Development of flood risk mapping in Kota Tinggi, Malaysia

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Abstract. Flood risk maps provide valuable information for development of flood risk management. Geospatial technology and modeling enable us to monitor natural disasters around the world. Flooding is the most severe natural disaster that causing huge economic losses every year. Flood risk maps are an essential tool for assessing the consequences of flooding. The main aim of this study is to initiate a framework to develop a local-based flood risk map. Flood risk maps can be produced by using integration of geospatial technology and hydrodynamic modeling. Results show that a flood risk map for Kota Tinggi is produced with unsatisfactory information in term of flood damage.

1. Introduction
Every disaster occurred in every part of the world causes small or substantial losses and damages that depend upon the magnitude or probability of the disaster and the development at the affected place. Consequence, disasters influencing seriously on country’s economy, causing resources shortage, environment deprivation and zoology unbalance [1]. Sustainable development at the accident area also is reducing as resources, environment and zoology is affected by disaster [1].

Digital Earth is a concept introduced by former US vice President Al Gore in 1998. The concept of digital earth enable us to understand very well of our planet via technological innovation that able to produce very much information to represent our planet and this information has georeferenced. According to Gore [2], the technologies are needed to develop digital earth included computational science, satellite imagery, internet, interoperability, and metadata. Thus, digital earth can be used for many purposes in which one of the purpose is decreasing and preventing disaster [1]. Decreasing and preventing disaster can be very much relied on remote sensing to provide essential and up-to-date data, geographic information system (GIS) analyses and modelling for a real event.

Floods is the most widespread and destructive natural disasters around the world in term of economic losses. According to the OFDA/CRED International Disaster Database, the average annual economic loss due to flooding is about US $ 18 billion for last 30 years. This figure may continuously increase because of the effect of climate change, which might change the intensity, duration and frequency of rainfall [3].

Different types of flood maps have been produced to disseminate different types of information [4], but flood maps is prerequisite step for developing flood risk management strategies [5]. According to

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[5], he has proposed four types of flood maps, which are flood danger map, flood hazard map, flood vulnerability map and flood damage risk map. Depending on the use and user, flood maps can be used for increasing awareness among people at risk, providing information for urban land-use planning, helping to assess the feasibility of structural and non-structural flood control measures [5]. Among all the different types of flood maps, only flood risk map illustrates the information on the consequence of flooding [6], which can be expressed by monetary losses and unacceptable risk area. In fact, very few countries in Europe have developed this kind of map, even in Malaysia. In this study, different magnitudes of flood risk maps (2, 25, 50, 100, and 200-year return period) were produced to determine the consequence of every flood event to the study area.

2. Study Area
Kota Tinggi is a town in Johor state (green box in Figure 1), Malaysia. It is located approximately 40 kilometres northeast of Johor Bahru, capital city of Johor state. The district of Kota Tinggi is located at the east of Johor state with 65% of its border is surrounded by the sea. Kota Tinggi district consists of an area of 3,500 km² (364,399 hectares) and divided into 11 sub-districts (Figure 1). Urbanization in this area is growing rapidly focus in agricultural activities and housing development with a population of more than 200,000 people. The administrative town of this district also was named Kota Tinggi. The average elevation of Kota Tinggi is 6 meters above mean sea level.

3. Data used and Methodology
This study is primarily based on an optical Landsat TM 5 image, hydrological data (water level and discharge), LiDAR Digital Elevation Model (DEM), river networks and cross sections, cadastral data and real estate value information. The Landsat TM 5 image was captured on 2005 is obtained at U.S. Geological Survey (USGS) website. Hydrological data was provided in the format of 2, 25, 50, 100 and 200-year return period by the Department of Irrigation and Drainage (DID), Malaysia. This study also provided by DID one-meter resolution DEM data, river networks and cross sections with one-km interval along the Sungai Johor. For Cadastral data and real estate value information were obtained at Kota Tinggi District Council and Valuation and Property Services Department, Johor Bahru, respectively. Completion of this study has to undergo 3 main parts, i.e. pre-processing part, main-processing part and lastly is analysis part.

Pre-processing part is mainly focus on radiometric correction to Landsat TM 5 image and re-sampling DEM resolution. In this study, Landsat TM 5 image was corrected radiometrically using FLAASH model. The radiometrically corrected image was used to produce land use/cover map using maximum
likelihood technique. The overall accuracy and kappa coefficient of the classified image are 67.52% and 66.16 respectively. One meter DEM was re-sampled into 30 m in order to match the Landsat image resolution. Thus, every DEM pixel contains one surface roughness value that is an important parameter for flood simulation.

Main processing is to simulate different flood scenarios using 1D2D SOBEK hydrodynamic modelling. The main parameters are required for schematization of 1D2D SOBEK included DEM, boundary conditions (discharge at upstream, water level at downstream), cross section and Manning’s roughness coefficient. Calibration is an important step for any simulation in order to produce a simulation that closes to the observed data. The most important parameter for model calibration is roughness coefficient of the channel and land surface [7]. Thus, in this study, total of 2 set of Manning’s n values were used in the calibration step.

Two important outputs produced from hydrodynamic modelling are the maximum flood extent and the maximum flood depth. In this study, a hazard classes proposed by Japanese International Cooperation Agency (JICA) was adopted to determine the flood hazard, which based on flood depth information. The flood hazard map is an important input for the vulnerability assessment. But, a comprehensive study of flood vulnerability is very complicated as it taking into account of every elements of risk associated to the hazard. The elements are referring to the human system, built environment and natural environment [5], such elements are the pollution, economic activities, public services, utilities and infrastructure, building and civil engineering works, ecosystem ad etc. [5,8]. This study mainly focuses on physical elements at risks for vulnerability assessment, which are dwelling, commercial and industrial area. Three different depth-damage functions have been adopted that produced from the Netherlands, United States, and JICA were used for determining the vulnerability of the various physical elements at risks.

The vulnerability value, sometimes, can refer to damage factor is the range from 0 to 1, which based on flood depth as reference. Generally, flood risk is a product of hazard (probability) and vulnerability (consequence). In this study, flood risk is defined as the potential damage associated with a flood event and expressed as monetary losses. Thus, flood damage of one unit property can be estimated as damage factor multiplied by building value. An average damage expressed as RM/m² is the standard unit show in flood risk map. The average damage is calculated by sum up of damage unit divide by total affected area.

4. Results and Analysis

4.1 Calibration of Flood Simulation
Remote sensing has proved an indispensable tool for model calibration and validation [9,10]. Due to there are no available satellite data captured during the peak time of flooding, calibration of flood model is only can be done by visualization. A 100-year simulated flood event was compared to a flood map produced by DID.

4.2 Flood Maps
In this study, three different flood maps (flood hazard map, flood vulnerability map and flood risk map) have been produced for Kota Tinggi city. Figure 2 shows the flood map in 200-year.
Figure 2. Flood maps show in 200-year (a) flood hazard map; (b) flood vulnerability map; (c) flood risk map (monetary losses); (d) flood risk map (risk zones).

Flood hazard map shown 5 hazard classes in term of flood depth. This map found that those areas are proximity to river is experiencing more hazards compared to those areas far from river. Areas with low topography also cause an area more hazard, which shown in the middle of Figure 2(a) where the hazard level is reached to very high category.

Flood vulnerability map displays the information of affected elements at risks, which produced by overlying of flood extent and cadastral data. This kind of map tells us the specific location of a place. So, when flooding happen, rescue works can priority on senior citizen and children at old folk home and kindergarten, respectively or patients at hospital.

Flood risk map can be delivered into qualitative and quantitative ways. Figure 2 (c) is a quantitative map which show the average flood damage of a particular area. For dwelling, commercial and industrial area, their average flood damage per meter square are RM 200/m², RM 800/m² and RM 30/m², respectively. These values are derived using depth-damage function from the Netherlands. Figure 2 (d) show which areas are unacceptable high risk.

5. Conclusion
The objective of this study was achieved where flood risk map has been produced for Kota Tinggi city. Production of flood risk map is very important as it provide valuable information for implementing flood risk management. But, the result of this study is not ideal due to the depth-damage function. A local-based depth-damage function should be developed in order to enhance the flood risk map information. Thus, a further study should carry out.

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