in the map, the higher the rainfall received on that area. From Figure 2, it shows that in year 2005 and 2006, the rainfall occurred was heavier than usual, which are exceeding 2500 mm per year.

Figure 3 shows that the highest rainfalls occurred in 2007 recorded at Ladang Sri Gading station was 4444 mm. In addition, the stations at Pintu Kawalan Parit Saidi Barat, Pintu Kawalan Parit Bintang, Pintu Kawalan Sembrong, Pintu Kawalan Separap and Ladang Union in Yong Peng has also recorded that the highest rainfall occurred at each station over the past 10 years were in 2007. In the same figure clearly shows that Rumah Pengawas Parit Raja, Pusat Kawalan Parit Bintang, Pintu Kawalan Sembrong, Ladang Union in Yong Peng and Pintu Kawalan Tampok have similar rainfall reading start from 2004 until 2013 with average 1823 mm. Furthermore, the average rainfall for each year was also been calculated and the results show that the highest average per year over 10 years was occurred in year 2007 followed by 2006, 2012, 2011, 2004, 2005, 2013, 2008, 2009 and 2010. From the analysis, it can be shown that the presence of heavy rains were occurred in 2006 and 2007.

This study further proved by an analysis of the pattern of rainfall in December 2006 until February 2007. This analysis has created by using cumulative monthly rainfall data for 3 months data starting from December 2006 until February 2007. From the analysis, it shows that heavy rainfall has certainly occurred in 2006 and 2007. The analysis of rainfall patterns using GIS application has identified almost all areas in Batu Pahat received the rainfall exceeds 1000 mm within 3 months. The total rainfall in Batu Pahat in this period was the highest rainfall in the whole of Peninsular Malaysia. The results of rainfall pattern using GIS applications were compared with isohyet map produced by the DID. Isohyet map from DID shows that the highest rainfall also occurred in Batu Pahat District in year 2006 and 2007 where it shows that Batu Pahat district received rainfall more than 1000 mm. From the comparison, it proved that a heavy rain was absolutely occurred in the area of Batu Pahat in December 2006 – February 2007. Figure 4 shows the comparison between rainfall pattern using GIS and isohyet map from DID where both of the isohyet map show the same result which are both of them received rainfall more than 1000 mm within 3 month. It means that the analysis of using GIS has proven the effectiveness in analysing the rainfall data in the mapping form or visual form.

The results of this study then were used to identify the causes and effects that occur by consequences of heavy rains in 2006 and 2007. According to meteorological expert [10], floods in Johor in year 2006 and 2007 was due to extraordinary rains caused by element tropical climate phenomenon called the Madden Julian Oscillation (MJO). MJO originates from the Indian Ocean and across 4 times a year. When MJO meet Northeast Monsoon season in Peninsular Malaysia by the end of the year, it will rain more often than usual.

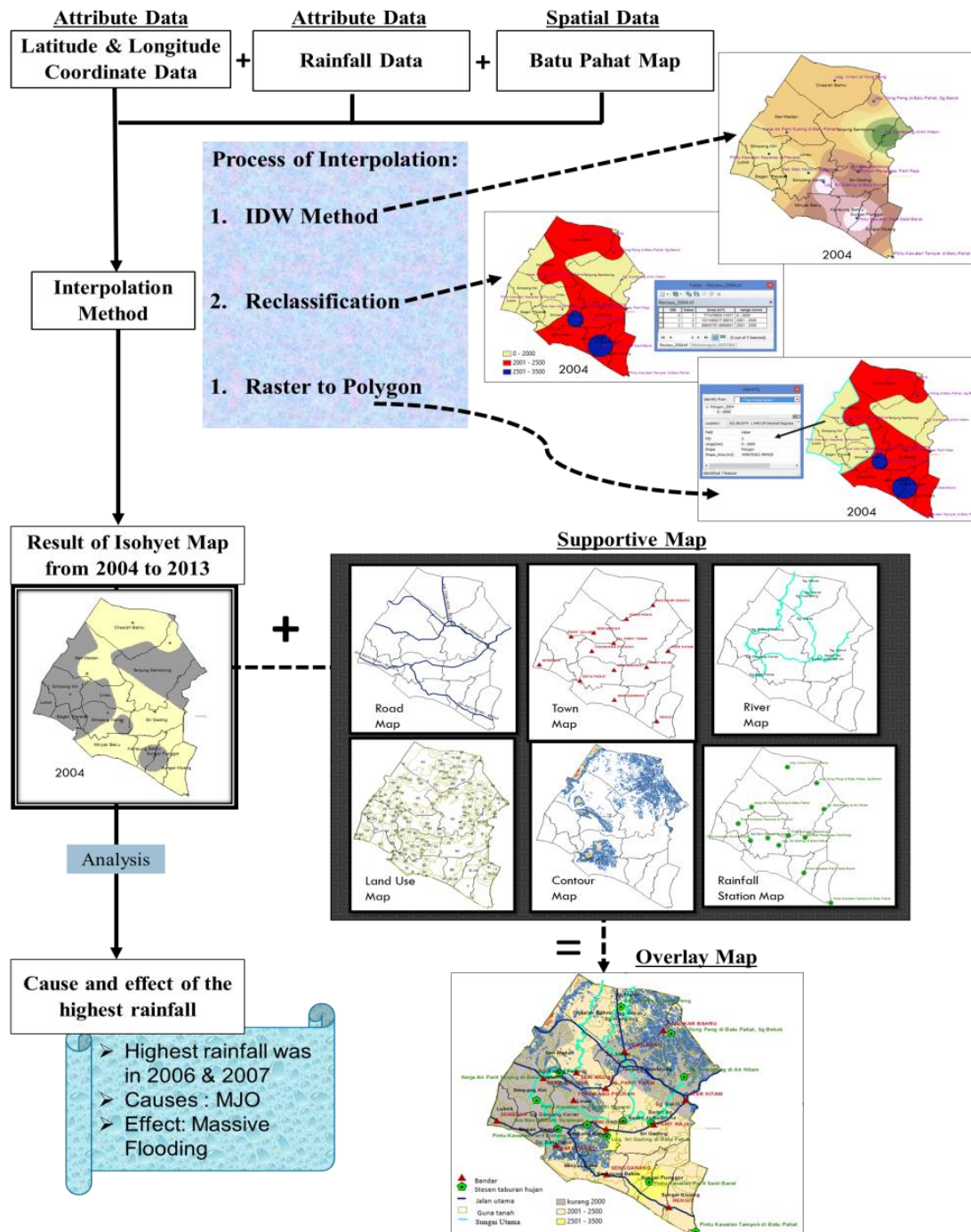


Figure 1. Methodology of analyzing the rainfall distribution patterns in Batu Pahat district.

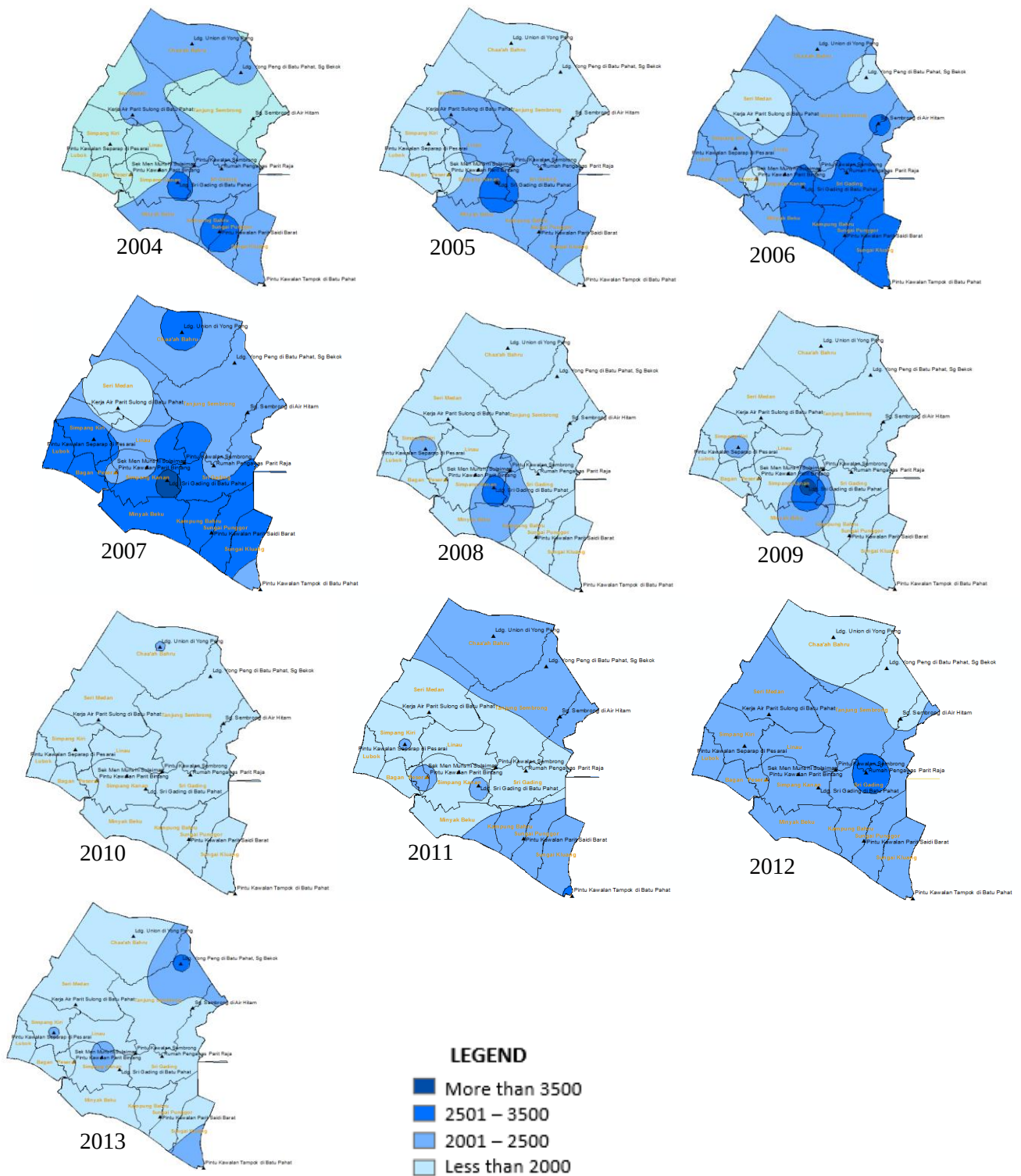


Figure 2. Distribution patterns of rainfall in Batu Pahat area year 2004 – 2013.

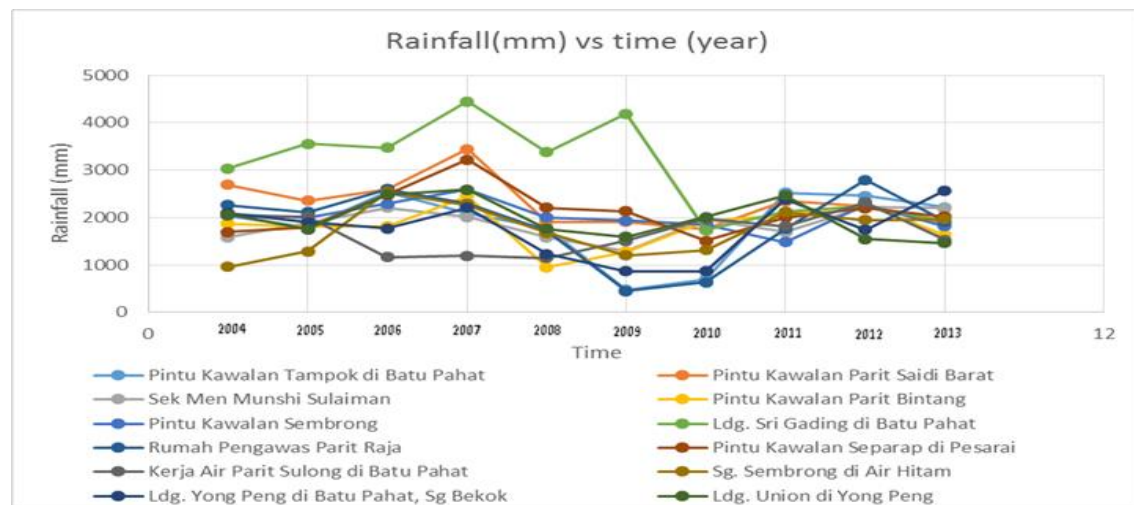


Figure 3. Graph of rainfall (mm) versus time (year).

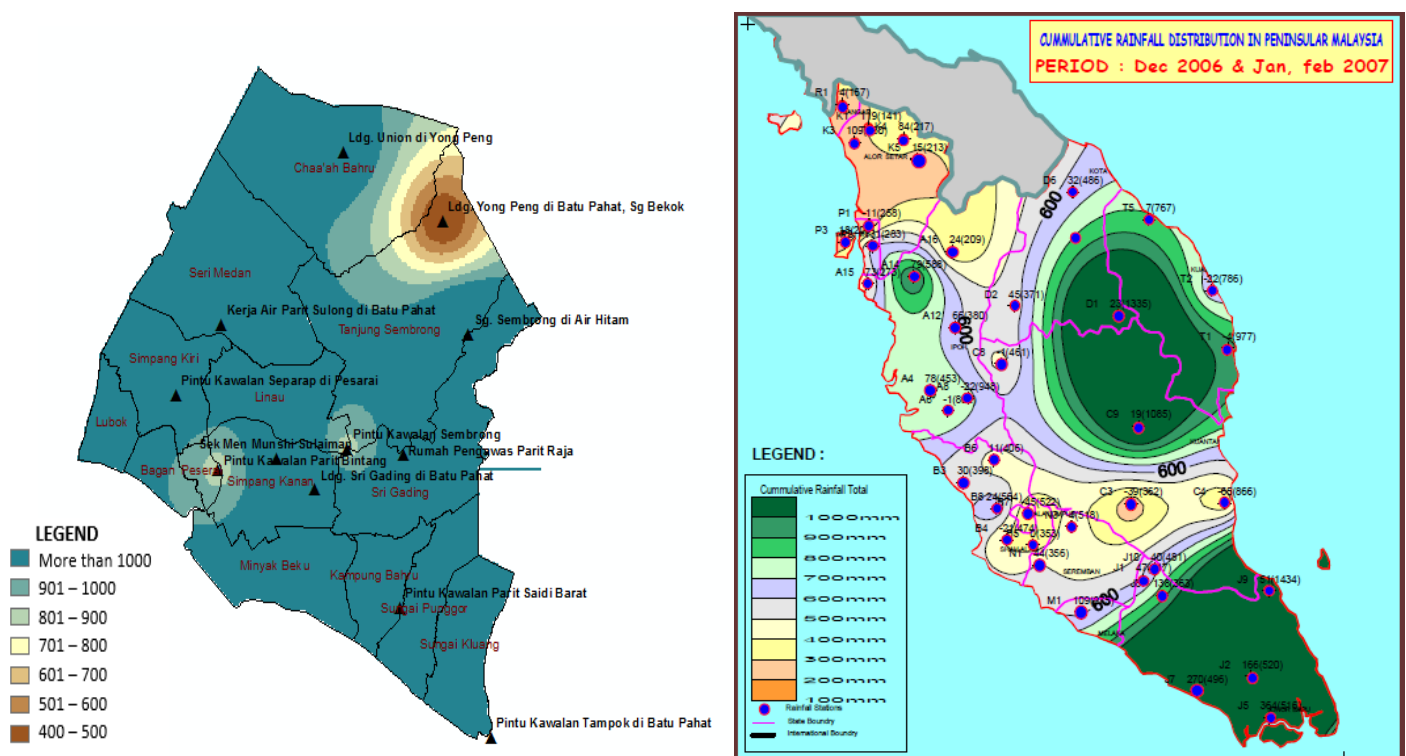


Figure 4. Comparison between rainfall pattern using GIS and isohyet map from DID.

MJO increase the amount of the northeast wind that brings excess water and encourage extraordinary monsoon rains when the monsoon came across to Peninsular Malaysia. Although the MJO across 4 times a year, but rainstorms only occur when it reaches the other climate phenomena such as monsoon. While the impact of heavy rains have proved that Johor was hit by severe flooding on 19 to 31 December 2006 (first flood) and on 12 to 17 January 2007 (second flood) involved eight districts including Johor Bahru, Kota Tinggi, Batu Pahat, Muar, Segamat, Kluang, Pontian and Mersing. The phenomenons of extraordinary heavy rains have caused severe damages to this all eight districts due to extreme flood. As the result more than 103,000 were ordered to move in evacuation centers. In addition, the floods have also killed at least 17 peoples during the flood when it happens where people are beginning to move back home after the first floods began to recede. Furthermore, many schools, the administration of local authorities, hospitals and business activities also disrupted due to flooding [11]. Figure 5 indicates the flood image in 2006 and 2007, where the flood will normally happens at the

northeast of Peninsular Malaysia. However in 2006 and 2007, flooding occurred in the southern of Peninsular Malaysia which are normally should experience a dry period. This phenomena occurred due to the increasing amount of northeast winds and bring more heavy rains to the southern of Peninsular Malaysia.

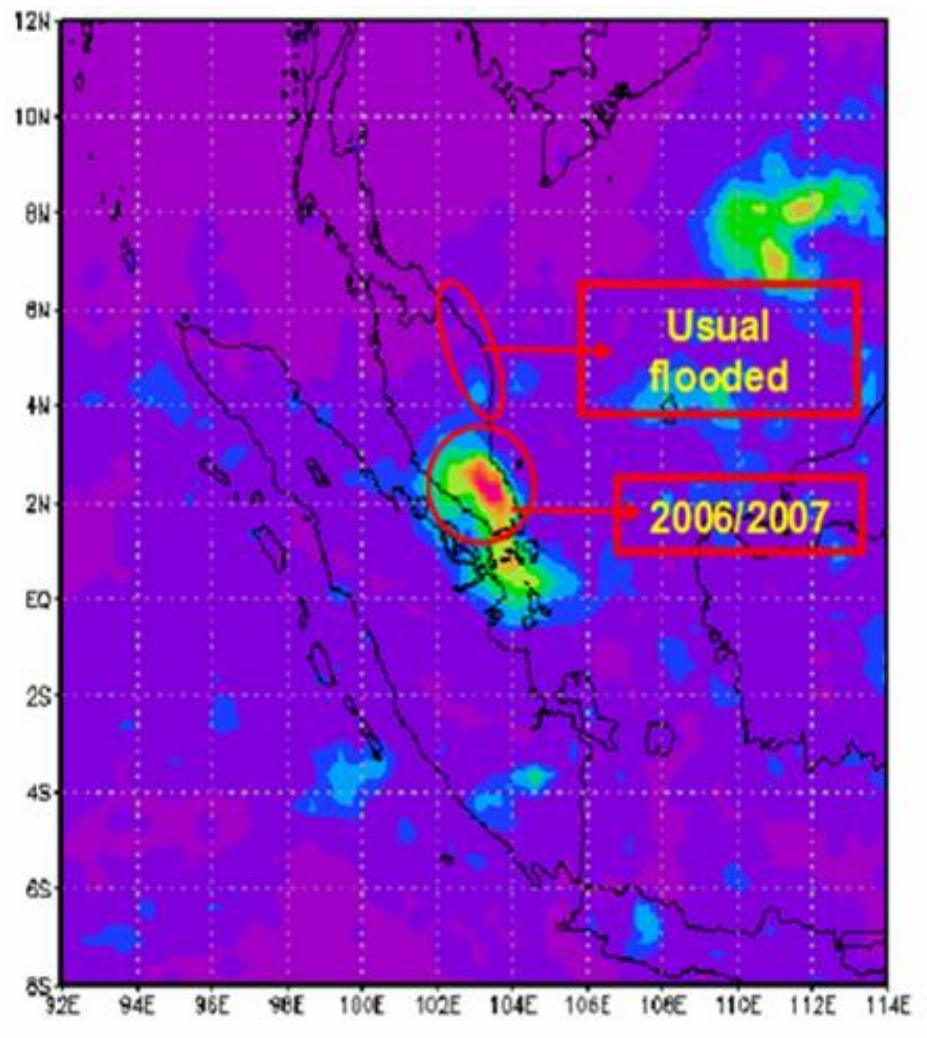


Figure-5. Flood image (2006 and 2007).

4. Conclusions

In conclusion, application of Geographic Information Systems (GIS) in determining the distribution patterns of rainfall in Batu Pahat area have proved their effectiveness where the analysis have shown that 2006 and 2007 were the years of the heavy rainfall occurrence and the application has proved the existence of massive flooding event caused by heavy rains that year.

Overall, the application of GIS is one of the appropriate tools in handling information and involved operation such as planning, observation, collection, storage, management and analysis of data to produce information that can used in the decision-making process. GIS applications are also able to create a better performance in term of hydrological processes rather than using rain gauges alone.

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