FLOOD MAPPING OF NORTHERN PENINSULAR MALAYSIA USING SAR IMAGES

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Dedication

To my beloved husband and my little ones

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ABSTRACT

Malaysia is one of the evident countries whose recurrence of floods proves that floods are getting worse. The northern peninsular of Malaysia has lost a lot of lives and property worth billions to the series of floods that have been occurring for many years. Many disaster management strategies have been adopted by the Malaysian government in handling these flood disasters but it is still a topic in the annual agenda. This research project aimed at using fusion techniques in mapping the flood extents in the northern peninsular Malaysia in order to contribute to the flood disaster eradication by extracting more and better information through the fusion of RadarSat 1 and TerraSAR-X images. The Principal Component Analysis was also used and compared with the fusion techniques which include the Hue Saturation and Value (HSV), the Brovey Transformation (BT), the Gram Schmidt (GS), and the Principal Component Spectral Sharpening (PCSS). The best principal component of the PCA, that is the PC2 which classified and compared with the classification of the other fusion techniques using Maximum likelihood (ML) and support Vector Machine (SVM). The results indicated BT technique has the highest overall accuracy of 70.9615% and kappa coefficient of 0.3418. This method showed relative improvement on the classification of the flooded and non-flooded area which was used to produce the flood extent Map that was further validated with the DEM data. The final results in this study showed that more information on the areas that are affected by the floods especially the extents, became more exposed after the classification of the fused images.

ABSTRAK

Malaysia merupakan salah satu negara yang mengalami banjir yang semakin teruk. Di kawasan Utara Semenanjung Malaysia telah banyak kehilangan nyawa dan harta benda yang mencecah nilai berbilion-bilion akibat daripada banjir yang telah berlaku selama bertahun-tahun. Banyak strategi pengurusan bencana telah dilaksanakan oleh kerajaan Malaysia dalam menangani bencana banjir ini tetapi ia masih menjadi satu topik dalam agenda tahunan. Kajian ini bertujuan untuk menggunakan teknik "*fusion*" dalam memetakan kadar banjir di Utara Semenanjung Malaysia untuk menyumbang kepada pembasmian bencana banjir dengan mengekstrak maklumat dengan lebih lanjut dan lebih baik melalui gabungan imej Radarsat 1 dan TerraSAR-X. "*Principal Component Analysis*" juga digunakan dan dibandingkan dengan teknik "*fusion*" yang mana merangkumi "*Hue Saturation And Value*" (HSV), "*Brovey Transformation*"(BT), "*Gram Schmidt*" (J), dan "*Principal Component Spectral Sharpening*" (PCSS). Komponen utama terbaik PCA, iaitu PC2 yang diklasifikaikan dan dibandingkan dengan teknik kalsifikasi "*fusion*" yang lain dengan menggunakan "*Maximum likelihood*" (ML) dan "*Support Vector Machine*" (SVM). Keputusan menunjukkan teknik BT mempunyai ketepatan keseluruhan yang tertinggi iaitu 70,9615% dan kappa coefficient dengan nilai 0.3418. Kedah ini menunjukkan peningkatan berbanding klasifikasi kawasan ditenggelami air banjir dan kawasan yang tidak ditenggelami banjir yang telah digunakan untuk menghasilkan peta limpahan banjir yang terus disahkan dengan data DEM. Keputusan akhir dalam kajian ini menunjukkan bahawa maklumat lanjut mengenai kawasan-kawasan yang terjejas oleh banjir terutamanya keluasan lebih dapat dikenal pasti selepas klasifikasi "fused" imej.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF AND ABBREVIATIONS

ALOS	-	Advance Land Observing Satellite
ASTER	-	Advance Spaceborne Thermal Emission and Reflection Radiometer
BT	-	Brovey Transformation
CRISP	-	Center for Research and Industrial Staff Performance
DEM	-	Digital Elevation Model
DID	-	Department of Irrigation and drainage
ENVI	-	Environment for Visualizing Images
FEMA	-	Federal Emergency Management Agency
GCP	-	Ground Control Points
GIS	-	Geographic Information Sciences
GS	-	Gram Schmidt
HSV	-	Hue Saturation Value
MOMS		Modular Optoelectronic Multispectral Scanner
ML	-	Maximum Likelihood
NASA	-	National Aeronautics and Space Administration
NDMRC	-	National Disaster Management and Relief Committee
NE	-	North East
NNW	-	North Northwest
NSC	-	National Security Council
PALSAR	-	Phased Array type L-band Synthetic Aparture Radar
PCA	-	Principal Component Analysis
PC	-	Principal Component
PCSS	-	Principal Component Spectral Sharpening
RADAR	-	Radio Detection and Ranging
RGB	-	Red Green Blue
RM	-	Ringgit Malaysia
RMSE	-	Root Mean Square Error
RSO	-	Rectified Skew Othomorphic

SAR	-	Synthetic Aperture Radar
SD	-	Standard Deviation
S.E	-	South East
S.POT	-	System Pour l'observation de la Terre
SRTM	-	Shuttle Radar Topography Mission
SVM	-	Support Vector Machine
SW	-	South West
USA	-	United State of America
USD	-	U.S Dollars
USGS	-	United State Geological Survey
USM	-	University Sains Malaysia

CHAPTER 1

INTRODUCTION

1.0 Overview

This chapter describes the background of the study by summarizing general studies on floods, and highlighting the problems/ research gaps to be filled. The scope of this research is set to achieve the objectives. Organization of this thesis and the research contributions are stated at the end of this chapter.

1.1 Background of the Study

Floods are among the most destructive natural hazards that affect humans, property and settlements (Khan et al., 2011; Dano Umar et al., 2011, Dano Umar et al., 2013; Ayobami and Rabi'u 2012). Flooding is a devastating natural phenomenon that affects and disrupts the well being of the societies especially poor people who are vulnerable to disaster due to limitation of their resources. Most of the economic losses in most parts of the world are as a result of damages caused by floods. Many countries have experienced loss of lives, injuries and destruction of property which resulted from natural hazards. Floods, earthquakes, volcanic eruptions, tornadoes and landslides persistently caused setbacks in mostly developing and even the developed nations, killing millions of people and destroying high amount of dollars annually (Dano Umar et al., 2013). As the world increases rapidly, so also the frequency, the tendency and magnitude of these natural increase (Dano Umar et al., 2011). According to the Federal Emergency Management Agency (FEMA) of the USA, floods are one of the most typical and prevalent natural disasters, killing an average of over 225 people accompanied by loss of property that worth over USD3.5 billion due to smashing up by severe rainfall along with annual flooding (FEMA, 2014).

In Asia, most of the natural disasters are related to flood and cause maximum damage to life and property in comparison to other disasters (Pradhan, 2010). Although Malaysia located in a geographically and firmly fixed region where it should be natural disasters free, it is yet affected by landslides, floods, haze as well as anthropogenic disasters, exposing life and property to damages every year. Among all the disasters in Malaysia, floods are recently the most frequent as they occur annually and thereby increasingly cause great damages. Therefore floods are regarded as the most severe type of disaster that is encountered in Malaysia (Chan 2012a; Varikoden et al., 2011; Toriman et al. 2009b). The yearly recurrence of floods varies in severity and location but the most susceptible people are lowland residents i.e. near river banks and flood inclined locations especially in Malaysia where flash floods are most common (Toriman et al. 2009c; Dano Umar et al., 2013). These residents are farmers and fishermen who are concerned mainly with the way of their income and are less aware or regardless of the consequences of residing in such low flood prone areas. Malaysia has experienced different climatic and weather events including El Nino 1997 and La Nina in 2011 and 2012, leading to severe droughts and floods respectively. Both cases of flash and monsoonal floods are experienced including other natural disasters such as landslides and haze, causing heavy life and property loss, and the deterioration of the quality of air (Chan, 2012a). The monsoonal floods which occur annually vary in terms of pace, severity and time of occurrences with the 2010 flood of Kedah and Perlis listed among the worst floods that the country has ever encountered (Chan, 2012a). In December 2006, Perlis experienced its most severe floods in 30years covering two third of the state, as a result of a three day nonstop rainfall destroying an estimated 26000ha of paddy fields in Kedah and Perlis, estimating losses of RM81 million. The November 2010, April and September 2011 floods, led to the loss millions of dollar worth property and many injured lives (Chan, 2012a). The October 26 2003 flood affected most of the northwestern peninsular including Penang, Kedah and northern Perak (Ghani et al., 2012).

Ninety percent (90%) of the impacts encountered from natural disasters by the country are as a result of flood , with an annual average of USD100 millions lost, and additional damages done on infrastructures, highways, agricultural areas, residential areas and most importantly livelihood (Pradhan, 2010).

Disaster management in Malaysia is dependent almost completely on government based approaches. The National Security Council (NSC), is under the office of the Prime Minister, and is in charge of controlling policies, and the NDMRC that is the National Disaster Management and Relief Committee is in charge of controlling relief operations in the three phases of the disaster i.e. before, during and after a disaster (Chan, 2012a).

According to the Department of Irrigation and Drainage (DID) Malaysia, around 29000km of the total land area and over 22% of individuals are affected by these floods yearly accompanied by damages accounting for an approximate amount of about RM915 million (Toriman et al., 2009b). Flash floods are typical in Malaysia and a significant number of urban areas encountered this type of floods, which usually occur during the time of monsoon, for example the North-East monsoon from November to march and the and South-West Monsoon from May to September (Toriman et al., 2009b; Lawal et al., 2012).

Remote sensing is recently one of the most important tools available for disaster management professionals, which make planning projects much more possible and more accurate, compared to earlier times. Application of remote sensing and GIS in the mapping of floods will make planning easier and provide more effective non structural means of reducing the destructive effects as well as impacts of flood, as compared to previous models which were validated by the use of ground truth surveys and were not completely reliable (Dano Umar et al., 2011)

Applying remote sensing in natural disaster management is gradually becoming common in creating awareness on environmental issues and providing recent imageries to the public. With the boost in technology, there is rise in expectations for latest monitoring and visual imagery to be provided for emergencies and natural disaster management (Ghani et al., 2012)

Remote sensing data are accurate and suitable for mapping natural hazards such as floods, due to their large area coverage, timely, availability and temporal frequency (Walker et al., 2010). Remote sensing images can be used to map the flood areas and extent provided they are acquired at the time of the occurrence or immediately after the flood. Such timely data acquisition largely depends upon satellites pass and the climatic condition over the flood affected areas. Optical remote sensing is only possible under clear weather conditions, whereas, radar remote sensing data is more advantageous due to its all weather capability. For extraction of useful information and more accurate processing of flood events, different remote sensing data can be used either separately or combined (Huang et al., 2010)

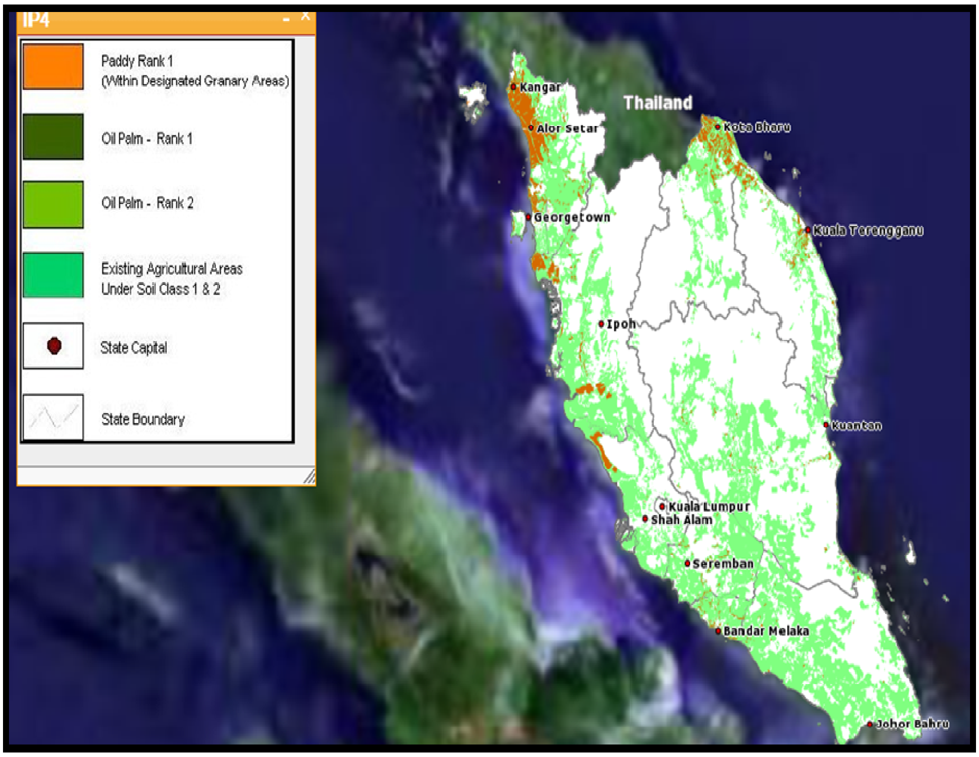
Flood mapping in general is a means of addressing the effects that are presented in hazard and risk maps which serve as one of flood risk management approaches, i.e. prevention of buildup of new risks, reduction of existing risks and adaptation to changes risk factors (Anh, and Nguyen 2009). Flood mapping with radar images is preferred because prolonged rains and cloud cover during flooding makes acquisition of optical images difficult (Anh, and Nguyen 2009). Though radar data can have a reasonable spatial resolution (3-100 meters), land cover identification and extraction is extremely difficult. In radar data, it is difficult to visually differentiate ground features as many of them reflectively appear similar (Dano Umar et al., 2013).

The purpose of this research work is to integrate and evaluate between three different SAR images: RadarSat-1 preflood image, RadarSat-1 post flood image and TerraSAR-X during flood image, in order to produce a composite image for better identification of features, and the goal here is to obtain information of greater quality. This project dedicates to the investigation of the most suitable technique for identification flood occurrences in the study area.

1.2 Problem Statement

For ages, the chain of reactions for flood catastrophe were limited to implementing mechanisms to regulate flooding such as building flood control works, dams, levees, seawalls and delivering disaster relief to flood victims. However these strategies failed to lessen losses caused as a result of flooding, neither did they dissuade the improper developments taking place in flood prone zones. Moreover, in the last few years reactions based mainly on flood were actually adjusted to a more improved methodology which includes mechanisms such as insurance, prediction, forewarning as well as evacuation and land use planning. This strategy is generally designed to lessen the susceptibility of humans to flood in lieu of relying solely on physical confrontation with flood incidents.

More efforts, newer technologies and latest approaches such as the use of satellite imageries should be adopted especially in areas like northern part of peninsular Malaysia where very important and socioeconomic contributing states are situated, such as its major rice producing states(as shown in Figure 1.1), tourist sites and traditionally reserved area. In fact the best possible means of addressing flood in this part of the country should be adopted in order to prevent the disaster that could lead to any possible damage in the study area as it will cause relative damage to the country as a whole. This research integrated three different SAR data for more accurate information in mapping the flooded areas which is an important strategy in flood disaster management.



Source; http://www.townplan.gov.my

Figure 1.1: Major Rice producing areas situated at the northernmost part of the country

1.3 Aim and Objectives of the Study

The aim of this study is to use data fusion techniques of radar data in mapping flooded areas in Northern peninsular Malaysia. The Objectives include the following:

1. To perform fusion of Radarsat 1 and TerraSAR-X band imagery and

determine if it can improve classification result.

2. To investigate the best fusion techniques for flood mapping of the study area.

1.4 Scope and Limitation of Study

This research work focuses on mapping flooded areas in the Northern Peninsular Malaysia using RadarSat-1 and TerraSAR-X images. The study area was extracted from the data combination of Preflood, during flood and post flood images of Northern part of Peninsular Malaysia, using the Envi software. The extracted study area included the two northernmost states of Perlis and Kedah, which were the only states involved in further processing in order to ensure that all techniques used are applied within the range of the intersection of all the three images. The techniques used include the Principal Component Analysis (PCA), Hue Saturation and Value (HSV), Brovey Transformation (BT), Gram Schmidt (GS) and the Principal Component Spectral Sharpening (PCSS). The RadarSat-1 Pre and RadarSat-1 post flood image were used in production of the change detection map, while the TerraSAR-X during flood was used in mapping the flood extent.

The limitation of this research is the difficulty in acquisition of ground truth data from the study area which requires sufficient time, but could not be obtained due to the time limit for the duration of the study. Therefore the land use map provided in chapter 3 was used as a substitute.

1.5 Significance of study

The recurrence of floods requires extensive production of flood maps, but the foundation of an accurate map is dependent on the quality of the satellite images. Growing expectations from the public for better flood management tools, matches the efficiency and effectiveness of remote sensing, where satellite is a solid foundation to mapping flooded areas and also the important role it plays in the four phases of any disaster management cycle, i.e mitigation, preparedness, response and recovery.

Many studies have been done using different bands of SAR for classification purposes but the TerraSAR-X is a newer data recently applied in a few studies compared to other bands with longer wavelengths. Most research has been concentrated on fusion of SAR and optical imageries, but little has been done on fusion of different SAR bands, like the TerraSAR-X with RadarSat-1 especially not in the study area.

However fusion of SAR and Optical data is not reliable because the possibility of having both remote sensing data (SAR and Optical) is difficult in some cases due to its incompatibility with all weather conditions. On the other hand, flood areas and damages can be detected using SAR data due to its all weather performance ability. This makes it worth to compare different types of SAR data in flooded area detection using fusion and classification of images; this is in order to determine whether it is a more appropriate decision to fuse the various bands of SAR data for further flood classification. The goal of this research is to combine three SAR images of different spatial resolution to form a new image that contains more interpretable information and improvement of boundaries. Some recent articles integrated between radar images with multi bands. However, this research project integrates single band SAR images to investigate the efficacy in providing more interpretable information that can aid in addressing the flood disastrous challenges in the study area.

This study will contribute in assisting planners to understand more about the regions that are most prone to flood occurrence, constructors will have more detailed information on where it is best to build and individuals and business owners will have better knowledge and ability to make better financial plans and protection of their property. By achieving this, decision making and relief coordination of flood management in this part of the country will become easier, and more appropriate measures and precautions can be taken. Reducing flood problems in some part of the country is a step in reducing flood problems nationwide.

1.6 Research Questions

1. How serious is flooding Problem in Northern Peninsular Malaysia?
2. Does fusion of data make a significant contribution in flood mapping?
3. How effective is the fusion of images on flood area mapping of the study area?

1.7 Organization of Thesis

The layout of this thesis is presented in the form of five chapters, including this introductory chapter which reviews the background of the research and point out the problems and gaps. It also highlights the objectives and scope of the study, at the end of this chapter contribution of this research work and the thesis layout are presented.

Chapter two covers the review of relevant literature Floods and its impacts in the study area, and the application of remote sensing in dealing with the effects

Chapter three provides extensive methodology used in this research. It describes procedure of all the stages adapted to achieve the above objectives.

Chapter four covers the results and discussions of the finding of this research work, the results in this chapter follow the chronological order of the methodology which is set to answer the objectives.

Chapter five presents the conclusions, which answer all the objectives, recommendation and future work, is also presented in the end of this chapter which is based on the results obtained from this study.

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