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FLOOD DAMAGE ASSESSMENT IN AGRICULTURAL AREA IN SELANGOR RIVER BASIN

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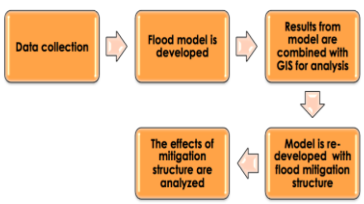
Graphical abstract



Abstract

Flooding is the major natural hazard that occurs in Malaysia. Flooding causes loss of lives, injuries, property damage and leave economic damage to the country, especially when it occurs in an agricultural area. There is still a lack of information available on floodplain especially on the impact of flooding in the agricultural area. This study focused on flooding and flooding impact in oil palm plantations, fruits and vegetables area. A river modeling is required to study the impact of flooding and to mitigate the floods using one mitigation option. A flood model was developed using InfoWorks Integrated Catchment Model (ICM) to carry out the analysis for flood damage assessment. With the aim of creating a flood damage map, Geographical Information System (GIS) was combined with the flood model to provide an ideal tool for the analysis of the flood damage and the effect of mitigation to flood damage. The estimated total damage for three different flood event; 10 ARI, 50 ARI and 100 ARI involved millions of ringgits. In order to reduce the flood impact along the Selangor River, a flood mitigation structure which is a retention pond was suggested, modeled and simulated. The effects of the retention ponds were analyzed and evaluated for 10 ARI, 50 ARI and 100 ARI. With this retention pond, flood extents of the flood events in agricultural area were shown capable of reduction significantly by 65.57% for 10 ARI, 76.18% for 50 ARI and 72.51% for 100 ARI.

Keywords: Flood model, agricultural flood damage, flood mitigation

1.0 INTRODUCTION

Natural catastrophe is a disaster resulting from natural processes of the Earth. Natural catastrophes such as earthquakes, tornados, floods, volcanic eruptions, and landslides have become important issues in many regions around the world. Many nations experience loss of lives, injuries, property damage, and economic damage because of these natural catastrophes. The rapid increased of the world's population has increased the number of the natural catastrophes occur due to uncontrolled development.

Flooding is the most significant natural hazard in Malaysia in terms of population affected, frequency, flood extent, flood duration and social economic damage. The basic causes are the incidence of heavy monsoon rainfall and the resultant large concentration of runoff, which exceeds river capacity [1] [2]. The climate is influenced by the northeast and southwest monsoons.

Malaysia has recorded, the nation's flood catastrophe where floodwater control turns to be a rising matter of debate among authorities, researchers as well as non-public sectors since 1973 [3]. More than thirty-five years, the magnitude and frequency of flood were tremendously accelerated particularly triggered by human actions; for example land clearing for urbanization or farming activities, building of structures such as freeways, roads and bridges which repeatedly alters the flood behavior [2] [4].

There are two types of flood damages which are direct flood damage and indirect flood damage. Direct flood damage occurs due to the physical contact of objects with the flood water while indirect flood damage is induced by flooding, but occurs in space or time outside the actual event. Because agricultural plots are usually located in the vicinity of rivers and creeks, adverse effects on plant growth are the most important damage rather than other cost [5].

Agricultural lands which located in catchment areas have the probability to involve in flood events through their surface run-off waters. Agricultural lands are the receptors of flooding other than urban areas. Recent massive flood that hits Thailand in October, 2011 had destroyed approximately 10% of the nation's rice crop [6]. In Malaysia, in year 2012, Baling was hit by flash flood due to heavy downpour. It affected the villages and economic in that area as it destroyed more than 50 hectares of agricultural lands in Kupang.

A river modeling needs to be simulated in order to see the mitigation effect on floods. In order to overcome the problem, the condition and the characteristics of the rivers need to be understood. To meet the purpose, a comprehensive flood model was developed using InfoWorks Integrated Catchment Modeling (ICM) that covers main river and floodplain. Besides, Geographical Information System (GIS) in combination with appropriate flood models provide ideal tools for the analysis and management of flood risk. GIS overlays of the land use and the flood extent can be used to study the impact of flooding in agricultural area and to calculate the flood damage.

2.0 METHODOLOGY

2.1 Study Area

This study has been carried out at Selangor River, which is located in a Selangor river basin, one of the major basins in the state of Selangor. However, this study only covered a part of the Selangor River, which involved only Kuala Selangor, Pasangan and Bestari Jaya. Figure 1 shows the location of the study area. The economic characteristics of the Selangor river basin is related to its physical land use characteristics. The majority of the economic activities in the Selangor river basin are agriculture base followed by fisheries and industry, trade, forestry and tourism [7]. Oil palm is the main commercial crop in the study area. Oil palm plantations are scattered mainly towards the south of the Selangor River in Kuala Selangor. Other crops that can be found in the study area are rubbers, coconuts, sugarcanes and bananas.

2.2 Data Collection

There are two types of data required for this study, which is spatial data and non-spatial data. The spatial data include topographic data and land use data while the non-spatial data includes rainfall intensity and river water level. In order to develop a good InfoWorks ICM model, good quality of GIS data of the catchment and good quality of DEM data to represent natural depressions and embankments on the ground are required. Table 1 shows data requirements and their sources for this study.

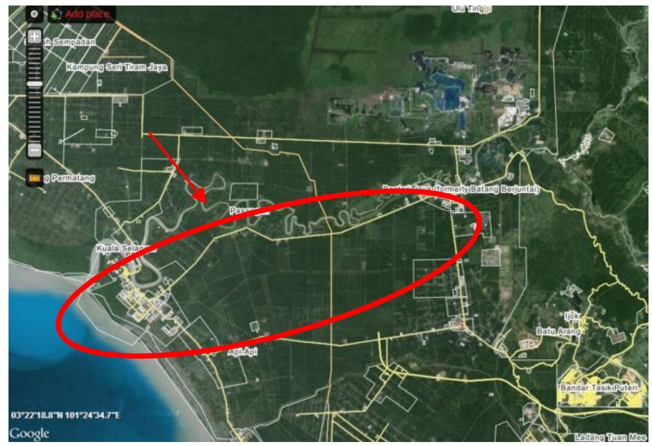


Figure 1 Selangor river in Kuala Selangor, Pasangan and Bestari Jaya areas (source: www.wikimapia.org)

Table 1 Data requirements and their sources

Data requirements	Data sources
Topographic map	Department of Land and Survey
Land use data	Department of Agriculture
Rainfall data	Malaysian Meteorological Department
River data	Department of Irrigation and Drainage
Satellite imagery	Google Earth/Wikimapia

Terrain conditions of forested lands can be conveniently assessed with a desktop computer with the availability of affordable elevation data including Shuttle Radar Topography Mission (SRTM), and Interferometric Synthetic Aperture Radar (IFSAR) data in Malaysia. Terrain is analyzed to avoid lands with steep slopes above permitted limits while regional watershed studies are performed to identify flood-prone areas. In this study, IFSAR data were used in developing the DEM for flood model.

IFSAR data are best used in sparsely vegetated areas with relatively low slopes and away from urban areas. IFSAR data are appropriate for watershed-scale analysis. Because of its wider swath and greater flying speeds, IFSAR are more appropriate and more cost effective for large area applications. IFSAR is used in creating elevation models of the terrain from airborne platforms at superior levels of spatial detail typically 1-5 meters sample spacing and accuracy which is 15 cm – 3 meters RMSE vertical [8].

InfoWorks ICM creates 2D mesh by using an irregular triangular mesh where the size and orientation of the triangles varied. Irregular mesh is more efficient than using a regular grid where the layout is fixed. It allows for more details and complexity in locations where it is needed. The 2D mesh is composed of triangles; each has three points of elevation. The triangle represents the average elevation between the three points. When the 2D mesh covers an area, the elevation changes are represented. Therefore, water can flow over and follow the topographically lowest route through the mesh. Figure 2 shows the model network, which made up from irregular triangles.

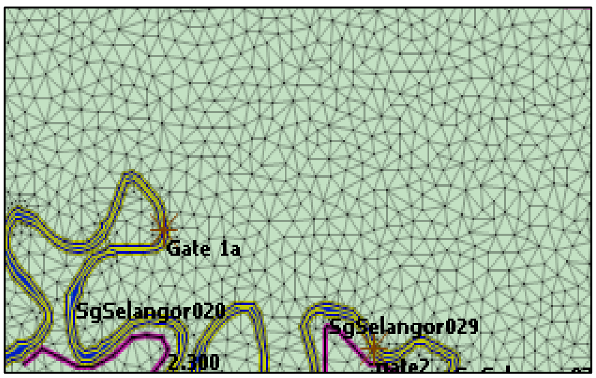


Figure 2 Model network made up from irregular triangles

Hydrological data that include cross section and water level data were imported into InfoWorks ICM. In any hydrodynamic river simulation, the most important input would be the shape of the river, which is represented by the cross section, hydraulic structure, water level and river flow.

3.0 RESULTS AND DISCUSSION

3.1 Flood Damage Map

Simulations using various return periods were carried out to determine the flood extents and flood depths which then were being exported to ArcGIS. In a report of Water Resources Planning Institute of Vietnam, it is suggested to use a 10 ARI as a flood standard for agricultural flood protection activities [9]. In addition, 100 ARI has been universally used to describe a reasonable flood protection level. Therefore, this study used three flood scenarios which are 10 ARI, 50 ARI and 100 ARI to assess the impacts of floods on agriculture in the Selangor river basin area. Using the overlay process between the flood maps and coupled with the land use map, the flood damage assessment has been done. The flood risk maps resulted from the flood model was overlaid with the land use maps to assess the impact of 10 ARI, 50 ARI and 100 ARI in agricultural land use in the study area. Figure 3 shows the results for three various return periods which are overlaid with the land use map.

3.2 Floods in Agricultural Sector

The flood model predicts that the greatest sector affected by the flooding in the study area is the agricultural sector. This is due to the fact that agricultural areas are located in the flood plain areas. Based on agricultural cycle, excessive rainfall is detrimental to crops as yield is significantly affected, especially in oil palm plantations. However, for the flood damage assessment in agricultural area, only area that will be flooded by 0.5 to 1.2 m and above of floods will be calculated. Table 2 shows the estimated agricultural land that the model predicts to be affected.

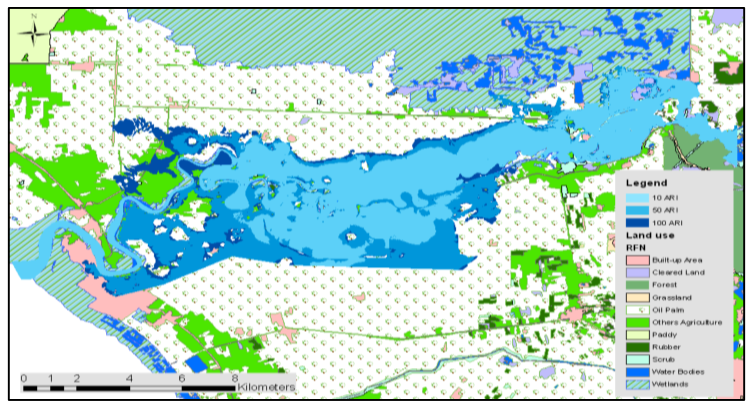


Figure 3 The results for 10 ARI, 50 ARI and 100 ARI in Pasangan and Bestari Jaya area

Table 2 Estimated area of agricultural land affected by flood scenarios

Flood Scenario	Flooded area (ha)		
	10 ARI	50 ARI	100 ARI
Oil palm	1759.97	3642.32	4249.62
Fruits and Vegetables	260.76	576.19	657.19
Total agricultural area	2020.73	4218.51	4906.81
Total flooded area	**5846.35**	**9173.57**	**10178.40**

The largest area affected by the floods is oil palm plantations, followed by the mixture of various types of agricultural crops. This is because oil palm plantations are the major crop planted along the Selangor River.

3.2.1 Estimation of Direct Flood Losses in Oil Palm Plantation

Excessive rainfall would likely have a negative effect on palm oil production [10] [11]. Many plantations have experienced circumstances where water is logged for an extended period of time after flooding particularly on flat terrain. Hence, it damages oil palm trees. From the total area of oil palm plantations that will possibly flooded, the losses of oil palm products can be determined by calculating the total ringgit loss per hectare.

In order to simplify the calculation of losses in oil palm plantations, this study assumed that all oil palm trees were in the same maturity and they were in the early stage of growth. Besides, this study postulated that once the oil palm plantations are flooded, all the oil palm trees are damaged and cannot be harvested. These assumptions were made due to the limitation of information and less research has been done in determining the crop resistance to flood.

The average monthly Fresh Fruit Bunch (FFB) yields reported from Malaysian Palm Oil Board (MPOB) for March 2014 in Selangor state was 1.39 tonnes/hectare [12]. The reference price for FFB at the mill gate on March 18, 2014 is 634 RM/tonne. This reference price was chosen because the simulation of flood model was carried out on March 18, 2014. Table 3 shows the total area affected, total FFB and total price loss for each return period.

Table 3 The losses in oil palm plantations for each return period

Flood Event (years ARI)	Total Area (ha)	Total FFB (tonnes)	Total Price Loss (million RM)
10	1759.97	2446.36	1.55
50	3642.32	5062.82	3.21
100	4249.62	5906.97	3.75

3.2.2 Estimation of Direct Flood Losses in Fruits and Vegetable Area

Other agricultural crops that can be found planted in the study area are industrial crops such as coconut, fruits such as banana and pineapple, and vegetables such as okra and spinach. Instead oil palm, Industrial crop which is coconuts are the most planted crops in the study area. However, the losses of industrial crops are not discussed in this paper because the coconut trees are rarely damaged during flooding.

This study focuses mainly on the losses for vegetables and fruits because they are the most affected crops during floods. Once the areas are flooded, all the vegetables and fruits are damaged and cannot be harvested. From the statistics reported by DOA in 2012 [13], the average value of production for vegetable was RM3.19 per kilogram and average value of production for fruit was RM1.89 per kilogram.

The exact areas for other agricultural crops are unknown because various crops were simplified into one category in the land use map. Thus, the exact areas for vegetables and fruits are unknown. In the same report from DOA [13], the planted area of vegetables in Kuala Selangor was 196.78 ha while the planted area of fruits was 42.50 ha. This study assumed the vegetables covered 8.1% and fruits covered 1.75% from the total flooded area of agricultural crops. Table 4 shows the estimated losses in the area planted with vegetables and fruits.

Table 4 Estimated flood losses for vegetables and fruits

Flood Event (years ARI)	Planted Area (ha)		Total Price Loss (million RM)	
	Vegetables	Fruits	Vegetables	Fruits
10	21.12	4.56	0.81	0.12
50	46.66	10.08	1.79	0.27
100	53.22	11.49	2.05	0.30

3.3 Flood Mitigation Structure in the Study Area

Mitigation is a strategy to reduce the long term impacts of disasters face by a nation or community. Flood mitigation refers to any structural or non-structural measures taken to reduce the flooding impacts. The flood mitigation structure proposed in this study was a retention pond. The retention pond was chosen because it is used to collect storm water runoff for the purpose of controlling of this runoff and it has been proved to be the effective mitigation option to reduce flooding.

The retention pond is located at an appropriate location along the Selangor River. It is located at 101°24'23.839"E and 3°25'57.396"N. The retention pond was built in a lower area so that water can easily flow from higher to lower land and go into the pond. Besides, the pond is located in an abandoned mine area in Bestari Jaya. This location was chosen to ensure that the pond does not disturb any residential area. If the location of the retention pond has landowners, it will be a time and cost consuming as the authorities need to ask for landowner permission they need to pay for the compensation. Figure 4 shows the location of the retention pond in Google Earth.

The area of the retention pond is 341.5 ha. The depth of the retention pond is 8 meters depth. The size of the retention pond is determined based on the volume for 10 ARI, 50 ARI and 100 ARI. The retention pond can store only 27,320,000 m^3 of water. Thus, this pond cannot store all the excessive water flows during the 10 ARI, 50 ARI and 100 ARI because the total volumes for these three various return periods are larger than that. However, it can help in reducing the impacts of flood as it reduces the flood depths and flood extents. After the input of the retention pond was ready, the simulations of the model were re-run to study the scenarios of the flood after being mitigated. Table 5 shows the area that will be flooded before mitigation, the area that will be flooded after mitigation and percentage reduced after flood mitigation is done.

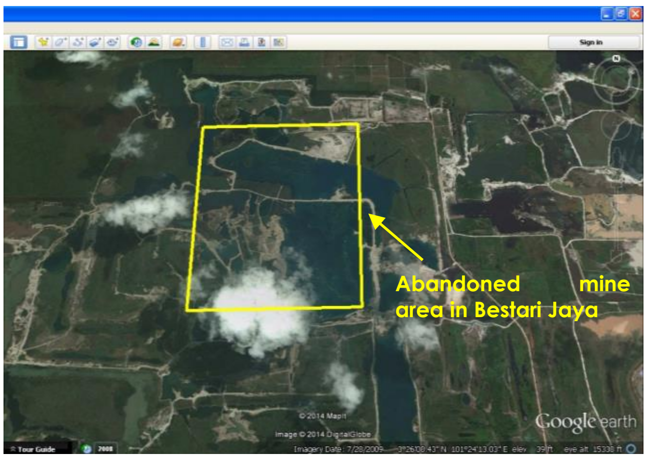


Figure 4 The location of the retention pond

Table 5 Percentages reduced in the study area after using flood mitigation structure

Flood Event (years ARI)	Area Before Mitigation (ha)	Area After Mitigation (ha)	Percentage Reduce (%)
10	4368.94	2642.93	39.51
50	6969.5	3163.09	45.38
100	7841.61	3649.29	53.46

To assess the flood damage more clearly, the flood maps were overlaid with the land use map. The flood maps, which were the results obtained from the flood model were overlaid to study the impact of 10 ARI, 50 ARI and 100 ARI in agricultural land in the study area. Figure 5 represents the results of the flood maps overlaid with the land use map.

After the flood mitigation, the estimated flooded area in agricultural area has been reduced. This shows that the retention pond help in reducing the floods in agricultural areas. Table 6 represents the percentage reduced in agricultural area after building the retention pond.

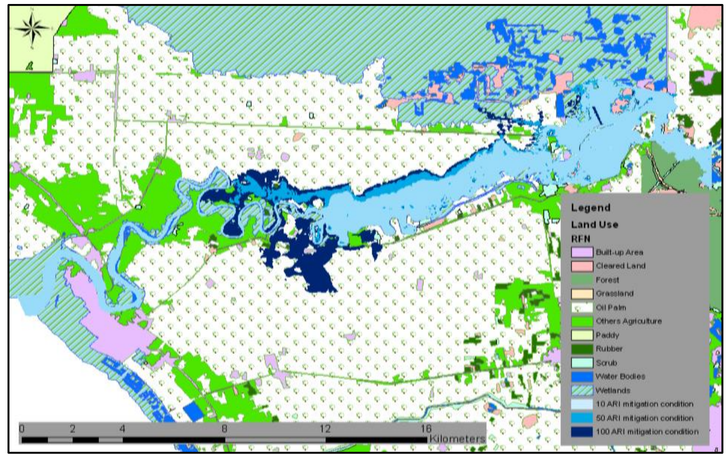


Figure 5 The results of 10 ARI, 50 ARI and 100 ARI overlaid with the land use map after mitigation

Table 6 Percentage reduced after building the retention pond in the agricultural area

Flood Event (years ARI)	Agricultural Area Involved (ha)		Percentage Reduced (%)
	Before Mitigation	After Mitigation	
10	2020.73	709.5	64.89
50	4218.51	1021.77	75.78
100	4906.81	1370.83	72.06

3.3.1 Estimation of Flood Losses in Oil Palm Plantation after Mitigation Condition

The oil palm plantations are still the most affected area during the floods due to the location of the plantations, even after implementing the retention pond. In order to synchronize the price, this study used the same date as the simulation of the first flood model so that it is clearer to study the difference between the flood losses before mitigation and the losses after mitigation. Table 7 shows the estimated losses on oil palm plantations on various return periods. Table 8 shows the difference between the price losses before and after flood mitigation.

Table 7 The difference between the price losses in oil palm area before and after mitigation

Flood Event (years ARI)	Total Losses (million RM)		Percentage Reduced (%)
	Before Mitigation	After Mitigation	
10	1.55	0.55	64.52
50	3.21	0.80	75.08
100	3.75	1.05	72.00

3.3.2 Estimation of Direct Flood Losses in Fruits and Vegetables Area

The average values of production to calculate the flood loss after mitigation are the same values that are used in the previous calculation. Table 8 shows the estimated losses in the area planted with vegetables and fruits. Table 9 shows the difference between the price losses before and after flood mitigation.

Table 8 The difference between the losses before and after mitigation in fruits and vegetables area

Flood Event (years ARI)	Total Price Loss (million RM)				Percentage Reduced(%)
	Before Mitigation		After Mitigation		
	Vege-tables	Fruits	Vege-tables	Fruits	
10	0.81	0.12	0.23	0.03	72.04
50	1.80	0.27	0.30	0.04	83.57
100	2.05	0.30	0.45	0.07	77.87

3.4 Total Flood Damage in Agricultural Area before and after Flood Mitigation

In order to determine the difference between the flood damage that occurs in the agricultural area before and after mitigation, the total flood loss of each plantations area which are the oil palm plantations, and vegetables and fruits area are summed up. Table 9 shows the total damage before and after flood mitigation and percentage reduced after simulating the flood model with retention pond.

Table 9 The difference between total damage before and after flood mitigation

Flood Event (years ARI)	Total Damage (million RM)		Percentage Reduced (%)
	Before Mitigation	After Mitigation	
10	2.51	0.82	67.33
50	5.32	1.15	78.38
100	6.15	1.59	74.15

4.0 CONCLUSION

As agriculture is an important sector in Malaysia, this study presented an overview of flood mapping and GIS technology in order to determine the flood losses on agricultural land along the Selangor River. The flood model used in this study was developed using InfoWorks ICM. The impacts were determined in term of the price losses when the areas are flooded by three different flood event; 10 ARI, 50 ARI and 100 ARI. The flood damage for each flood events was calculated in the oil palm plantation area, and in fruits and vegetables area. An appropriate flood mitigation structure which was a retention pond was suggested in reducing the flood scenarios along the Selangor River. The effects of the retention ponds were analyzed and evaluated for 10 ARI, 50 ARI and 100 ARI. With this retention pond, flood extents of the flood events in agricultural area were shown capable of reduction.

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