FLOOD IMPACT ASSESSMENT USING GEOSPATIAL TECHNOLOGIES AND HYDRODYNAMIC MODELLING

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ABSTRACT: Flood occurred when heavy and continuous rainfall exceeding the absorptive capacity of soil and the flow capacity of rivers, streams, and coastal areas. Land areas that are most subjected to floods are areas situated adjacent to rivers and streams, that are known as floodplain and therefore considered as “flood-prone”. These areas are hazardous to development activities if the vulnerability of those activities exceeds an acceptable level. According to the Department of Irrigation and Drainage in Malaysia, about 29, 000 sq. km, or 9% of the total land area and more than 4.82 million people (i.e. 22% of the population) are affected by flooding annually. Damage caused by flooding is estimated about RM 915 million (£160 million). An unprecedented heavy rainfall occurred in Malaysia in December 2006 to January 2007. The consequence of this extreme event has resulted severe impact on few area of Malaysia where Kota Tinggi in Johor state is one the affected area. The objectives of this study are; to identify the element at risk in flooding, to estimate the land use/cover that affected by flooding in different return periods. Multiple RADARSAT SAR imagery with the aid of DEM data used to extract inundated area and study the characteristics of flooding. Different return period in term of flooding will be simulated using hydrodynamic model named SOBEK to determine its impact on land use/cover. Landsat TM was used to classify the land use/cover. SOBEK is an integrated 1D-2D hydrodynamic model. Such model can overcome the limitations of 1D and 2D models where it could reduce the computation time, simplify the modeling procedure and enrich the results.

1. Introduction

A disaster is defined as a serious disruption of the functioning of a community or a society causing widespread human, material, economic or environmental losses that exceed the ability of the affected community or society to cope using its own resources (International Strategy for Disaster Reduction, 2003).Therefore, there is no perfect system to prevent damage or loss cause by disaster because then it would not be a disaster. Referring to Mansourian *et al.*, (2006), disaster is divided into three main groups as natural disasters, technologies disasters and man-made disasters. Among the natural disasters in the world were registered in The International Disaster Database (EM-DAT), flood has the higher-frequency occurrence. Figure 1 shown the three types of natural disasters were registered in EM-DAT.

Flood occurred when heavy and continuous rainfall exceeding the absorptive capacity of soil and the flow capacity of rivers, streams, and coastal areas. Land areas that are most subjected to floods are areas situated adjacent to rivers and streams, that are known as floodplain and therefore considered as “flood-prone”. These areas are hazardous to development activities if the vulnerability of those activities exceeds an acceptable level.

Likewise, flood is the most significant and serious disaster affecting Malaysia largely because of the monsoon season, convection and rapid land use changes (Chan, 1995).According to Liu and Chan (2003), the Department of Irrigation and Drainage in Malaysia has estimated that about 29,000 sq. km, or 9%, of the total land area and more than 4.82 million people (i.e. 22% of the population) are affected by flooding annually. The damage caused by flooding is estimated to be about RM915 million (£160 million).The objectives of this study are; to identify the element at risk in flooding, to estimate the land use/cover that affected by flooding in different return periods.

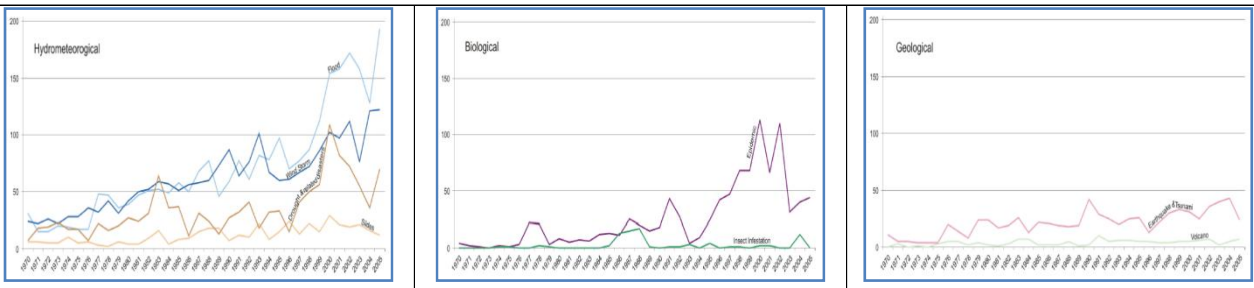

Figure 1: Number of natural disasters by types in between 1970 - 2005.
(Source: EM-DAT: The OFDA/CRED The International Disaster Database.
http://www.emdat.be/, UCL - Brussels, Belgium.)

2. Study Area

Kota Tinggi is a small town in the state of Johor of Malaysia. The main reason Kota Tinggi was chosen as study area because of this area had experienced two severe flood scenarios in the past five years. The first flood scenarios occurred in the year of 2006/2007. According to Department of Irrigation and Drainage (2007), this flood event is due to a couple of "abnormally" heavy rainfall which caused massive floods, the estimated total cost of these flood disasters is about RM 1.5 billion, considered as the most costly flood events in Malaysian history. The second flood scenario was happened in the early of this year. According to local resident claimed that this flood event is worse than the flood event occurred in the year 2006/2007.

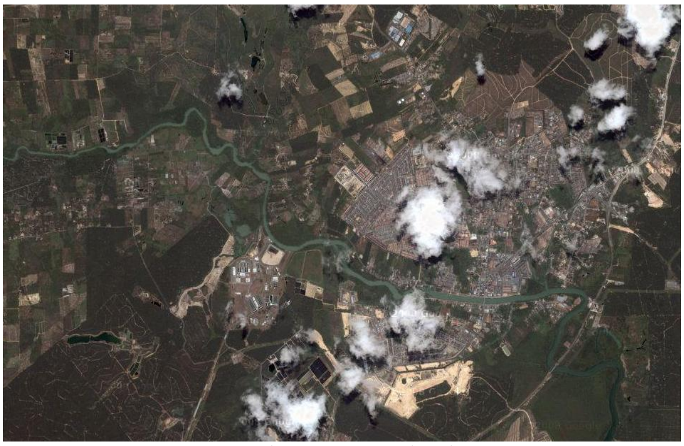

Figure 2: Kota Tinggi.

3. Data and Methodology

This section explained the main data used in this study and the methodology as well.

3.1 Satellite Image, Hydrological Data and DEM

A Landsat TM satellite image on the year of 2005 was obtained from the USGS website (http://glovis.usgs.gov/) is used to perform land-use/cover classification. Hydrological data include stream flow and water level, DEM and geometry data (cross-section) are main inputs for hydrodynamic model. The hydrodynamic model used in this study is integrated 1D2D SOBEK model. The advantage of 1D2D modeling is bringing the result of the model more closer to real physical behavior (Dhondia and Stelling, 2002) and capable to simulate flood event more accurately (Shaviraachin, 2005). The main of choose SOBEK model in this study is SOBEK could support high resolution DEM (>20m) for flood simulation (Dhondia and Stelling, 2002). The DEM resolution is 20 meter.

3.2 Methodology

The methodology of this study is illustrated in Figure 3.

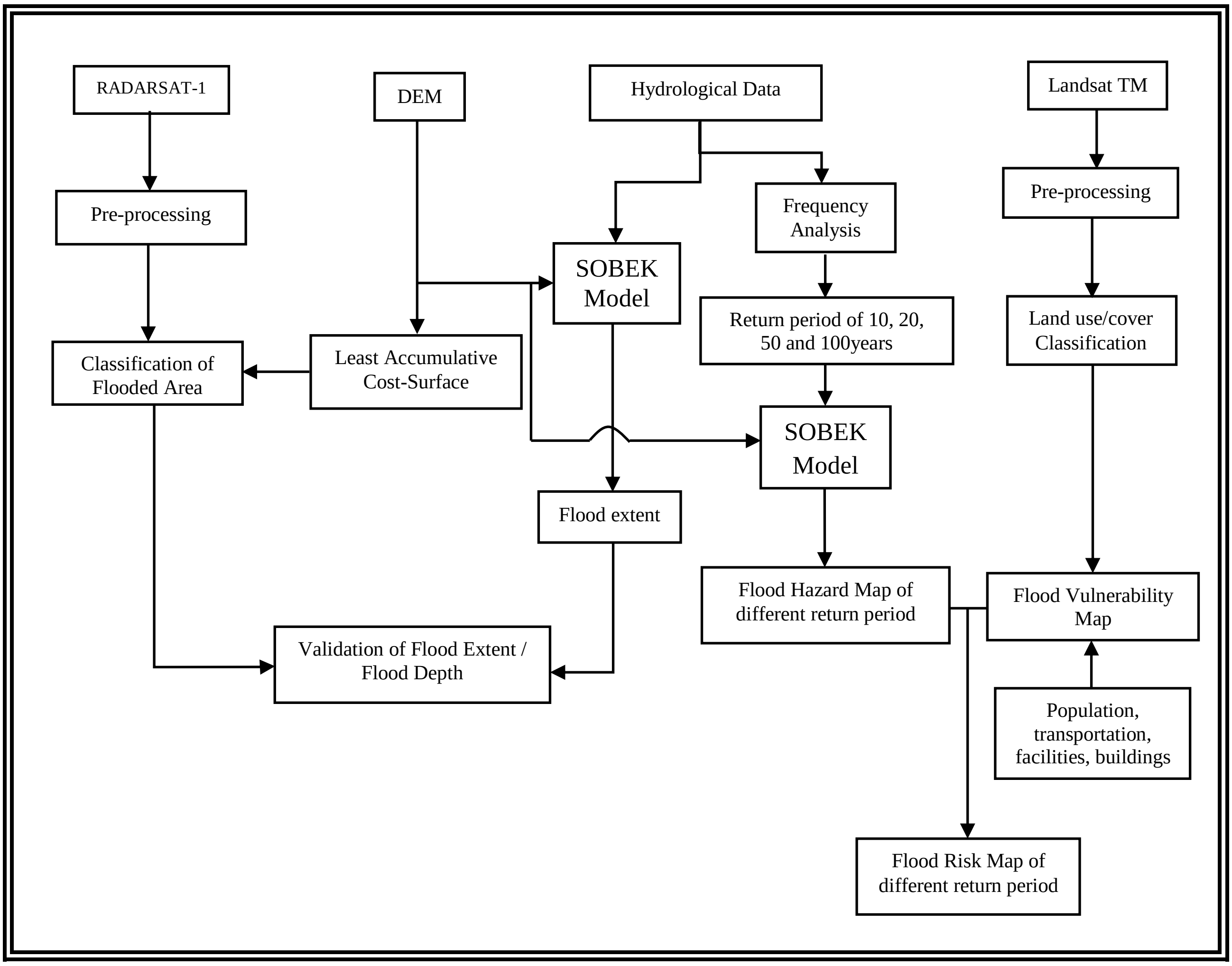

Figure 3: Methodology of this study.

4. Discussion

This section described the different type of flood map, its meanings and the important of risk map. The method of validate flood model explained in this section.

4.1Different of Flood Map

According to Merz*et al.*, (2007), there have four typical types of flood map at the local scale where the Table 1 briefly described each type of definition of flood map.

Type of map	Definition
Flood danger map	Show the spatial distribution of the flood danger without information about the exceedance probability
Flood hazard map	Shows the spatial distribution of the flood hazard, i.e. information on flood intensity and probability of occurrence for single or several flood scenarios
Flood vulnerability map	Shows the spatial distribution of the flood vulnerability, i.e. information about the exposure and/or the susceptibility of flood-prone elements (population, built environment, natural enviornment)
Flood damage risk map	Shows the spatial distribution of the damage risk, i.e. the expected damage for single or several events with a certain exceedance probability

One of the basic information of flood risk management is it provide the information of people at risk and it will help related-authorities and agencies to increase flood protection and prevention in effectively and efficiently (Merz *et al.*, 2007) and act as a tool to guide any future development in the flood prone areas and the necessary measures to control the risk. A flood risk map include information on the consequences of flooding, however, there are very few countries have developed flood risk in Europe (Moel *et al.*, 2009). Therefore, it’s very important to spin from flood danger maps to damage risk maps in Malaysia.

Risk is a result from the interaction of hazard and vulnerability (Merz *et al.*, 2007). Risk can be presented as:

$$\text{Risk} = \text{Hazard} \times \text{Vulnerability (exposure and loss)}$$

4.2 Validation Method for Flood Simulation

Field data on flood inundation and flood levels are required for model validation. Data can be available through observed time series data or through satellite image that provide complete coverage of the inundation area. (Tesfaye, 2009).

Validation using remote sensing data is desirable especially captured satellite images on peak floods. In this case, microwave remote sensing is more suitable for flood mapping. Townsend and Walsh (1998) and Townsend (2001) stated that the advantage of radar for flood mapping where microwave can penetrate through the atmosphere regardless of time of day and all weather conditions. The timing of satellite to capture flood area is the main limitation of using remote sensing date to validate flood simulation. Bates (2002) used SAR images to calibrate and validate simulated flood extent for River Seven in UK.

References

Bates, P. D., (2004). Remote sensing and flood inundation modeling. Hydrological Processes. 18, 2593-2597.

Chan, N. W., (1995).A Contextual Analysis of Flood Hazard Management if Peninsular Malaysia.Ph.D. thesis, Middlesex University (UK).

Department of Irrigation and Drainage, (2007).Flood and drought management in Malaysia.

Dhondia, J. F. and Stelling, G. S., (2002). Application of One Dimensional – Two Dimensional Integrated Hydraulic Model for Flood Simulation and Damage Assessment. Hydrodynamics.1-12.

International Strategy for Disaster Reduction (2003).Basic term of Disaster Risk Reduction.International Strategy for Disaster Reduction, United Naions.Retrieved on 2 July 2010, from http://www.adrc.or.jp/publications/terminology/top.htm.

Liu, P. S. and Chan, N. W., (2003).The Malaysia flood hazard management program.International Journal of Emergency Management.1(3).205-214.

Mansourian, A., Rajabifard, A., ValadanZoej, M. J., Williamson, I. (2006). Using SDI and Web-Based System to Facilitate Disaster Management.Computers & Geosciences. 32(3), 303-315.

Moel, H. D., Alpen, J. V., danAerts, J.C.J.H., (2009). Flood maps in Europe – methods, availability and use. Naturals Hazards and Earth System Sciences. 9, 289-301.

Shaviraachin, T., (2005). FLOOD SIMULATION A case study in the Lower Limpopo Valley, Mozambique using the SOBEK flood model. Master Thesis, International Institute for Geo-Information Science and Earth Observation.

Tesfaye, H. T., (2009). Two-Dimensional Hydrodynamic Modelling of Flooding using ASTER DEM in Ribb catchment, Ethiopia. Master Thesis, International Institute for Geo-Information Science and Earth Observation.

Townsend, P. A. (2001). Mapping Seasonal Flooding in Forested Wetlands Using Multi-Temporal Radarsat SAR.Photogrammetric Engineering & Remote Sensing. 67(7), 857-864.

Townsend, P. A. and Walsh, S. J. (1998).Modeling floodplain inundation using an integrated GIS with radar and optical remote sensing.Geomorphology. 21, 295-312.

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