Spatial Analysis in Determination Of Flood Prone Areas Using Geographic Information System and Analytical Hierarchy Process at Sungai Sembrong's Catchment

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Abstract. Floods that struck Johor state in 2006 and 2007 and the East Coastal in 2014 have triggered a greatly impact to the flood management here in Malaysia. Accordingly, this study conducted to determine potential areas of flooding, especially in Batu Pahat district since it faces terrifying experienced with heavy flood. This objective is archived by using the application of Geographic Information Systems (GIS) on study area of flood risk location at the watershed area of Sungai Sembrong. GIS functions as spatial analysis is capable to produce new information based on analysis of data stored in the system. Meanwhile the Analytical Hierarchy Process (AHP) was used as a method for setting up in decision making concerning the existing data. By using AHP method, preparation and position of the criteria and parameters required in GIS are neater and easier to analyze. Through this study, a flood prone area in the watershed of Sungai Sembrong was identified with the help of GIS and AHP. Analysis was conducted to test two different cell sizes, which are 30 and 5. The analysis of flood prone areas were tested on both cell sizes with two different water levels and the results of the analysis were displayed by GIS. Therefore, the use of AHP and GIS are effective and able to determine the potential flood plain areas in the watershed area of Sungai Sembrong.

Keywords: Flood management, geographic information systems, analytical hierarchy process.

1. Introduction

Flooding is an overflow of water covering the land which is usually dry. Flooding also defines as a groundwater cover. Floods usually caused by continuous rain and quantity of water in river rose than normal and overflow into the river [1]. Flooding also occur due to several factors such as high rainfall, low topographical area, riverbank erosion and rising water levels caused by global warming. Efforts to reduce the floods impact involve a lot of work especially in data collection. Heaps of data from multiple sources will complicate the process of selecting the appropriate data. In addition, the decision-making process will be much more complex if the situation still in below expectation. Compromise on this issue, Analytical Hierarchy Process (AHP) is used to managing data. AHP is a structured technique for controlling and analyzing complex decision, based on mathematics and psychology. AHP has been widely used in the process of producing results in various fields. AHP integrated with GIS applications is a systematic way to generate analysis of preliminary data related to the study area.

This study was conducted to identify areas of potential flooding in the catchment of the Sungai Sembrong in spatial methods. The study area is in Sungai Sembrong where Sembrong Dam which serves as a source of domestic water for the needs of the people around Batu Pahat. Topographically, Batu Pahat is flat and on average area is lower than 5 meter above mean sea level. Therefore, AHP is used to determine the weighting of criteria in causes of floods. GIS in the study used to analyze and demonstrate the potential flood area in Sungai Sembrong use all the criteria provided by the method of AHP.

Floods can bring a lot of problems for residents in the affected area. In Peninsular Malaysia, Johor was the second high-risk flood refers to flood Batu Pahat in 2006 [2]. Flood occured by the heavy rains in long period. High quantity of water that cannot be accommodated by the river and catchment areas will cause overflow into the lower regions. Higher sea levels tidal also contribute to flooding and coupled with the amount of rain water that causes the water to increase much above normal and then overflow to the river bank [3]. There are several other factors that cause floods. Among the factors are natural factors that cannot be controlled, such as rainfall, soil sedimentation in rivers and topography of the area. Due to the impact of

human development is the process of urbanization, river erosion caused by construction and drainage systems that were not designed [2].

Choosing the right design concept stage of product development is not an easy decision. Inaccurate results will lead to a final result cannot be to believe. Then, Analytical Hierarchy Process (AHP) is one of the processes that can be used in the design stage. AHP has been widely used to solve various issues and criteria for decision making in research, particularly in engineering. AHP brings the concept of flexible, especially in determining the best results [4]. AHP provides a framework in which hierarchical multi-attribute decision problems can be structured. Using AHP scale ratio along with allowing relative comparison allows AHP to compare the features of insignificant. AHP method is now a widely used methodology in the field of research by developing a user-friendly software package to solve the AHP model [5].

Nowadays, most studies conducted were using GIS. The system's ability to store and process data necessary to refer to an area or space makes this system was used as a tool to solve problems in terms of management and planning. Mapping method used in this system can provide information visually to the user and can also be used as a reference to make predictions about something [6]. GIS is very effective in identifying the components of the flood in flood management. GIS shows the spatial distribution of the actual view of flood phenomenon. GIS is used to measure the location of flooded areas and provide a measurable estimation of the land and infrastructure affected by the floods [7]. The main advantages of using GIS for flood management are to generate the flood area figure and also to analyze the potential flood area. Analysis that carried out is to estimate the probability of damages caused by floods [8].

2. Analytical Hierarchy Process in GIS

In determining the areas of potential flooding in the catchment area of the Sungai Sembrong, several levels of analysis have been done. First is the process of determining the factors that caused flooding in the study area. Each factor will then be analyzed using Pair-wise Comparison Method (PCM) to get the weightage for each criterion. PCM is part of the AHP is used to simplify decision-making process using a matrix method. Each factor that causes floods are organized according to the weightage and will be included in GIS applications. The factors that have been prepared to facilitate the process of overlapping maps using GIS applications in order to determine areas of potential flooding in the Sungai Sembrong catchment area.

2.1 Selection and Evaluation of Criteria

The criteria considered in this study were selected according to factors that cause flooding in the study area. Selection Criteria causing floods may also be referred to the procedure for the determination of the flood area or process to build catchments using ArcGIS 10. The criteria used in this study were referred from previous studies. Factors to consider are digital terrain, rainfall, flow direction, flow accumulation and catchment areas. PCM is used to determine the relationship between the factors related to the flooding to determine areas of potential flooding in the catchment area of Sungai Sembrong. PCM is one of the methods used to determine priority criteria in decision making. PCM is pairwise comparisons were made on a scale of relative importance to the selection criteria set out in the ratio scale. Table 1 shows the scale of assessments for PCM.

Table 1: Continuous Rating Scale for Pairwise Comparison of Saaty's Method [9].

1/9	1/7	1/5	1/3	1	3	5	7	9
Extremely	Very Strongly	Strongly	Moderately	Equally	Moderately	Strongly	Very Strongly	Extremely
	Less Important					More Important		

Table 2: Continuous Rating Scale for Pairwise Comparison.

Criteria	DTM	Flow direction	Flow accumulation	Catchment area
DTM	1	3	3	3
Flow direction	0.3	1	5	3
Flow accumulation	0.3	0.2	1	3
Catchment area	0.3	0.3	0.3	1

Weightage for each criterion will be calculated using the matrix method. Refer with Table 2, all the criteria are organized by each weightage. Criteria which have a higher weightage values are very high priorities and followed by next criteria. The estimated weights are then calculated to produce the consistency ratio for scale banding pairs. If the consistency ratio >0.10, the scale of pairs should be calculated to be recomputed to get the consistency ratio <0.10. After the comparison process is completed, the priorities weighted that have been produced as refer to Table 3.

Table 3: The weightage for each criteria.

Criteria	Weightage
DTM	2.07
Flow direction	1.46
Flow accumulation	0.62
Catchment area	0.36

CR = 0.09 < 0.10 is accepted.

The consistent ratio data set in this study is 0.09, which is less than 0.10, and then set PCM data and methods used can be received and forwarded in the order of use in GIS. If the ratio is more consistently obtained from the 0.10, it indicates that matrix data set is unacceptable and needs to be reviewed.

2.2 GIS Database Design

ArcGIS 10 software is used to display the spatial data and attribute data that has been set up using the data needed to establish potential areas of flooding in the Sungai Sembrong catchment area. Catchment areas should be produced before the process of determining the potential flood areas. Design and development data in this study include the process as described below;

i. Develop the Digital Terrain Model (DTM) of the study area.
ii. Produce the flow direction.
iii. Produce the flow accumulation.
iv. Setting the position of pour points.
v. Produce the catchment area.
vi. Determination of potential flood areas.

Each criteria necessary data to establish potential areas of flooding should be changed to the shape file types that can be read and displayed by the software ArcGIS 10. Use of Raster Calculator function in the GIS application is to calculate and display the area at risk of flooding in the Sungai Sembrong catchment area. The height of the water level refers to the water level rises above sea level. The height of which is placed in Raster Calculator is in unit of metre. Then the potential flooded areas will be displayed by GIS. Refer to equation (1) to enter the height of the water level using the Raster Calculator to determine potential flood areas.

$$DTM <= height\ of\ water\ level \quad (1)$$

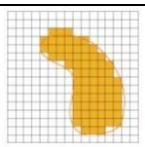
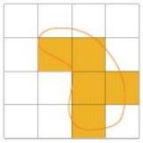
3. Results and Analysis

The process of database development using GIS application is the process of overlap of the data according to criteria to form a spatial layer containing attribute data layer itself. Overlapping layers according to the criteria will be done until the flooded areas can be determined as specified in the objectives of study.

3.1 Cell Size Analysis

In this study, two cell sizes are used to view the end result of the difference between the sizes of the cell. The cell size of 5 and 30 were analyzed until the flood potential is formed. Table 4 is an explanation of the difference between the use of cell sizes of 5 and 30.

Table 4: Differences in the use of cell sizes of 5 and 30.

Characteristics	Cell size 5	Size cell 30
Figure of cell size		
Resolutions	High	Low
Spatial accuracy	More accurate	Less accurate
Speed of display	Slow	Faster
Speed of data processing	Slow	Faster
File size	Larger	Smaller

3.2 Catchment Area Analysis

Determining size and the location of catchment area is dependent on the location of the pour points which is placed at all the point of intersection between the river and flow accumulation. Figure 1 is the location of Sungai Sembrong catchment in Batu Pahat. The analysis is related to the size of the cells used which are cell size of 5 and 30. The results reveal that the catchment area produced using cell size 5 is more detailed and closer to the actual terrain compared to the catchment areas resulting in cell size of 30. Figure 2 and Figure 3 shows the difference between the resulting catchment area using cell size of 5 and 30. Table 5 shows the difference of size between the catchments with cell size 5 and 30.

Figure 1: Sungai Sembrong catchment area.

Figure 2: Catchment area using cell size 30.

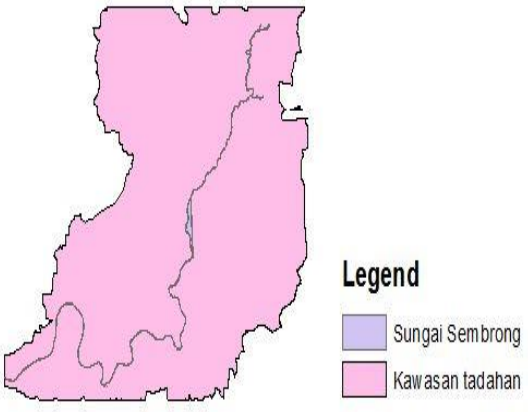


Figure 3: Catchment area using cell size 5.

Table 5: The size of the catchment area of the cell 30 and 5.

Cell size	Size of catchment area (m^2)	Percentage of catchment area (%)
30	11845808	6.5
5	12762114	7.0

3.3 Potential Flood Areas

Determination of potential flooding in the Sungai Sembrong catchment were calculated using the Map Algebra in ArcGIS. The analysis determines the extent to potential areas flooded when water from the river level rise caused by various factors. In the study area, high rainfall levels are key factors to lead to an increase in the water level. The ground water flow rate is also a factor because the existing drainage does not cope with large amounts of water in a short period and cause overflow. Water levels were set at 7 meters and 10 meters from mean sea level (MSL). The maximum water level is selected to determine the areas at risk of flooding in the catchment area of Sungai Sembrong. Potential areas of flooding were also analyzed using two different cell size which is the size of the cell 5 and 30. Figure 4 and Figure 5 shows the difference between a potential flood area produced by the cell size of 5 and 30. Table 6 shows the difference between the size of the flooded area with a cell size of 5 and 30.

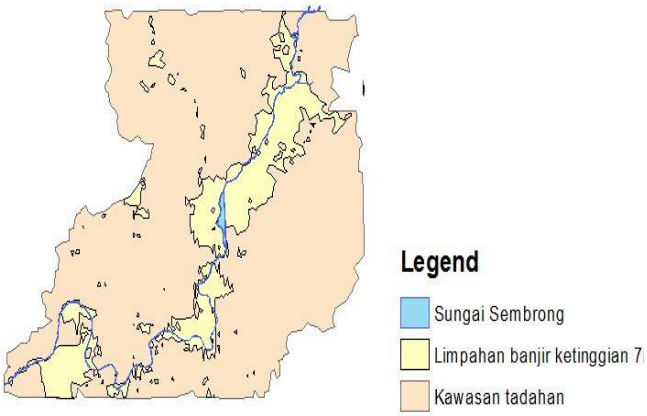


Figure 4: Flood area using cell size 30

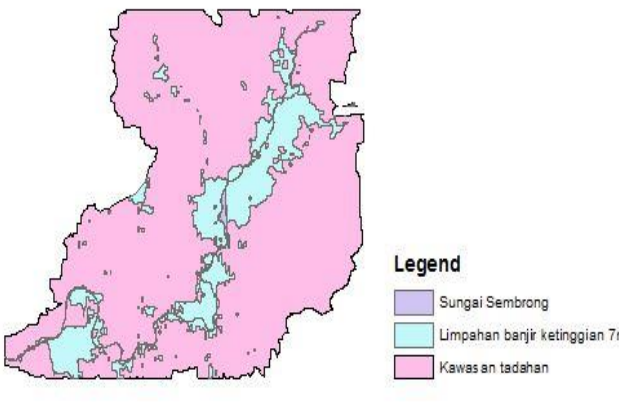


Figure 5: Flood area using cell size 5

Table 6: The size of the flood area of the cell 30 and 5

Cell size	Size of potential flood areas (m^2)	Percentage of potential flood areas (%)
30	1,962,493	16.6
5	1,987,963	15.6

3.4 Effectiveness of AHP with GIS in Determination of Potential Flood Areas

Previously, related study was conducted using GIS in the Tanjung Sembrong area [3]. The study using hydrological models and water balance model based on rainfall data to determine the location and size of the flood area. For this study, the location and size of flood area is determined using the maximum height of the water level. Tested water levels were referring to water levels during floods in 2006. Based on the results, the potential flood area in Sungai Sembrong catchment area can be determined. In conclusion, the use of AHP and GIS in determination of the potential for flooding in the catchment area of Sungai Sembrong is effective.

4. Summary

GIS is a tool for planners to analyze the planning region. Results of the determination of flood-prone areas are expected to be a consideration for decision makers so as not to focus settlement construction in areas prone to flooding. In addition , the need for flood mitigation efforts in this area such as the construction of dikes, dredging to increase the capacity of the river as well as perform other businesses from upstream to downstream to prevent flooding.

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