FLOOD INUNDATION MODELLING USING GIS SPATIAL ANALYST: CASE STUDY OF PEKAN SUB-DISTRICT, PAHANG

BY

MUHAMMAD SHAHEED BIN SHAMMODIN

A thesis submitted in fulfilment of the requirement for the degree of Master of Science (Biosciences)

Kulliyyah of Science
International Islamic University Malaysia

DECEMBER 2018

ABSTRACT

A flood modelling study was carried out focusing on flood prone area, Pekan sub-district, Pahang. 3-dimensional inundation map model was used to simulate and predict flood affected zone within the area. The observation of inundation pattern mainly highlights the relativity between land topography with surface water level from Department of Irrigation and Drainage (DID) gauge station of Pahang River located at Pulau Jawa pump house. Methods involved of processing multiple types of spatial information gathered from remotely sensed data within a GIS environment. Data was collected from close and open source provider for the input during modelling process. A set of satellite imagery and digital elevation data was used to build a 3D spatial features of Pekan sub-district. Normal gauge reading of Pahang River was identified from DID infobanjir website at 1.0m and the hazard level increase at 2.44m, 3.05m, and finally 3.66m. Multiple water body layers were populated based on these data and flood pattern was observed until 5.50m gauge reading projection. 3D terrain model was created with assimilation of terrain information from digital elevation model. Water body offsets projection were generated and flood was observed in stereo mode within GIS software. Pekan sub-district was tessellated into square grid networks of $250m^2$ each. The technique allows identification of flood affected region in relation with water level offsets in simulation. Affected grids were assigned with different color codes for user recognition purpose. A set of feature class were created which represent important infrastructures especially main routes, community halls, hospital, and schools. This supplementary information could be used to assess the rate of habitability and accessibility during flood. Finally, DID historical datasets comparison together with on-site surveys were carried out to determine and validate the outcome of the simulated inundation model with real flood situation. According to SRTM raster data, it is found that Pekan sub-district has about 50% of terrain between 0-10m level. These areas are the most prone to flooding due to accumulation of stagnant water which naturally will be concentrated on low lying ground verified using watershed analysis. With simulation and supporting historical datasets and digital images, Pahang River expansion is not the real caused of flood spread over this region. This study was aimed to produce a flood prediction model that deliver interface that can be understood easily by any level of audience. It will help in earlier preparation especially for the locals if flood were to be discovered in the near future. Information provided on affected region and infrastructures that were emphasized will allow systematic planning and support flood relief committee in emergency period.

خلاصة البحث

أجريت هذه دراسة كنموذج للفيضانات، مع التركيز على منطقة بيكان الفرعية في ولاية باهانغ التي تعرضت للفيضانات. تم استخدام نموذج خريطة فيضانات ثلاثية الأبعاد لمحاكاة وتوقع المناطق المتأثرة بالفيضانات داخل المنطقة. تسلط الدراسة الضوء بشكل رئيسي على النسبية بين تضاريس الأرض مع مستوى المياه السطحية المأخوذة من محطة القياس التابعة لوزارة الري والصرف لنهر باهانغ الواقعة في غرفة المضخة في بولاو جاوا. تضمنت الأساليب المستخدمة معالجة أنواع متعددة من المعلومات الموقعية التي تم جمعها من البيانات المستشعرة عن بُعد في بيئة GIS. تم جمع البيانات من المصادر القريبة والمفتوحة للمُدخلات أثناء عملية النمذجة. تم استخدام مجموعة من صور الأقمار الصناعية وبيانات الارتفاع الرقمية لبناء ميزات موقعية ثلاثية الأبعاد لمنطقة بيكان الفرعية. تم التعرف على قراءة المقاييس الطبيعية لنهر بهانج من الموقع الإلكتروني infobanjirالتابع لوزارة الري والصرف على بعد 1.0 متر، حيث ازداد مستوى الخطر عند 2.44 متر، و3.05 متر وأخيراً عند 3.66 متر. تم ملء طبقات مياه متعددة بالاعتماد على هذه البيانات وتمت ملاحظة النمط الفيضاني إلى مستوى 5.50 مترا لمقياس العرض. تم إنشاء نموذج تضاريس الثلاثية الأبعاد بالاعتماد على المعلومات التضاريسية من نموذج الارتفاع الرقمي. تم إنشاء إسقاط إزاحة جسم الماء ولوحظت الفيضانات في وضع الاستريو داخل برنامج GIS. وُزعت منطقة بيكان الفرعية على شبكات مربعة سعة كل منها متر مكعب واحد. سمحت هذه الطريقة بتحديد المنطقة المتأثرة بالفيضانات بالاعتماد على تعويض منسوب المياه في المحاكاة. تم تعيين الشبكات المتأثرة بشفرات لون مختلفة من أجل التعرف عليها من قبل المستخدم. تم إنشاء مجموعة من الفئات الخاصة التي تمثل البنى التحتية، وخاصة المسارات الرئيسية، والمراكز المجتمعية، والمستشفيات، والمدارس. بالامكان استخدام هذه المعلومات التكميلية لتقييم معدل قابلية السكن وإمكانية الوصول البري أثناء الفيضانات. في النهاية تم إجراء مقارنة مع قواعد بيانات وزارة الري والصرف الماضية مع دراسات استقصائية في الموقع لتحديد وتأكيد نتائج نموذج محاكاة الفيضانات مع أوضاع حقيقية للفيضانات. وفقًا لبيانات SRTM النقطية فقد وجد أن في منطقة بيكان الفرعية حوالي 50٪ من التضاريس ارتفاعها بين 0-10 أمتار. هذه المناطق هي الأكثر عرضة للفيضانات بسبب تراكم المياه الراكدة والتي سوف تتركز بشكل طبيعي على أراض منخفضة والتي تم التحقق منها باستخدام تحليل مستجمعات المياه. اتضح من محاكاة البيانات التاريخية الداعمة والصور الرقمية أن توسع نهر باهانغ ليس السبب الحقيقي في انتشار الفيضانات في هذه المنطقة. هدفت هذه الدراسة إلى إنشاء نموذج للتنبؤ بالفيضانات والذي يوفر واجهة يسهل على المستخدمين فهمها من أي مستوى. سوف يساعد هذا النموذج في الإعداد المبكر خاصة للسكان المحليين خاصة ما إذا كان سيتم اكتشاف الفيضانات في المستقبل القريب. ستسمح المعلومات المقدمة عن المناطق والبنى التحتية المتأثرة التي تم التأكيد عليها بالتخطيط المنتظم وستدعم أيضا لجان الإغاثة في فترات الطوارئ.

APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion, it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Science (Biosciences).

……………………………………….
Zuhairi Bin Ahmad
Supervisor

……………………………………….
Ranjit Singh
Co-Supervisor

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Science (Biosciences).

……………………………………….
Mohd Zaini Mustapa
Examiner

……………………………………….
Wardah Tahir
Examiner

This thesis was submitted to the Department of Biotechnology and is accepted as a fulfilment of the requirement for the degree of Master of Science (Biosciences).

……………………………………….
Mardiana Binti Mohd. Ashaari
Head, Department of Biotechnology

This thesis was submitted to the Kulliyyah of Science and is accepted as a fulfilment of the requirement for the degree of Master of Science (Biosciences).

…………………………………..
Shafida Abd Hamid
Dean, Kulliyyah of Science

DECLARATION

I hereby declare that this thesis is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

Muhammad Shaheed bin Shammodin

Signature .... Date ....

INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA

DECLARATION OF COPYRIGHT AND AFFIRMATION OF FAIR USE OF UNPUBLISHED RESEARCH

FLOOD INUNDATION MODELLING USING GIS SPATIAL ANALYST: CASE STUDY OF PEKAN SUB-DISTRICY, PAHANG

I declare that the copyright holders of this thesis are jointly owned by the student and IIUM.

No part of this unpublished research may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording or otherwise without prior written permission of the copyright holder except as provided below

1. Any material contained in or derived from this unpublished research may be used by others in their writing with due acknowledgement.

2. IIUM or its library will have the right to make and transmit copies (print or electronic) for institutional and academic purposes.

3. The IIUM library will have the right to make, store in a retrieved system and supply copies of this unpublished research if requested by other universities and research libraries.

By signing this form, I acknowledged that I have read and understand the IIUM Intellectual Property Right and Commercialization policy.

Affirmed by Muhammad Shaheed bin Shammodin

……..…………………….. ………………………..

Signature Date

ACKNOWLEDGEMENTS

All glory is due to Allah, the Almighty, whose Grace and Mercies have been with me throughout the duration of my Master study. Although, it has been tasking, His Mercies and Blessings on me ease the herculean task of completing this thesis.

I am most indebted to by supervisor, Asst. Prof. Dr. Zuhairi bin Ahmad, whose enduring disposition, kindness, promptitude, thoroughness and friendship have facilitated the successful completion of my work. I put on record and appreciate his detailed comments, useful suggestions and inspiring queries which have considerably improved this thesis. His brilliant grasp of the aim and content of this work led to his insightful comments, suggestions and queries which helped me a great deal. Despite his commitments, he took time to listen and attend to me whenever requested. The moral support he extended to me is in no doubt a boost that helped in building and writing the draft of this research work. I am also grateful to my co-supervisor, Assoc. Prof. Sr. Ranjit Singh, whose support and cooperation contributed to the outcome of this work.

I am also grateful with the assistantship from the staff of Kulliyyah of Science and INOCEM Research Centre during the whole study period. Not to forget the cooperation from government departments especially Department of Irrigation and Drainage, Malaysia Remote Sensing Agency, and Public Works Department, for the privileges of providing data and knowledge for students.

My gratitude goes as well to my beloved parents; for their prayers, understanding and endurance while away.

Special thanks to the research funding by International Islamic University Malaysia (IIUM) under Research Initiative Grant Scheme (RIGS 15-140-0140).

Once again, we glorify Allah for His endless mercy on us one of which is enabling us to successfully round off the efforts of writing this thesis. Alhamdulillah.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE

INTRODUCTION

1.1 GENERAL

Natural disaster is comprehended as turmoil, mess, or disturbance that is caused by Earth natural activities. It can be described into four classes which are climatological, geophysical, hydrological, and meteorological disasters (Guha-Sapir et al., 2012).

Death from floods had the largest share of natural disaster fatalities in 2013 representing 45.4% of global disaster mortality. In June 2013, 6,054 deaths were reported due to monsoon flood in India (Guha-Sapir et al., 2014). Putting deaths aside, heavy floods also lead to an economic damage in which it could cost up to billions of dollars. These numbers show how the catastrophe will impact a whole nation, due to the severe economic loss.

Most of big cities around the world reside near rivers or floodplain areas. This is because historically, humans are known to settle down near the riverbank areas. The locations are strategic as source of foods and fresh water. Over decades, the growth of economic transactions activities has greatly improved. Urban areas like Kuala Lumpur (Malaysia), New York (US), Incheon (South Korea), Tokyo (Japan), and Dhaka (Bangladesh) are the results from rapid development over riverine areas.

Although flood issues are well informed by the flood prone communities, the level of awareness are still lacking. Rather than moving to other safer locations, people have learnt to cope and to adapt with such situations. According to Adger (2004), a shift in paradigms is observed from a technical oriented flood protection towards flood risk management, and the change in focusing from 'impact-led' approach to 'vulnerabilityled' approach and living with the risk are already recognized. The recent advancement in technologies gives the most impact for the change on that ideology.

Flood study and assessment are very important on areas where risks are significant. Every aspect including the source, causes, mapping, and management have to be analyzed carefully to get accurate results. For example, a study on Ara Damansara River basin, Kuala Lumpur, has been carried out to model flood over urban areas (Alaghmand, 2012). The simulation based flood model uses hydraulic and hydrological datasets and visualize the impact of flood with GIS approach.

Higher quality datasets nowadays ranging from satellite imagery, terrain model, weather forecast, and hydrological data are mostly reachable with ease of access. The availability of advanced software packages is now capable to process the data precisely. These accurate information is crucial for a comprehensive flood risk management (De Bruijn et al., 2015). These resources are manipulated for the betterment in current flood management strategies development.

Initiation to assess the risk of flood are mostly led by the government and carried out by educational institutions and private sectors. Flood studies consisting Geographic Information System (GIS), hydrological, and meteorological datasets were introduced not too long ago to produce flood mapping. Applications of GIS in flood mapping are boundless but the main essential is to minimize the fatalities and economic loss of flood prone areas.

Several types of remote sensing datasets will be utilized within this study. These data were captured via satellites or airborne. Drone images are the latest trend to date that offer high resolution images but with setback in sensors availability. Hence, data usage are limited for original plan view mapping services.

The quality of 3D GIS model map to be produced depends heavily on the resolution of acquired data for an exceptional model visualization. Other spatial information and supporting data on the study area will be used to simulate inundation. Finally, assessments on areas exposed to flood as well as prediction on its pattern are made possible.

1.1.1 Definition of Flood

Flood is generally defined as water which overflows its confined area or water body that spreads to the land area. Definitions also differ among hydrologists, GIS analysts, and other experts. This is affected by their own working environments and fields of expertise which led to their own unique perspectives over this subject.

Table 1.1 Different version of flood definition by researchers

Researcher	Flood Description
Jarvis, 1925	A relatively high flow as measured by either gauge height or discharge rate whenever the stream channel in an average section is overtaxed, causing overflow to the usual channel boundaries, the stream is then said to have flood stage
Linsley, 1949	The result of runoff from rainfall and/or melting snow in quantities too great to be confined in the low water channels of streams
Ward, 1978	Flood is a natural phenomenon and the terminology is explained as a body of water, which rises to overflow land that is not normally submerged
DID, 2003	relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or overland runoff before entering a watercourse and/or coastal inundation resulting from super elevated sea levels and/or waves overtopping coastline defenses
Alias et al., 2016	the geographical characteristics, unplanned urbanization, and the proximity to the South China Sea, leaves East Coast of Peninsular Malaysia vulnerable to monsoon flood

There is a generic consensus on how flood is explained. Researchers agreed that the main reason of flooding is due to river overflow from excess of water causes by rainfall or melted snow (Table 1.1). Criss & Shock (2001) added on the engineering structure as attributes to flood. While in Malaysia, flood is always linked together with monsoon season. On another note, anthropogenic factors also play major role to intensify flood situations (Howe & White, 2010; Arrighi et al. 2018).

1.1.2 Flood in Malaysia

Malaysia generally is enclosed by over 4800 km of coastlines and the weather along these coastlines is influenced by convective rain, while the rainfall distribution is greatly influenced by topography and monsoon winds (Ching et al., 2013). Major flood in the East Coast of Peninsular Malaysia usually comes around November to March. Seasonal changes between continents result to pressure differences which finally form the world wind system. North East monsoon season originated from cold air that moves out from Siberia as North West wind and then changes upon arriving China coast before heading down to Southeast Asia (MMD, 2012).

The most recent flood tragedy occurred in 2014 which struck mostly the East Coast states. A week-long heavy downpour came in November on the coastal stretch with 800mm precipitation. In addition, over 1100mm precipitation recorded in just two weeks in December had worsen the flood situation (Ooi et al., 2017) where extreme rainfall that occurred over inland and mountainous areas contributed to the extensive damages on vulnerable areas, Pekan sub-district and likewise.

The root causes of flood are generally the similar. Board of Engineers Malaysia (BEM) explained several key elements that contribute to flood which are localized rainfall on small areas, tidal backwater effect, siltation and inadequate river capacity, failure of dams and drainage system; and increased runoff from uncontrolled urbanization (Wing, 2004). Regardless, the main cause of flood was extreme rainfall during monsoon season in Malaysia (Colin et al., 2010; Suhaila et al., 2010).

1.2 INTRODUCTION TO THE STUDY

Pekan sub-district (Figure 1.1) has a total area of 182.74km² which is located in Pekan district of Pahang. This region is one of the four East Coast states in Peninsular Malaysia that is susceptible to flood. It covers most part of the Pahang river estuary, the longest river (477.97km) in Peninsular Malaysia, which originates from the Main Range of Titiwangsa.

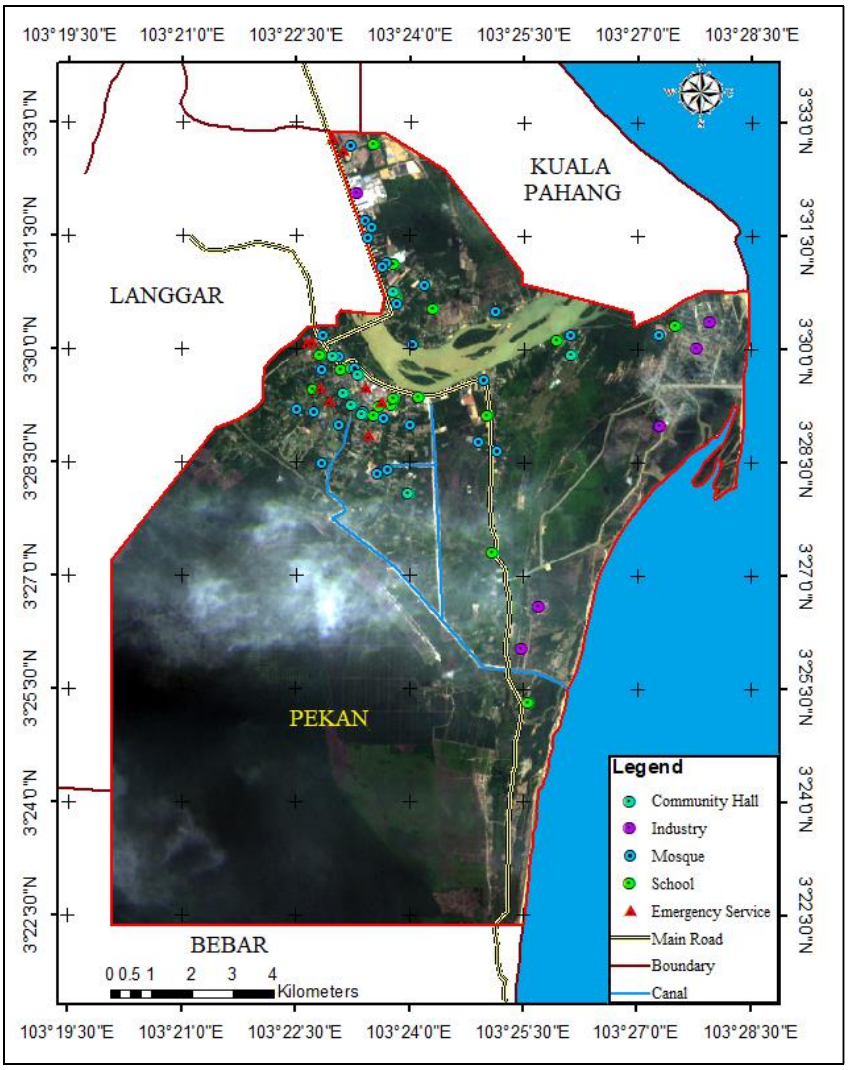

Figure 1.1 Digital map of Pekan sub-district

The climate is equatorial, with uniform air temperature throughout the year, varying from 24ºC to 28ºC with an average relative humidity approximately 80% (MMD, 2016). Almost every year during monsoon season from November to March, this area is exposed to flood, as precipitation quantities for these months are abnormal (Lun et al. 2011; Basri et al. 2016). The flood that is caused by heavy rainfall during this period is termed as monsoon flood.

Pekan sub-district was chosen for this research because it was an area prone to flood considering the location itself at the river basin of Pahang River. Additional conditions include its low topography, monsoon season, river overflow, and tidal behavior which are the natural causes of flood (Mohit & Sellu, 2013). Economical activities and recent developments have also grown rapidly within the area. These assets are increasingly located on land exposed to hazards due to lack available space and rapid development, and thus, potential economic exposure has also increased over time (Gencer, 2013). Flood study was therefore prominent to reduce the scale of economic loss with efficient risk management (Safi et al. 2016).

This study which focused more on GIS approach provided necessary spatial information on areas inundated during flood. The final product from this research was a map model that could be easily comprehended by public users. This information is necessary in mitigating, preparing, recovering, and responding to flood disaster.

1.3 RESEARCH OBJECTIVES

This research was conducted to produce a flood inundation model with public information map or data (unrestricted) focusing on GIS approach. These were the sub-objectives to be fulfilled during the designated research period;

i. To produce a 3-dimensional (3D) map modelling using GIS spatial analyst.
ii. To simulate flooding and determine the inundation pattern of Pekan sub-district based on Pahang River water level.
iii. To identify and locate flood affected zones.

1.4 AIM OF THE STUDY

The aim of this study was to introduce a different approach on flood map which was not only cost effective but also acceptable as legitimate reference model. By fulfilling the stated research objectives, an accurate inundation model was produced from investigating the consistency between 3D flood simulations with actual situation over Pekan sub-district. Hence, 3D inundation map models will become a user entrusted product for flood related situations.

Using readily available resources on most flood prone areas, river hydrology especially from DID (Department of Irrigation and Drainage Malaysia) 'infobanjir' website and decent computing powers, manipulation of these information can actually depicts flood on serious event. 3D modelling will produce a comprehensive model with historical, live or future demonstration of flood affected zones especially on the higher risk areas through simulation. Through simulation, a simply understood digital map will also encourage communities to raise their awareness against flood.

This study also aimed to entail the development in flood risk map modeling as one of the contribution for non-structural approach in Malaysia Flood Management Committee.

1.5 PROBLEM STATEMENT

Heavy precipitation during monsoon season causes river to overflow on the floodplain zones. These places have been the most occupied area filled with developments, housing projects, industrial activities, and center for authorities i.e. Pekan sub-district. There were plenty of studies on Pahang Riverine concerning flooding over its basins. But until recently, massive efforts to mitigate and redirect inevitable floods have resulted in some of the most ambitious engineering efforts ever seen (Zakaria, 2017).

GIS as non-structural approach has been used globally on facing flood issues. Multiple types of data are utilized to investigate, predict, and simulate flood situations depending on field of expertise. Researchers have also agreed that low lying ground areas especially developed areas at river basins are prone to flood. Therefore, terrain modelling should be utilized together with other approaches in flood studies by following this sentiment. Moreover, earth terrestrial data are available from remote sensing technology.

Compared to GIS, structural approach are time consuming, uses a lot of energy, and costs a fortune. More so, problems may not subside due to inappropriate practice on flood assessment. Application of flood modelling techniques with GIS software helps in better visualization for identifying the root cause of flood. GIS flood analysis should be used as justification before shifting into structural approach.