EVALUATION OF RIVERBANK EROSION BASED ON MANGROVE BOUNDARY CHANGES IDENTIFICATION USING MULTI-TEMPORAL SATELLITE IMAGERY

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DEDICATION

This thesis is dedicated to my father, who taught me that the best kind of knowledge to have is that which is learned for its own sake. It is also dedicated to my mother, who taught me that even the largest task can be accomplished if it is done one step at a time.

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ABSTRACT

Evaluating riverbank erosion in mangrove forests is dynamic and challenging because of the complex environment that is exposed to tidal and sedimentation factor. Besides, assessing riverbank erosion in this environment requires a technique that reduces dependency on tidal and sedimentation without affecting the quality of the assessment. Hence, this study evaluated riverbank erosion based on mangrove boundary changes using multi-temporal satellite images comprising Quickbird, WorldView-2 and Pleiades-1B. The first objective of this study is to determine mangrove boundary shifting and its long-term impact towards riverbank features followed by validating the mangrove boundary shifting of satellite imagery with field measurement data, which comprise Real Time Kinematic-Global Positioning System (RTK-GPS). Next, the study assessed the rates of changes of the riverbank erosion and accretion and the final objective developing a riverbank erosion prediction model. In this study, a change detection technique was used to identify the mangrove boundary changes of Kilim River at different timelines. The extracted mangrove boundary from satellite images for the years 2005, 2012 and 2017 were used to identify changes in the riverbank features such as line shifting, river width, erosion, and accretion. Subsequently, a vector image overlay was used to determine the mangrove boundary shifting for the corresponding years and evaluate the erosion and accretion rates using symmetrical difference and erase tool in ArcGIS software. Sequentially, Root Mean Square Error (RMSE) analysis validated the accuracy of image geo- referencing process while residual analysis was employed to validate the accuracy between satellite imagery and field measurement data comprising RTK-GPS and erosion pin data. Then, line buffering and kernel density analysis were used to develop a riverbank erosion prediction model based on three parameters, namely distance of erosion, area of erosion and direction of shifted mangrove boundary. The initial findings of this study showed that the mangrove boundary changes shifted backwards in the opposite direction from the river and the range of shifting was different according to the intensity of boat traffic. One of the findings showed that the increasing rates of riverbank erosion ranged from 11302.019 square meters in the first epoch to 15674.721 square meters in the second epoch. Another finding illustrated the riverbank erosion prediction model which displayed several areas such as Sections A, B, I and L which are potentially facing serious riverbank erosion problems in the future in comparison to Sections C, D, E, F, G, H and K. The final finding discussed data validation between Pleiades-1B and GPS-RTK which recorded 0.305 of the r-square value whereas 0.477 was recorded as the r-square value for both Pleiades-1B and the erosion pin. The other validation comprised the second epoch of satellite image (WorldView-2 and Pleiades-1B) and the erosion pin data which revealed the r-square of 0.9347 and showed the strong relationship between both data. As a conclusion, the findings have shown that the evaluation of the riverbank erosion based on mangrove boundary changes using multi-temporal satellite images is capable of assisting stakeholders including the Langkawi Development Authority (LADA), Department of Irrigation and Drainage Malaysia (DID) and Marine Department Malaysia to have in-depth understanding of riverbank erosion issue that would enable them to prepare a mitigation plan in the future.

ABSTRAK

Menilai hakisan tebing sungai dalam kawasan bakau bersifat dinamik dan mencabar disebabkan persekitaran kompleks yang terdedah kepada faktor pasang surut dan pemendapan. Selain itu, menilai hakisan tebing sungai di persekitaran ini memerlukan teknik yang boleh mengurangkan pergantungan pada pasang surut dan pemendapan tanpa menjejaskan kualiti penilaian. Oleh itu, kajian ini menilai hakisan tebing sungai berdasarkan perubahan sempadan bakau menggunakan imej satelit pelbagai tempoh masa yang merangkumi *Quickbird*, *WorldView-2* dan *Pleiades-1B*. Objektif pertama kajian ini adalah untuk mengenal pasti anjakan sempadan bakau dan kesan jangka panjangnya terhadap tebing sungai diikuti dengan pengesahan anjakan sempadan bakau antara imej satelit dengan data ukur lapangan, yang merangkumi Sistem Penentukedudukan Sejagat-Masa Hakiki Kinematik (RTK-GPS). Seterusnya, kajian ini menilai kadar perubahan hakisan dan tokokan tebing sungai dan objektif terakhir membangunkan model ramalan hakisan sungai. Dalam kajian ini, teknik pengesanan perubahan digunakan untuk mengenal pasti perubahan sempadan bakau yang berlainan garis masa. Sempadan bakau yang diekstrak daripada imej satelit pada tahun 2005, 2012 dan 2017 digunakan untuk mengenal pasti perubahan tebing sungai seperti anjakan sempadan, lebar sungai, hakisan dan tokokan. Kemudiannya, penindanan imej vektor digunakan untuk menentukan anjakan sempadan bakau yang berlaku tahun tersebut dan menilai nilai hakisan dan tokokan menggunakan fungsi perbezaan simetri dan padam dalam perisian *ArcGIS*. Seterusnya, Analisis Min Selisih Punca Kuasa Dua (RMSE) mengesahkan ketepatan imej geo-rujukan manakala analisis sisa digunakan untuk mengesahkan ketepatan antara imej satelit dengan data ukur lapangan merangkumi data RTK-GPS dan data pin hakisan. Berikutnya, garisan penampan dan ketumpatan kernel digunakan untuk membangunkan satu model ramalan hakisan berdasarkan tiga parameter, iaitu jarak dan luas hakisan serta arah anjakan sempadan bakau. Penemuan awal kajian ini menunjukkan perubahan sempadan bakau yang menganjak kebelakang secara bertentangan daripada sungai dan kadar anjakan berbeza berdasarkan kesibukan lalulintas bot. Salah satu penemuan menunjukkan kadar hakisan pada epok pertama ialah sebanyak 11302.019 meter persegi manakala epok kedua menunjukkan pertambahan sehingga 15674.721 meter persegi. Satu lagi penemuan mempamerkan model ramalan hakisan tebing sungai yang menyaksikan sesetengah kawasan seperti Seksyen A, B, I dan L berpotensi mengalami masalah hakisan tebing sungai yang serius pada masa hadapan jika dibandingkan dengan Seksyen C, D, E, F, G, H dan K. Penemuan terakhir membincangkan pengesahan data antara *Pleiades-1B* dan GPS-RTK yang merekodkan nilai kuasa dua r sebanyak 0.305, sementara nilai kuasa dua r untuk *Pleiades-1B* dan pin hakisan ialah sebanyak 0.477. Data pengesahan yang lain melibatkan epok kedua imej satelit (*WorldView-2* dan *Pleiades-1B*) dan data pin hakisan yang merekodkan nilai kuasa dua r sebanyak 0.9347 serta menunjukkan hubungan yang kuat antara kedua-dua jenis data. Kesimpulannya, penemuan kajian menunjukkan bahawa penilaian hakisan tebing sungai berdasarkan perubahan sempadan bakau menggunakan imej satelit pelbagai tempoh masa berkemampuan untuk membantu pihak seperti Lembaga Pembangunan Langkawi (LADA), Jabatan Pengairan dan Saliran (JPS) serta Jabatan Laut Malaysia (JLM) bagi mendapatkan pemahaman mendalam tentang isu hakisan tebing sungai yang memudahkan mereka merancang satu pelan mitigasi pada masa hadapan.

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LIST OF ABBREVIATIONS

ANN	-	Artificial Neural Network
DBMGP	-	Dayang Bunting Marble Geoforest Park
DEM	-	Digital Elevation Model
DID	-	Department of Irrigation and Drainage
DTM	-	Digital Terrain Model
DIP	-	Digital Image Processing
EDM	-	Electronic Distance Measurement
ESRI	-	Environmental System Research Institute
EU	-	European Union
GCP	-	Ground Control Point
GGN	-	Global Geopark Network
GIS	-	Geographical Information System
GNSS	-	Global Navigation Satellite System
GPS	-	Global Positioning System
GS	-	Gram-Schmidt
GSD	-	Ground Sampling Distance
HSC	-	High Speed Crafts
IGD	-	Integrated GIS Database
ISMP	-	Integrated Shoreline Management Plans
KKGP	-	Kilim Karst Geoforest Park
LADA	-	Langkawi Development Authority
LULC	-	Land Use and Land Cover
MCGP	-	Machincang Cambrian Geoforest Park
MDM	-	Marine Department Malaysia
MIHS	-	Modified Intensity- Hue-Saturation
MLC	-	Maximum Likelihood Classification
MOTAC	-	Ministry of Tourism and Culture
NAHRIM	-	National Hydraulic Research Institute Malaysia
NOAA	-	National Oceanic and Atmospheric Administration

NIR	-	Near Infra-Red
OBIA	-	Object-Based Image Analysis
QGIS	-	Quantum GIS
RGB	-	Red Green Blue
RMSE	-	Root Mean Square Error
RSO	-	Rectified Skewed Orthomorphic
RTK	-	Real-Time Kinematic
SGW	-	Ship Generated Wave
SLR	-	Sea Level Rise
SQL	-	Structured Query Language
TLS	-	Terrestrial Laser Scanner
UAV	-	Unmanned Aerial Vehicle
USGS	-	United States Geological Survey
USLE	-	Universal Soil Loss Estimation
UNESCO	-	United Nations of Education, Scientific and Cultural Organization
UTM	-	Universal Transverse Mercator
VHR	-	Very High Resolution
WGS	-	World Geodetic System
WLNR	-	Water, Land and Natural Resources
WPCA	-	Wavelet Principal Component Analysis
WRI	-	World Resources Institute

LIST OF SYMBOLS

C_1	-	Classes can be represented in Baye's classification
N	-	The number of classes for determining the class of a particular pixel with measurement vector
V	-	Member of the class
P(v|Ci)	-	The set of class conditional probability
$P(C_i)$	-	The probability that pixel from class C_i appears anywhere in the map
P (v)	-	The probability of finding a pixel with measurement vector
P (Cj)	-	The conditional probability function is estimated from labeled training data for each class
Zi	-	The mean vector of the data
Yi	-	Covariance matrix of the data

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Malaysia has 641,446 hectares of mangrove forest, with Peninsular Malaysia having 104,200 hectares of mangrove forest from this total area (Abd. Shukor et al., 2004). Although mangrove forest is globally decreasing, Malaysia's mangrove forest is still intact under a mangrove management system such as mangrove forest reserve and the establishment of Ramsar sites (Jusoff, 2013). However, a study from the World Resources Institute (WRI) revealed that Malaysia lost 4.6% of its mangrove forests from the year 2001 to 2012, about the size of the whole Federal Territory of Kuala Lumpur (Lee, 2015). The same study also stated that least 1000 hectares of mangrove forest in Malaysia is vanishes every year, especially in the year 2009 which recorded a loss of 4052 hectares (Lee, 2015). Lee (2015) stated that several issues such as fish farming, urbanisation, agriculture, sea level rise, boat wake effects, and deforestation are factors that decrease mangrove forest area in Malaysia.

Mangrove forests are vital sources to the economy of Malaysia, especially in fishery, timber, and tourism sectors. Within the fishery sector, mangrove forest is considered as the breeding nurseries for several marine species such as barramundi and banana prawn (Jusoff, 2013). Mangrove forests provides an ideal habitat for fish, crab, and prawn to grown up well. Mangrove forests is harvested for its high calorific value and good quality of wood for the combustion process compared to other woods. In the aspect of tourism, mangrove forest is capable to attract tourist due to its uniqueness and the beauty of its ecosystem. Tourist surging is not only increase the reputation of mangrove forest eco-tourism but also generate several incomes including boat tour activities, restaurant, and souvenir shop.

Mangrove forests play an important role in maintaining the sustainability of ecology, biodiversity, and environmental values. Mangrove forests is considered as the natural protector from riverbank erosion by reducing the silt accumulation in the marine habitat. It also could stop sediment movement by trapping it at the root of the mangrove tree. Mangrove forests protect the coastal area from the storm surge and tsunamis by reduce the impact of the huge wave to the half or three-quarter from actual strength (Onrizal et al., 2017). The previous study in Vietnam showed the reduction of the wave increased with the height of water (Bao, 2011). Another study discovered the capability of mangrove forests in created the "live sea-walls" which is cost effective compared to concrete sea-wall and other man-made structure in protecting the coast (Ca and Xuyen, 2008). In aspect of sea level rise, mangrove forests has the capability to adapt with sea level dwelling and interact well with tidal changes. This is because of natural characteristic of mangrove forests which is dynamically subjects to the periodic fluctuation in climate and its response to the changes of sea level.

Mangrove degradation in Malaysia was serious and worrisome since the year 1980s (Rahman and Asmawi, 2016). According to Table 1.1, it rated mangrove forest in Peninsular Malaysia as critically degraded while mangrove forest in Sabah and Sarawak as degraded (Dasgupta et al., 2013). The situation showed that Peninsular Malaysia faced a critical mangrove forest degradation compares to Sabah and Sarawak.

Table 1.1 Environmental and ecological setting of Indo-Malayan mangroves (Revised from Dasgupta et.al, 2012)

Category	**Indus River Delta**	**Godvari-Krishna mangrove**	**Suburban mangrove**	**Burmese Coast mangrove**	**Indochina mangrove**	**Sunda shelf mangrove**
Type	Backwater estuarine	Deltaic/estuarine	Deltaic	Deltaic and coastal	Coastal	Coastal
Dominance	Transboundary	Domestic	Transboundary	Transboundary	Transboundary	Transboundary
Major rivers	Indus	(i) Mahanadi	(i) Ganges	Ayeyarwady	(i) Mekong	Mahakam River
		(ii) Godavari	(ii) Brahmaputra		(ii) Red River	
		(iii) Krishna	(iii) Meghna			
Species richness	4	34	36	41	40	43
Total forest area (sq - km)	6000 (approx.)	7000 (approx.)	25000 (approx.)	3822 (approx.)	26936 (approx.)	40000 (approx.)
Mangrove under protected area (sq -km)	823	920	2700	125	820	6530
					(i) Thailand (east coast)	(i) Sabah and Sarawak
	Western of India and eastern	Eastern coast of India	(i) Bangladesh	(i) Myanmar	(ii) Cambodia	(ii) Indonesia
	Coast of Pakistan	(Orissa to Tamil Nadu)	(ii) India	(ii) Thailand (West coast)	(iii) Vietnam	(iii) Brunei
					(iv) Peninsular Malaysia	
Occurrence					(v) Philippine	
	Critically degraded and	Degraded			Critically degraded	Degraded
Status	fragmented					

Based on Table 1.2, Malaysia lost 110 000 hectares of its mangrove forests from the year 1980 to 2005. The annual change between the year 1980 until 1990 is -0.5% while the annual change for the year 1990 until 2000 is -0.8% and the annual change for the year 2000 until 2005 is -8.0% (FAO, 2007). During first decade (1980–1990), mangrove forest was degraded because of land conversion for agriculture, shrimp ponds or urban development purposes. Shrimp farming spread rapidly in the countryside, especially in peninsular Malaysia, which led to the clearing of large areas of mangrove forest.

Table 1.2 Status and trends in mangrove area at Malaysia from 1980 until 2005 (FAO, 2007)

Country / Area	Most recent reliable estimate		1980	1990	Annual change 1980-1990		2000	Annual change 1990-2000		2005	Annual change 2000-2005	
	ha	Ref. year	ha	ha	ha	%	ha	ha	%	ha	ha	%
Malaysia	564971	2005	6740000	642000	-3200	-0.5	589500	-5250	-0.8	565000	-4900	-0.8

This issue is a global concern since Asia continent is the major contributors to the mangrove population in the world. As illustrates in Figure 1.1, mangrove forest degradation is caused by few factors including mangrove clearing, residential purpose, commercial area, agriculture, aquaculture and others factor (Shahbudin and Kamaruzzaman, 2011). However, mangrove clearing dominating the percentages of mangrove degradation caused in Figure 1.1.

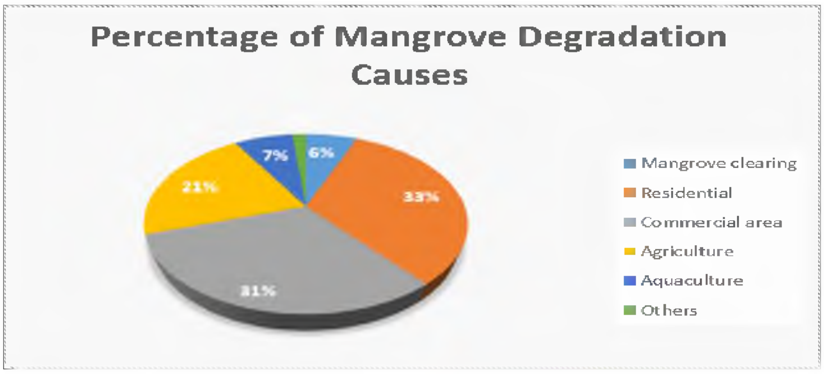

Figure 1.1: Percentage of mangrove degradation caused by coastal development (Shahbudin and Kamaruzzaman, 2011)

Mangrove forests clearing is frequently happened within the area which lacks monitoring and less protection by local authority. Even the area is well-protected, mangrove degradation is still happened when another factor prevails. Boat wakes is a factor which indirectly caused the riverbank erosion since the impact is a long-term and not instantaneous (McConchie et al., 2003). Boat wakes has potential to causes a mangrove degradation if the waves hold enough energy to erode the riverbank and if it frequently happened (Suprayogi et al., 2013). Boat wakes regularly existed within the busy waterways and contain enough energy to reach the riverbank (Gourlay, 2011). Less people aware of this situation since the impact of boat wakes taking a long time to be notice unless the effect is too severe and mangrove population drastically decreased.

This study assesses the impact of riverbank erosion based on mangrove boundary changes identification. For this assessment, Geographical Information System (GIS) and digital image processing are utilised to evaluate the mangrove boundary changes. Very High Resolution (VHR) satellite image is used as the sources of data to represent the earth surface in the years of 2005, 2012 and 2017. Integration of GIS and digital image processing techniques are capable to identify the changes of river morphology and could achieve the purpose of this study. The output enables the beneficiary to have a deep understanding on this issue and might assist for mitigation plan.

1.2 Problem Statement

Riverbank erosion is the major threat to mangrove forest. It is a process of soil loss at the cliff or riverbank because of soil run-off (Amsalu et al., 2014). The biophysical environment which comprising soil, climate, terrain and ground cover could generate the riverbank erosion. Riverbank erosion is causes by natural and anthropological factor. Riverbank erosion causes the changes of river morphology which is contributes to land degradation. Critical erosion would affect the riverbank structure and causes degradation of mangrove forest if it consistently happen. The collapsed riverbank would alter mangrove boundary location by shifting it from the original position.

Accreditation of Geopark status starting from 2007 until now, make it more popular and show the rising number of incoming tourist (Kamaruddin, 2014). As the popular place with mangrove forest and natural habitat of flora and fauna, requirement for boat operating service taking tour across mangrove forest in Kilim Geoforest Park is rising every year (Mohamad et al., 2018). The growing number of tourist visiting Kilim River and the increasing usage of boat tour service indirectly caused riverbank erosion. The boat-generated wave slowly erodes the riverbank and as the result, the mangrove area is slowly decreasing and it harming flora and fauna in the ecosystem (Tyler, 2014).

Riverbank erosion at Kilim River has become LADA's main issue since the area is the centre of KKGP (NAHRIM and NRE, 2015). The critical riverbank erosion might jeopardise the geo-heritage value of KKGP and threatens the incoming Geopark's accreditation. Geopark retraction would affect the entire concept of Geopark development including heritage conservation, economy and community development at Langkawi (Tyler, 2014). Identification of mangrove boundary shifting enables the beneficiaries such as Langkawi Development Authority (LADA) and Department of Irrigation and Drainage (DID) to collect useful information about the current condition of Kilim River. Despite of mangrove boundary shifting, the beneficiaries also could get the rate of riverbank erosion and riverbank erosion prediction model of Kilim River in the future.

Mangrove boundary is the important element in this study since it becomes the indicator for river morphological changes. Mangrove boundary shifting required multiple data to generate mangrove boundary for comparison (Adarsa et al., 2012). However, mangrove boundary is difficult to be identify since the extreme conditions of mangrove forest which is not suitable for the field measurement process (Hogarth, 2001). The condition of mangrove forests which is muddy, sandy and full of roots would complicates the data collection process. The measuring equipment such as a total station, Terrestrial Laser Scanner (TLS), Electronic Distance Measurement

(EDM) and other survey equipment which require tripod are difficult to be set up at this area.

Data of mangrove forests and river should cover the entire study area. Using survey equipment such as a total station, TLS and EDM would only collect the certain parts of study area. Although this kind of measurement techniques are very accurate, it will be a waste if it overlooks the important part of study area. The data redundancy is crucial when involved the large scale of study area. The coverage of whole study area is important and should be measured entirely.

The identification of mangrove boundary shifting requires multiple sets of geospatial data. Single geospatial data could not displays the long-term impacts of riverbank erosion towards river morphology. The relationship of past, intermediate and present data are crucial to illustrates the trend of mangrove boundary shifting and the morphological issue of Kilim River. However, collecting multiple datasets especially the past data is difficult to do. The images are usually expensive and restricted which urge the researcher to spend some money. VHR satellite images are not a downloadable item because it contains high resolution pixel of earth surface compared to a free image like Landsat, Sentinel or National Oceanic and Atmospheric (NOAA).

Evaluating the impact of riverbank erosion based on mangrove boundary changes identification needs an efficient technique of image processing. The problem would arise if the technique is not compatible with the images in the term of accuracy, error and the quality of output. Selection of suitable technique for classifying and extracting river feature would decide the output quality, accuracy and error. The problem get worse if the technique is only available in expensive and premium software. This situation would complicate the data processing unless the technique is available in open source or free software.

1.3 Aim and Objectives of Study

The aim of study is to evaluate changes of mangrove boundary due to riverbank erosion. This study support by four main objectives:

i. To determine mangrove boundary shifting and its impact towards riverbank features;

ii. To validate mangrove boundary shifting of satellite imagery and field measurement data;

iii. To assess the changes rates of riverbank erosion and accretion;

iv. To develop riverbank erosion prediction model of Kilim River

1.4 Research Question

The first objective is to determine mangrove boundary shifting and its impact towards riverbank features. It is supported by the following research question:

i. How the riverbank erosion does affects mangrove boundary shifting?
ii. What is the implications of mangrove boundary shifting towards river morphology?

The second objective is to validate mangrove boundary shifting of satellite imagery and field measurement data. Implementation of the second objective is supported by the following research question:

i. What is the technique to validate the accuracy of satellite imagery and field measurement data?
ii. What is the accuracy of satellite imagery and field measurement data?

The third objective is to assess the changes rates of riverbank erosion and accretion. The research questions for supporting this objective are:

i. What kind of technique is used to evaluate riverbank erosion and accretion rates?
ii. Where is the specific location of critical riverbank erosion at Kilim River?

The fourth objective is to develop riverbank erosion prediction model of Kilim River. Implementation of the fourth objective is supported by the following research questions:

i. What is the purpose of developing erosion prediction model at Kilim River?
ii. What would happens to Kilim River if riverbank erosion is consistently exist in the future?

1.5 Significance of Study

Riverbank erosion at Kilim River is concerned by several agencies. This is because Kilim River located within Kilim Karst Geoforest Park (KKGP). KKGP holds the title of Geopark which is granted by the United Nations Educational, Scientific and Cultural (UNESCO) started at 1 June 2007 (LADA, 2014). This study might captivates several beneficiaries such as LADA, DID, the Ministry of Tourism and Culture (MOTAC), National Hydraulic Research Institute Malaysia (NAHRIM), Department of Forestry Malaysia (DFM), and Marine Department Malaysia (MDM) for sharing the useful information in maintaining the status of Geopark at KKGP.

The main beneficiary of this study is LADA. LADA is responsible to managed Langkawi based on four functions comprise tourism, duty-free zones, investment and socio-economic (LADA, 2018). LADA's mission is to lead the tourism development that could benefit the locals, industry and tourist through strategic governance. As an island which is depending on tourism as the major attraction and the sources of an economy, Langkawi is really concerned about the tourist needs. Hence, LADA always put a priority on tourist satisfaction especially for all Geoparks namely Machincang Cambrian Geoforest Park (MCGP), Dayang Bunting Marble Geoforest Park (DBMGP) and Kilim Karst Geoforest Park (KKGP) (Fauzi et al., 2017). The entire Geoparks are the major contributors to Langkawi's economy and as an authority, LADA is responsible to maintain and improves the number of tourists for the upcoming years.

The second beneficiary is DID. DID is a government body which responsible to build, operates and maintains the facilities of irrigation, drainage and prepare the flood mitigation plan (JPS, 2018). DID is also responsible in supporting the management of water resources, flood, river basin and coastal zones by developing an Integrated GIS Database (IGD). IGD comprises the Integrated Shoreline Management Plans (ISMP), River Basin Information System (RBIS) and Flood Mapping. Most of the data in this database comprise of field measurement and geospatial data. However, some extracted mangrove boundary from DID database is not parallel with the actual mangrove boundary on the ground. This might happen because of poor sources of geospatial data and the improper method of DIP, particularly the image classification or feature extraction process. This study could provide the method to determine mangrove boundary using VHR image and using DIP technique to generate mangrove boundary.

This study of evaluating riverbank erosion based on mangrove boundary changes identification is crucial for the development of knowledge in environmental and coastal field. Integrating GIS and DIP technique could expand the knowledge about riverbank erosion and river morphology. Different data and techniques are capable to construct a new approach for environmental and coastal studies. This study could inspire many researchers to explore various method to evaluate the riverbank erosion impact towards river morphology.

1.6 Scope and Limitation of Study

The scope of study discusses few question marks which is comprise 'what', 'where', 'when' and 'how' the study is conducted. 'What' means the data used as the input of this study. 'Where' means the location of case study area selected based on few criteria. 'When' is defined as the time of study period and is depend on the time when the data collection take place. 'How' means the process and method to generate output and to prove if the objectives are achievable or not.

Several limitations exist in this study and would discuss in this section. Limitations of this study comprise the selection of geospatial dataset, the insufficiency quantity of erosion pin location, the harsh ground conditions of study area and the sudden changes of image classification techniques of this study.

1.6.1 Scope of Study

The data in this study comprise geospatial and field measurement data. For geospatial data, this study required VHR image as time-series data. This is because of quality from VHR image that reached below one meter of spatial resolution. The other reason of using VHR images as main data is because the availability of the historical data. VHR image usually stored their past data in the archive and might be useful for any study related to change detection. The comparison of the earth surface at past, intermediate and present are useful to distinguish any changes on the earth surface and are considered as the long-term evaluation of erosion impact. For field measurement data, this study needs GPS observation and erosion pin data to assess the rate of riverbank erosion for the short-term period.

The case study area is at Kilim River, Langkawi Island, Kedah, Malaysia. Kilim River is the strategic location at the centre of Kilim Karst Geoforest Park (KKGP), which is one of the famous Geoparks at Langkawi Island. The mangrove forests condition at this river is critical because of riverbank erosion is sourced by eco-tourism activities at KKGP. The condition of Kilim River become main concern since the accreditation of Geopark status is includes this area. The critical riverbank erosion that happens within this area might affect the next accreditation by the United Nations Educational, Scientific and Cultural Organization (UNESCO) in the future.

The time of this study decided in the year of 2005, 2012 and 2017, approximately 12 years apart. This period is depends on the date of VHR image from the year 2005 until 2017. The requirements of this study prefer the VHR image from the year 2000 until 2017. The reason is to provide the image of Kilim River before Geopark and after the accreditation by UNESCO. 12 years gapd are enough to monitor the changes of the earth surface due to riverbank erosion impact and to evaluate its impact towards river morphology.

The reason why mangrove canopy or mangrove crown is considered as the indicator of riverbank erosion is because of mangrove boundary delineation from satellite imagery only detects the mangrove canopy spread from aerial view. Here, any natural phenomenon such as sedimentation and tidal inundation that happen underneath the mangrove canopy would remain hidden from aerial view. Since mangrove boundary changes is used as the indicator of riverbank erosion, hence this study only highlights the mangrove tree spread above tree-land boundary. Subsequently, the effect of sedimentology and tidal inundation will be exclude from this study.

The process of generating an output is by integrate GIS and DIP techniques. It comprises GIS techniques such as erase, symmetrical difference and intercept tools while DIP comprise image enhancement, image classification, and feature extraction. The combination of GIS and DIP techniques would produce the output such as mangrove boundary shifting, erosion, and accretion map as well as erosion prediction model. Beside the map or model, the output of this study is also includes the value of mangrove boundary shifting and riverbank erosion rates in the term of area and distance.

1.6.2 Limitation of Study

Satellite imagery is consist of Quickbird, Worldview-2, and Pleiades-1B images. This study used different VHR image because of unavailability of images such as Quickbird, WorldView-2, and Pleiades-1B. Different VHR images would resulted in the different sensor, different spatial resolution, different bands and different swath width. The same VHR images generate the better output and less error. However, this problem is inevitable since the Quickbird image is only available until 27 January 2015. Thus, the suitable VHR image for the year of 2012 is from WorldView-2 satellite and for the year of 2017, the suitable VHR image is from the Pleiades-1B satellite images.

The second limitation is the insufficient quantity of erosion pin location for data validation. Less erosion pin would affects the residual analysis and provides fewer points for data validation. In this study, only 5 points of erosion pin location are available for data validation. To generate the better result of data validation, it needs more points of erosion pin. This limitation occurs because of the difficulty to get data at site. Erosion pin data is crucial in this study to validate the result from satellite imagery.

The third limitation of this study is the harsh ground conditions of study area. The conditions of study area which is surrounded by mangrove forest especially at the riverbanks has complicates the process of field measurement including RTK GPS and erosion pin technique. The abundant data from field measurement technique is better for comparison of satellite imagery and field measurement data. Kilim riverbank conditions is full of mangrove forests and muddy soil which are caused the field measurement technique of tripod-based equipment is hard to be set up. Tripod-based equipment need a firm and solid ground conditions to maintain its stability and to avoid the equipment from falling into the ground.

The last limitation of this study is the sudden changes of image classification techniques. The propose technique of image classification is supposed to be an Object-Based Image Analysis (OBIA). This technique is better for the classification of earth feature such as water, forest and hill in the term of quality of output and better accuracy. OBIA technique is widely used by researchers in delineating riverbank feature from the river and to notify the changes that occur at the river. However in this study, OBIA technique is facing an error at the middle of data processing and took a long time to process a single image. Since this study has limited duration of data processing, so OBIA technique was replaced by supervised classification technique and supervised classification work well according to the plan.

1.7 Thesis Outlines

This thesis comprises five chapters. Chapter 1 introduces this study by explaining the background of the study, problem statement, aims and objectives, the research question, the significance of the study, scope and limitation as well as thesis outlines. The content of this chapter introduces and describes the preliminary stage of the study.

Chapter 2 debriefs the literature review of this study, which comprises the definition of riverbank erosion, the factor of riverbank erosion, the impact of riverbank erosion towards river morphology, riverbank erosion issue at Kilim River, evaluation of riverbank erosion impact towards river morphology and the issue and research gap of the study. The content of this chapter describes the previous study of riverbank erosion impact towards river morphology using geospatial data.

Chapters 3 describes the methodology of this study. It outlines the methodology, scope of the study, data collection and data analysis. It also explains the case study area, pre-processing, data processing, data analysis and output. The content of this chapter describes the methodological process of generating output using the method described in general methodology.

Chapter 4 discusses the result of the study. It starts with the determination of mangrove boundary shifting and its impact towards riverbank features. Then, the assessment of riverbank erosion and accretion rates accomplished in the second objective. Later, the validation of satellite imagery and field measurement accuracy discussed as the third objective. The last analysis is the riverbank erosion prediction model discussed as the last objectives.

Chapter 5 describes if the study fulfils its objectives. Chapter 5 also discusses recommendations to improve future studies. The last section explains the conclusion of the whole thesis.

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