

A GIS-Based Flood Vulnerability Assessment in Pasir Mas, Kelantan

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Abstract. The flood events are now intense because of localized physical and climatic factors, resulting in risks to the environment and the population. Besides, the difficult to identify the flood vulnerable area at Pasir Mas, Kelantan had become the main problem because lack of comprehensive information which as a medium to communicating the flood risk, new unplanned developments and insufficient drainage systems. Hence, the development of a vulnerability map for flood risk of flooding management still lacks, which made the situation more considerable. Vulnerability is the primary construct in flood risk management. Therefore, this study aims to identify the variables which contribute to the risk of flooding based on the characteristics of the area and develop a flood vulnerability map using Geographical Information Systems (GIS) and Remote Sensing. In this study, the land use data, amount average of rainfall data and digital elevation model (DEM) data were used to produce a vulnerable flood map for the study area. The hydrology and weight overlay (spatial analyst) techniques were used to determine the flood vulnerable area on physical and climatic factors that cause flooding in Pasir Mas and to develop the vulnerable flood map in Pasir Mas. The vulnerability area had been determined based on the scale 1 (no vulnerability), 2 (low vulnerability), 3 (reasonable vulnerability), 4 (moderate vulnerability) and 5 (high vulnerability). The findings show that the area located at the water bodies recorded the most highly vulnerable compared to another area because water bodies store the water. When surface water run-off from the surrounding area exceeds the level of water bodies, it increases the flow capacity of the water and causes the flood. From here, it makes the water bodies and area surrounded it more vulnerable. It is expected within this vulnerable flood map will able to assist the responsible parties to communicate and give an option to those affected people to ensure the effectiveness of the emergency response assistance and aid to victims for better preparedness capability.

1. Introduction

Flood is one of the natural disasters can occur anytime as one of the weather-related natural disasters. Floods are a number of the most recurring and devastating natural hazards, impacting upon human lives and inflicting severe economic damage throughout the world [1].The capability for flood



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casualties and damages is likewise developing in Malaysia that happens every year and regularly. This appears because of the human population growth, circulation and channel obstruction due to lower drainage control system and other anthropogenic activities. This is because of several factors such as land use development and urbanization.

Flood risk is predicted to grow in frequency and severity, thru the influences of change on climate, intense weather within the form of heavy rains and river discharge conditions [2]. Flood arise due to the fact of the fast accumulation and launch of runoff waters from upstream to downstream. This happens due to heavy rainfall. The contemporary trend and future situation of flood risk consequently demand accurate spatial and temporal facts on the potential hazards and risks of floods. Kelantan becomes one of location that gets greatly impact by enormous flood disaster that located at the east coast of Peninsular Malaysia. Since 1927, the enormous flood in Kelantan with about the return period of rainfall of 1:1000 years [3].

Based on the previous research, the flood event contribute human life and properties risk and this happen due to difficult to identify the flood vulnerable area [4]. This was happened in Pasir Mas that becomes main issues due to lack of environmental disaster management and information. Mitigation of flood catastrophe may be success most effective when certain information obtained about the physical and climatic information on risks and areas vulnerable to risks are sufficient and having updated information. There is a need to increase the information about the vulnerability due it acts as the root reason for catastrophe. In the event of a flood, low-level areas were typically more vulnerable to the floods that dependent on geographical and metrological situations. Within new unplanned development, it can cause the problem with raise run-off and produce the risk during the flooding increases. Based on previous study, the flood damage increase over time due to more development in flood-affected areas [5]. Due to that, the developing of flood vulnerabe map in Pasir Mas can provide a safety in opposition to flood. Therefore, Geographical Information Systems (GIS) tool is necessarily important to flooding mapping in predict flood vulnerability for effective flood management [6].

2. Study Area

Kelantan is one of the states on the East Coast of Peninsular Malaysia. The state is exposed to the winds of the Northeast Monsoon from November to January and thus vulnerable to the flood event. Pasir Mas is one of the districts in Kelantan threated by the flood risk. Pasir Mas has been affected flood every year and it was reclassified under top five districts that most got affected by flood in Kelantan. Pasir Mas is one of fundamental town and centre of industrial exchange and management in the Kelantan state. Referred to its geographical location, it is present as the main gateway along the East Coast of Malaysia to Thailand and is additionally traversed by major road transport routes to the urban centre of Kota Bharu. The total population in Pasir Mas was about 185, 878 which represent the second largest district in Kelantan accordingly to data in 2010 [7]. However, due to its geographical characteristics, unplanned urbanization and proximity to the South China Sea, Pasir Mas has become extremely vulnerable to monsoon floods every year.

Rainfall plays a critical function to flood risk within the study area and with maximum threatening events from November to January. In 2014, Pasir Mas is one of location that get the big impacts from the “tsunami-like disaster” besides in 2016 and 2018, Kelantan state had confronted flooding within four episodes and Pasir Mas is one of location that got affected within all the episodes. The number of people at evacuation centres at this location also higher every year due to its geographical location and hydrological factors. The total area of Pasir Mas is 139 km² and the density around 1300/km² [8]. Figure 1 shows the map of Pasir Mas, Kelantan as a study area.

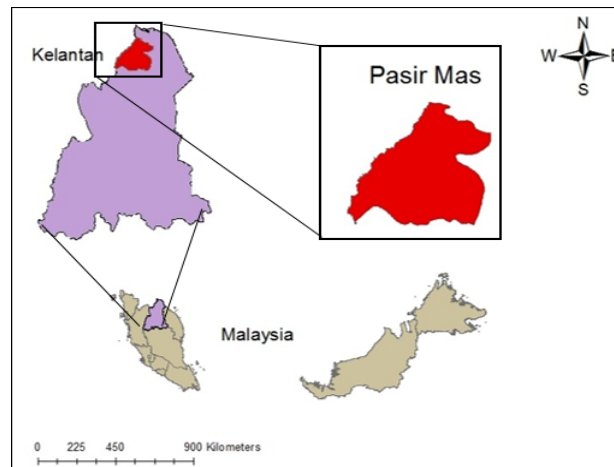


Figure 1. Pasir Mas Map

3. Methodology

3.1 Data collection

Flood vulnerability map demand extensive list of data pertaining to the study area, required for informed interpretations for achieved the objectives. In this study, only secondary data was required. The data required for running the various step for produced flood vulnerable map that obtained from different sources. The data collection was involved constructing a spatial data base from physical and climatic factors. Most of the data have obtained from authoritative organizations such as Department of Irrigation and Drainage (DID) for obtaining the annually amount of rainfall data in Pasir Mas. The data that obtained was in 2014, 2016 and 2018 in order to look the trend of the rainfall due to it one of factors that cause of flood and the overflow river basin that cause flooding. Besides, from the official web of public information of DID website (<http://publicinfobanjir.water.gov.my/>) also capable of extracted and pick out the water-degree in order to determined which district has high water-level and more vulnerable to the flood.

Meanwhile, the data was acquired from online methodologies which from the U.S. Geological Survey (USGS) (<http://www.usgs.gov/>) for getting the satellite imagery for providing the land use data on the study area. Landsat 8 OLI/TIRS C1 was downloaded from USGS for 2014, 2016 and 2018. However, Shuttle Radar Topography Mission (SRTM) 30M Global was downloaded for determine the other indices which Digital Elevation Model (DEM), slope and flow accumulation of drainage network in Pasir Mas. In this satellite imagery, the additional spatial data about the connection, meteorological and population data at Pasir Mas district also was provided including its coordinates, latitude and longitude of Pasir.

3.2 Data analysis

3.2.1 Land use analysis

The land use data that obtained from USGS was downloaded based on Landsat 8 OLI/ TIRS C1 and this satellite image was processed by using remote sensing method which ENVI 5.1 and ArcGIS 10.3 to produced land use maps for Pasir Mas district in 2014, 2016 and 2018. The satellite images picked out based on much less cloud coverage and have a terrific pleasant with a view to getting a clear vision of land use in Pasir Mas. Then, the satellite images were subset by using administrative map of the study area which was defined the boundaries that obtained from an official website of the Global Administrative Areas (GADM) (<https://gadm.org/>) to extract the area of interest from the image.

Moreover, after the stack was formed, a colour composite of bands 6, 5 and 4 was represented and resampled in the form of a new display. The band combination was used to provide efficient and

adequate when using landsat image data for detecting the flood vulnerability relation with land use classification. The land use classification is water body, agriculture, build up area, cleared land and forest. Once the colour composite, Region of Interest (ROI) vector frame was used for subset the images by using 250 random points and this ROI was represented from the Pasir Mas administrative map. Google Earth act as references images to determine the geometric correction where all other images utilized in this process were re-sampled and co-registered in the references image. Further, process classification of the subset colour composite image was used maximum likelihood classification and from here it will represent the land use classes.

Post classification operations consist of the confusion matrix was determined by using ground truth ROI, sieve class clump class, majority analysis, segmentation and classification to vector. In order to ensure the assessment in the effective ways, the accuracy assessment that forms the statistical outputs which used to determine the results classification quality. This method is needed to determine and reclassify the land use type. The high-resolution imagery important for got a clear visual of the extent of vulnerability beside it can produce to provide more accurate outcome. The image was then imported to ArcGIS 10.3 where it was vectorised and the area extent of flooded area and other land use classes determine after the post classification operations.

3.2.2 Spatial interpolation method

In an attempt to identify the amount of rainfall, the meteorological data from the Department of Irrigation and Drainage (DID) in Pasir Mas was acquired for the duration in 2014, 2016 and 2018. Analyzing the data was the next step based on the average amount of rainfall which in form as point shapefile that including the longitude and latitude of each station. From this, it was clipped out with the desired rainfall data in ArcGIS 10.3. Now, the data had used ArcGIS Statistical Analyst has the potential to use the spatial interpolation to input point data. The spatial interpolation methods were used ordinary kriging for spatially distributed rainfall data due to it acts as the developed geostatistical procedure. It generated for evaluated surface produce from a scattered set of points with z-values [9]. Moreover, statistical models were assessed for this method which including autocorrelation. Besides, it has the capability of producing a prediction surface and has a high accuracy of the predictions. The kriging method was one of the results of weighted estimates of the actual data which include the small data of rain and hence utilize the contours more agreeable trend.

3.2.3 DEM and Slope Using Spatial Analyst Tool

Data Digital Elevation Model (DEM) was downloaded from SRTM 30M Global at the USGS website. The DEM emerges land surface morphology information that used to represent the hydrology process of surface runoff [10]. From the DEM data, the elevation of Pasir Mas able was determined by using 3-Dimension (3-D) analyst tool in form of Triangular Irregular Networks (TIN) and it was converted into raster data. The DEM was classified based on the district's area elevation in form of meters into five classes.

The slope is considered as the rate of maximum change in z-value from each cell. The analysis method of the slope was produced from Digital Elevation Model (DEM) [11]. The overall procedure was asses using the GIS environment and a grid format which describe the spatial distribution of values among the variables involved. The slope of the land in the watershed was a major factor in determining the water velocity. The spatial analyst tool was utilized with the purpose to determine the slope degrees. The value range was around 0-30 and where the higher the slope degree, the lower the possibility of runoff and vice-versa. The slope degree values were subdivided into five classes. The topographic parameters of slope and DEM are inversely proportional to the level of floods.

3.2.4 Drainage Analysis

Flow accumulation was the indirect way of measuring drainage network and area. Moreover, it increases constantly starting at drainage divided to the outlet and river channels. The spatial analyst tool was applied to fill all depressions in the Digital Elevation Model (DEM) as a way to produced

hydrology analysis. This ensures perfection within the data to help prevent wrong depression areas. Hence, it allows the formation of flow direction using flow direction tool which the 3-D DEM was applied in each raster cell within the basin. The depression less DEM extracted from the fill was used to develop a flow direction raster [12]. The flow direction represents any possible direction of water runoff on the elevation model. This method was developing to the identification of the water accumulation points by utilizing the flow accumulation tool and used flow direction raster as input. Output cells with a high accumulation were determined for the areas with the concentrated flow and were used to produce stream channels or network. This map was as given it determines the locations where the water accumulation happen.

3.2.5 Weighted Overlay Spatial Analyst Technique

The data used to overlay command and assign a colour ramp to reveal the physical and climatic factors and inundation area layers to graphically displayed vulnerability that liable to flooding. The input raster has cell values and it was multiplied using the raster's weight. After that, the resulting cell values were added to form the final output raster. The output raster was produce used to flood vulnerable map that represent areas with different levels of flooding. The weighted overlay analysis was implemented to overlay the land use, average amount of rainfall, slope and DEM and flow accumulation raster datasets that were reclassified the form of usual measurement scale and weights. From here, each of them was correspond based on their importance to develop the final map. This methodology was represented on the scale that the relative vulnerability of the Pasir Mas district based on expert opinions by using weight overlay analysis. This analysis based on 1 to 5 that was represented from low to high vulnerable area to the flood

4. Results and Discussion

4.1 Process data image

In order to answer first objective, process data images were used in remote sensing to determine the physical factor. In this section, the image enhancement was used for identification of the image quality of the satellite image. Therefore, accuracy assessment was analyzed using similar validation dataset among the image. Accuracy assessment is performed by comparing the map created by remote sensing analysis to a reference map based on a different information source. It was compared the classified image to another data source that was considered to be accurate or ground truth data. Ground truth data can also derived from interpreting high-resolution imagery, existing classified imagery or GIS data layers. After process the data image, post classification was analysed and the result show the accuracy assessment. Accuracy of image classification is most often reported as a percentage correct has been shown as result in Table 1. This result was tabulated in Table 1 that in 2014 show 88.59%, 2016 with 89.48% and 2018 the overall accuracy is 91.90%. The table class confusion matrix of accuracy assessment for all land use class was included in Appendix A. The accuracy assessment was differentiate based on classification during selected the random points in produce land use map.

Table 1. Accuracy assessment and Kappa Statistic for 2014, 2016 and 2018 using Landsat 8 OLI/TIRS C1

Year	2014	2016	2018
Overall accuracy (%)	91.43	88.20	91.53
Kappa Statistics	0.8529	0.8175	0.8478

4.2 Physical and climatic factors that causing Flood

4.2.1 Land use land change (LULC)

The increases growth rate in Kelantan contributed to human activities such as deforestation, development, agriculture and others which tend to play a major role in transforming the land use land

change (LULC). The land use of Pasir Mas had been indicated based on their colour for different classification. Figure 2 shows the spatial area change for years 2014, 2016 and 2018 of five classification classes which are agriculture, build up area, cleared land, forest and waterbody. From the results shows there was increased land use changes for most of the classes except for the forest where it shows the decreased. The unplanned urbanization has resulted decreased in the existence of forest area including the natural catchments that urban growth as the vital reason. Land use like agriculture or forest affected the negative consequences on the capacity of the soil to play the role of water storage. Land use changes provide urbanization and growth of agriculture crucial roles in raising the intensity and frequency of floods which it forms from forestry to agriculture, the cleared land used for development, shift agricultural use to urbanized areas and become drivers of the flood. The outcome proved that the urbanization areas were without forest cover and it also contributes vulnerable to flooding due to the nature of their landscape that being mostly pavement. The land use change analysis was needed to determine the land use changes in the study area. Moreover, the result percentages of spatial area change had been determined for comparing spatial area change for each year. This result was used to determine each area of classes and to compare between years to see the development that contributed to the flooding.

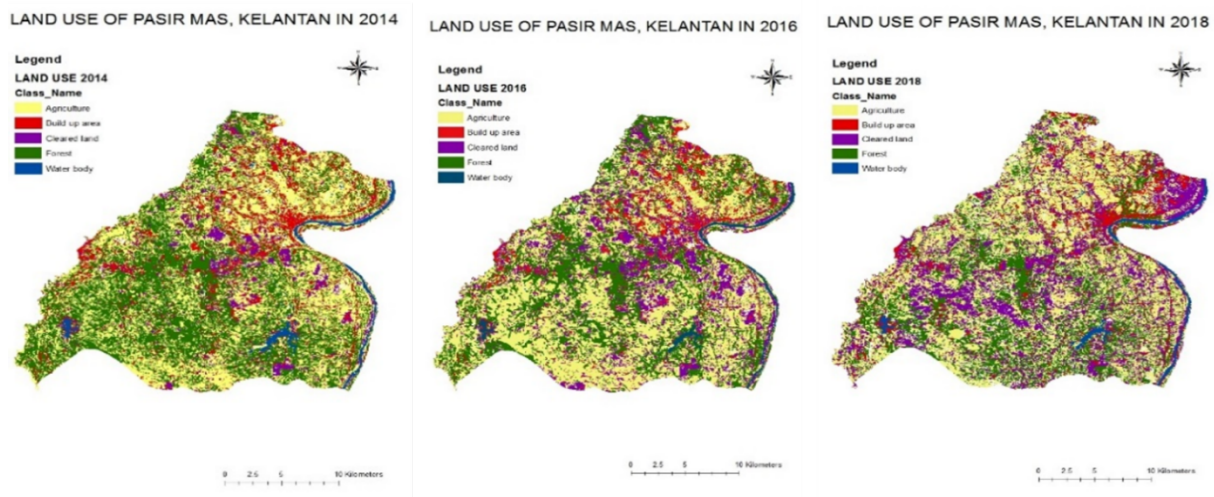


Figure 2. Land use map of Pasir Mas in 2014, 2016, and 2018

Meanwhile, Figure 3 shows the spatial area change graph with express in the form of percentages. Agriculture was the largest area for the three years compared to the other land use. In 2014, agriculture shows 52.64% lower compared to agriculture in 2016 which 55.03% and it continued to rise with 58.17%. This happened due to the main anthropogenic activities and main income in the Pasir Mas was agriculture. While, the build-up area was continuously increased from 2014, 2016 and 2018 with 10.46%, 10.51% and 11.22% respectively increases. The development of urban area raises every year corresponding with the raise population in Pasir Mas due to it one of the urban centres in Kelantan [13]. Similar to the cleared land, the percentage area was increased from 2014, 2016 and 2018 with respectively 10.30%, 10.75% and 10.86%.

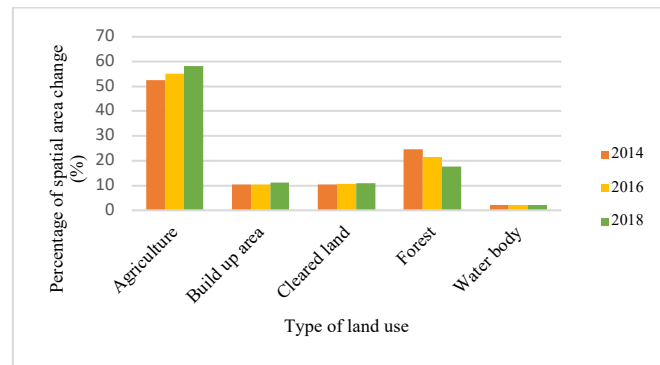


Figure 3. The spatial area change in 2014, 2016 and 2018

The next higher area beside agriculture was forest. In Kelantan there is more than 12,000 hectares of permanent forest reserves including in Pasir Mas. In 2014 the forest percentages were 24.54% while in 2016 showed 21.58% and 17.64% respectively in 2018. The results also show that water bodies were raised from 2.06% in 2014, 2.1% in 2015 and 2.12% in 2018. The water bodies important to indicate the drainage system that contributed to flooding events. The land use influences both the speed of surface runoff and water retention. The trend of forest in the study area decreasing due to the urban expansion and the rate of deforestation in Kelantan raise every year [14]. The deforestation for development can alter the hydrological respond of the land and contributed towards the flood. The transition area change for 2014, 2016 and 2018 was determined for area change within the same classes for different years. The transition area change for 2014 and 2016 of agriculture was 36.64%, while for build-up area show 51.93%, the cleared land represented 54.43%, 48.15% of area change for forest and 80.28% that determined for water bodies. However, in 2016 and 2018 the transition area changes were 31.55% for agriculture, 30.85% for build-up area, 37.93% for cleared land, 51.74% for forest and lastly 54.08% for water bodies.

4.2.2 Rainfall distribution

The amount of rainfall occurring on a real-time basis which can help in indicate the severity and immediacy of the threat. From the determining the amount of rainfall, it able estimated the level of flood risk. This amount of rainfall can be used for the present and future flood prediction. The average amount of rainfall has been show in Figure 4 in Pasir Mas, Kelantan. The rainfall map was analyzed using kriging analysis to produce a continuous raster rainfall data within and around the administrative boundary. Then it has been classified into five classes where each colour represented different average amount of rainfall. The monsoon climate along with heavy rainfall able result in the flooding. Floods related to excess rainfall as well as water that cannot immediately percolate directly into the ground flows down slope as runoff. The amount of runoff was related to rainfall intensity. Water river level's increases because of heavy rainfalls. When the level of water increases above the river banks, the water began overflowing. Hence, the water spill over to areas connecting to the rivers resulting in floods. This make the area in water bodies and surrounded it become vulnerable to the flood.

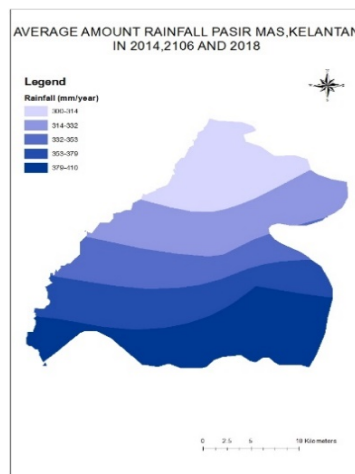


Figure 4. Average rainfall in Pasir Mas

4.2.3 Slope and DEM

The slope map simultaneously displays the slope which it steepness of continuous surface such as terrain represented in digital elevation model (DEM). Figure 5 shows the slope degree map and Digital Elevation Model (DEM) values in meter. Both of results show that most of the area has low level degree or in low land area. The low slope area represented with the green colour, which unfortunately is where development is possible and where the build-up area is located. Elevation and slope act as a main role in controlling the stability regarding a terrain. The slope affected the direction of and measure of surface runoff or subsurface drainage reached a site.

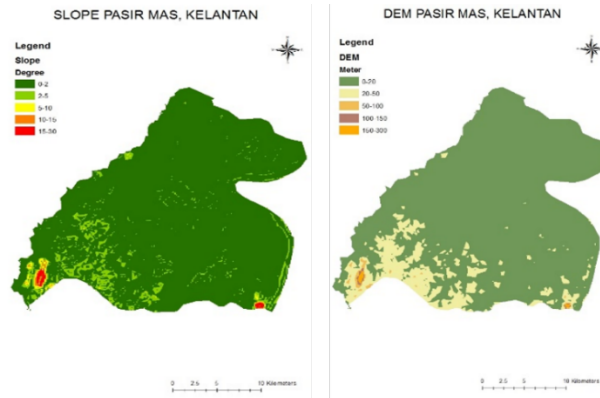


Figure 5. Slope and DEM of Pasir Mas

4.2.4 Flow accumulation

Figure 6 shows the flow accumulation classes. The black colour which no flow accumulation was dominant compared to the others. While the highest value with yellow colour show only several possible stream channels in an event of water runoff. Drainage was a main ecosystem controlling the risks as its densities denote the essence of the soil and its geotechnical characteristics. Flow accumulation was an indirect method of identifying drainage areas and raise perpetually from the drainage split to the outlet and stream channels. Accumulated flow sums the water moving down-slope into cells of the output raster and a weight of 1 was implemented to each cell if there no weight raster was given which consider as no possibility for vulnerable area [15].

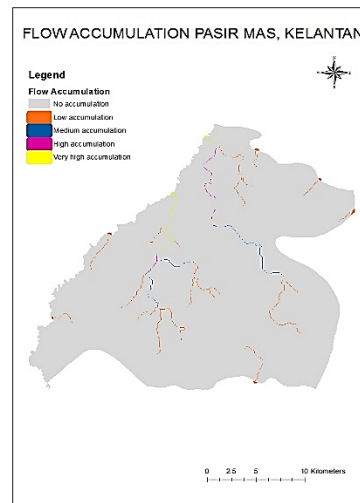


Figure 6. Flow Accumulation of Pasir Mas

4.3 Flood vulnerability area of Pasir Mas

The flood vulnerability means as a measure of area vulnerability to damages. Figure 7 shows the flood vulnerable area of Pasir Mas, Kelantan. The flood vulnerability also presents areas of high vulnerability in the surroundings of the rivers and the other location which mostly has the water body that represented in red colour. Meteorological and hydrological records proved that the main river in Pasir Mas which is Kelantan River usually overflows during monsoon season.

Besides, the moderate vulnerability was represented as orange colour that several locations that had been vulnerable to the flood. While reasonable vulnerability in yellow colour and low vulnerable in blue colour were dominated, some areas close to the river has high vulnerability and a few regions have moderate vulnerability. This happens because of heavy rainfall, affect nearly annual repetition of floods every year. Uncontrolled land use changes such as deforestation, raise rainfall intensity and other factors included slope, elevation and drainage network were possible causes for flood vulnerable area. This also have been supported in previous event which in December 2014, Pasir Mas was hit by flood event that causes the severe on records based on depth and level of flood in addition to the percentage of properties damages.

5. Conclusion

It is difficult to reduce the occurrence of natural disasters, including floods. The result sought to determine the flood vulnerable area on physical and climatic factors. The factors represented land use, amount of rainfall, slope and DEM and flow accumulation were applied to predict affected area of flooding. Each of these factors has been analyzed in details and taking into account to identify its level of contribution to the flood vulnerable area in Pasir Mas, Kelantan. The result shows that the physical and climatic factors had affected in determine the vulnerability of the area to floods. Secondly, the result sought to develop flood vulnerable map based on five physical and climatic factors. From the flood vulnerable map, it can be observed that most of the area in Pasir Mas, Kelantan was falling under reasonable to high vulnerability classes. This study has been conducted to assess the area that was vulnerable to flooding using integrated approaches of remote sensing and GIS. The GIS provides timely, cost effective and accurate information. Therefore, assessing area vulnerable to flooding disasters is one of the parameters in creating a flood vulnerable map. It can be used for disaster mitigation and urban planning besides to reduce the risk of life and properties losses due to the flood.

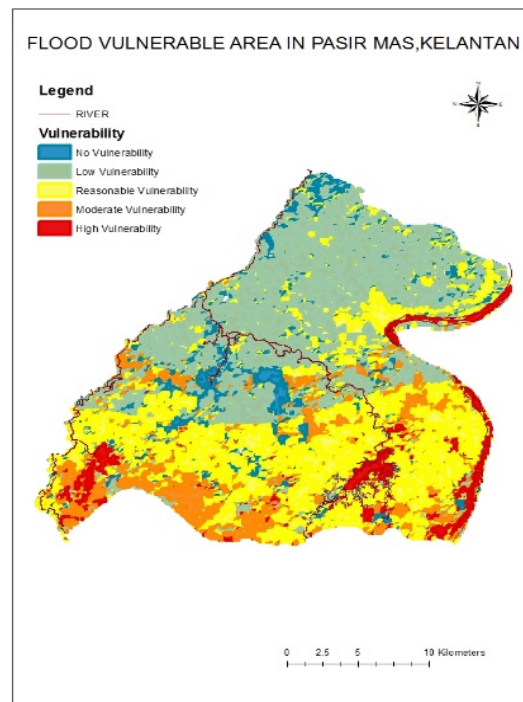


Figure 7. Flood vulnerable area map of Pasir Mas

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