INTEGRATION OF GEOSPATIAL TECHNOLOGY FOR ASSESSMENT OF MANGROVE HABITAT AND RIVERBANK EROSION

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DEDICATION

This thesis is dedicated to me for not giving up

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ABSTRACT

Kilim River, Langkawi has been declared as Kilim Karst Geoforest Park by the United Nations Educational, Scientific and Cultural Organization (UNESCO) in the year 2006. This has increased the number of tourists to Kilim River. However, the growing number of tourist and tourist boats activity has caused riverbank erosion and threaten the mangrove forest habitat. Therefore, the aim of this study is mainly to assess mangrove habitat and riverbank erosion using integrated geospatial technology. This study assessed the Kilim River physical properties which include salinity, pH, soil properties and mangrove species distribution along the river. Additionally, this study also estimates and projects the effect of Sea Level Rise (SLR). The data were analysed to identify relative dominance, density and frequency of mangrove species using ArcGIS. Rate of riverbank erosion were analysed using ArcMap extension Digital Shoreline Analysis System (DSAS) within three different timeline of year 2005, 2012 and 2017. Five different Very High Resolution (VHR) satellite imagery were used which is QuickBird, Worldview-II, Pleaides, Spot 7 and Sentinel. The salinity distribution along Kilim River during high water show a stratified increment from Bat Cave (upstream) towards the river mouth but there are no significant changes of salinity in depth. While on low water the salinity is lower compared to high water. Percentage of clay particle in soil at upper stream shows higher percentage of 21% compared to middle and lower stream. The dominant mangrove species at Kilim River are *Rhizophora apiculata* and *Rhizophora mucronata* with bigger size of mangrove based on diameter at breast height (DBH) at downstream area while smaller DBH at the upstream area. Riverbank erosions are highest at the middle stream which cover the jetty area, however significant accretion shown at upstream which means mangrove start to migrate into the river. Significance rate of erosion is found at the jetty area and active navigation route of tourist boats especially at narrow width of river. The SLR projection in year 2030, 2050 and 2100 are 0.11 m, 0.22 m and 0.68 m, respectively. Results from the inundation map shows no significant inundation in year 2030 and 2050. However, for the year 2100, the area that will be inundated is about 9518 m^2. In conclusion, this study has shown the result of physical properties for mangrove habitat, riverbank erosion and impact of SLR at Kilim River. Precaution measures should be planned by the local authority hence the status of popular tourism area and Kilim Karst Geoforest Park can be maintained.

ABSTRAK

Sungai Kilim, Langkawi telah diisytiharkan sebagai Kilim Karst Geoforest Park oleh Pertubuhan Pendidikan, Sains dan Kebudayaan Pertubuhan Bangsa-Bangsa Bersatu (UNESCO) pada tahun 2006. Ini telah meningkatkan bilangan pelancong ke Sungai Kilim. Walau bagaimanapun, pertambahan pelancong dan aktiviti bot pelancong telah menyebabkan hakisan tebing sungai dan mengancam habitat hutan bakau. Oleh itu, tujuan utama kajian ini adalah untuk menilai habitat pokok bakau dan hakisan tebing sungai dengan menggunakan teknologi geospatial. Kajian ini menilai sifat fizikal Sungai Kilim yang merangkumi kemasinan, pH, jenis tanah dan taburan spesies bakau di sepanjang sungai. Selain itu, kajian ini juga menganggarkan dan meramal kesan kenaikan paras laut (SLR). Data dianalisis untuk mengenal pasti dominasi relatif, kepadatan dan frekuensi spesies bakau menggunakan ArcGIS. Kadar hakisan tebing sungai dianalisis menggunakan ArcMap sambungan sistem digital analisis garispantai (DSAS) dalam tiga garis masa berbeza tahun 2005, 2012 dan 2017. Lima imej satelit Resolusi Sangat Tinggi (VHR) yang berbeza digunakan iaitu QuickBird, Worlview-II, Pleaides, Spot 7, dan Sentinel. Taburan saliniti di sepanjang Sungai Kilim semasa paras air tinggi menunjukkan kenaikan berstrata dari Gua Kelawar ke muara sungai tetapi tidak ada perubahan saliniti yang ketara dari segi kedalaman. Semasa paras air rendah, kadar saliniti rendah. Peratusan partikel tanah liat di hulu sungai adalah lebih tinggi 21% berbanding di kawasan tengah dan hilir sungai. Spesies bakau yang dominan di Sungai Kilim adalah Bakau Minyak *Rhizophora Apiculata* dan Bakau Kurap *Rhizophora Mucronata* dengan ukuran bakau yang lebih besar berdasarkan diameter pada ketinggian dada (DBH) di kawasan hilir sementara DBH lebih kecil di kawasan hulu. Kadar hakisan paling tinggi di kawasan tengah sungai yang meliputi kawasan jeti, namun pertambahan ketara ditunjukkan di hulu sungai yang menunjukkan bakau telah tumbuh ke dalam kawasan sungai. Kadar hakisan yang ketara dapat dilihat di kawasan jeti dan kawasan aktif laluan bot pelancong terutamanya di laluan sungai yang sempit. Unjuran SLR pada tahun 2030, 2050, dan 2100 adalah masing-masing 0.11 m, 0.22 m, dan 0.68 m. Hasil daripada peta limpahan air laut menunjukkan tiada perubahan ketara untuk tahun 2030 dan 2050. Namun, pada tahun 2100, kawasan yang mengalami limpahan paras air laut adalah seluas 9518 m^2. Kesimpulannya, kajian ini telah menunjukkan hasil dapatan berkaitan ciri-ciri fizikal habitat pokok bakau, hakisan sungai, dan kesan SLR terhadap Sungai Kilim. Langkah-langkah pencegahan perlu dirancang oleh pihak berkuasa tempatan bagi mengekalkan status kawasan tumpuan pelancong dan status Kilim Karst Geoforest Park.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AOGCM	-	Atmosphere – Ocean Global Climate Model
AR4	-	The Fourth Assessment Report
AR5	-	The Fifth Assessment Report
ARSM	-	*Agensi Remote Sensing Malaysia*
CVI	-	Coastal Vulnerability Index
DBH	-	Diameter at Breast Height
DEM	-	Digital Elevation Model
DID	-	Department of Irrigation and Drainage
DSAS	-	Digital Shoreline Assessment System
DSMM	-	Department of Surveying and Mapping Malaysia
DSMS	-	Digital Shoreline Management System
DTM	-	Digital Terrain Model
GCP	-	Ground Control Point
GCS	-	Geodetic Coordinate System
GIS	-	Geographical Information System
GSD	-	Ground Sampling Distance
HWS	-	High Water Slack
IPCC	-	Intergovernmental Panel on Climate Change
LADA	-	Langkawi Development Authority
LWS	-	Low Water Slack
NAHRIM	-	National Water Research Institute of Malaysia
PCS	-	Projected Coordinate System
PSD	-	Particle Size Distribution
RCP	-	Representative Concentration Pathway
RSO	-	Rectified Skew Orthomorphic
RTK	-	Real Time Kinetic
SLR	-	Sea Level Rise
SNAP	-	Sentinel Application Platform
UAV	-	Unmanned Aerial Vehicle
UNESCO	-	United Nations Educational, Scientific and Cultural Organization

WGS84	-	World Geodetic System 1984

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Research Background

Malaysia has coastline with 3771.5 km in Peninsular Malaysia and 5068.5 km in East Malaysia (DID, 2015). Sands are the most common coastal soils in Sarawak and along Peninsular Malaysia's eastern coast. The most natural soils along Peninsular Malaysia's western coast are clay and silt. Mangrove habitats, which are typically synonymous with clay and silt fields, line about half of the coast, providing natural coastal defense. Wave actions, storm events, and human activity are all contributing to the loss of mangrove vegetation.

Mangroves have been subjected to almost constant disruption over the past few thousand years because of changes in sea level (Alongi, 2008). The magnitude of energy absorption strongly depends on tree density, stem and root diameter, shore slope, bathymetry, spectral characteristics of incident waves, and tidal stage upon entering the forest. Climate change, the ultimate disruption, may result in a maximum global loss of 10-15 percent of mangrove habitat, but this is minor in comparison to current average annual rates of 1-2 percent deforestation (Alongi, 2008)

The natural mangrove ecosystem in the Kilim River region is being affected by tourist boat operations and contamination due to littering, according to a survey conducted by Sahabat Alam Malaysia (SAM). The use of engines of more than 200

horsepower (hp) has put the ecology of Sungai Kilim, Langkawi, in jeopardy. SAM suggests that tour boat operators only be licensed to operate in this area if their engines are 60 horsepower or less (Idris, 2016). This measure can reduce the adverse effects on the environment here (Hussain et al., 2016).

Geospatial technology of Digital Shoreline Analysis System (DSAS) is one of the methods chosen in carrying the analysis of riverbank erosion. The DSAS program is used to study the shorelines derived from satellite imagery to determine the rate of erosion and retreating along the coastal plain (Lewis et al., 2016). Remotely sensed data, on the other hand, may provide useful information with fair precision due to their spatial and temporal scales. This can be investigated using a geographic information system (GIS) by comparing historical and current shoreline positions (Misra et al., 2015). Remote sensing imaging is one method of documenting forest dynamics. Numerous studies have been conducted to explain seasonal variations in the spatial expansion of mangrove forests, such as species diversity transitions, changes in mangrove cover before and after natural disasters, and dynamics of mangrove forest forms (Berger et al., 2008).

1.2 Problem Statement

Kilim River is one of the main tourist attractions in Langkawi. The declaration from UNESCO as Kilim Karst Geoforest Park in 2006 had increased the number of tourists visiting Kilim River. The Langkawi Department Authority (LADA) is concerned about the issue of riverbank erosion along Sungai Kilim, which would influence the environment and, as a result, the tourist attraction status of the Kilim Geoforest Park. The tourism boats had eroded the banks along Kilim's canals and disturbed the area's vulnerable flora (Shahbudin et al., 2012). The main concern about the river is the erosion of the riverbank along Kilim River. The river had experienced changes of its riverbank throughout the years. Furthermore, it

demonstrates that present human activities, as well as increased tourism development, have a significant impact on the Kilim River's mangrove environment(Mansor, 2019). The riverbank erosion is alarming as it will cause the declaration made by UNESCO will be withdrawn. Langkawi will lose one of the most prestige's awards and it will cause the declining number of tourists visiting the place.

Therefore, the research made by the team is to assess the riverbank erosion rate and to studies the river physical properties and its impact on the mangrove migration. Temporal data of reports, charts, images, and others statistical data are collected as the study consist of certain period of time. Another factor related to this study is the long-term impact of sea level rise affecting the mangrove habitat.

1.3 Objectives of Study

The aim for this study is to integrate the geospatial technology for the assessment of mangrove habitat and riverbank erosion of a selected area. The selected site is along the Kilim River at Langkawi Island. The following objectives are formulated to achieve the aim of the study.

i. To determine the river physical properties of the selected site based on data collection
ii. To classify the mangrove distribution map using the satellite images
iii. To assess the riverbank erosion using the geographic information technology
iv. To predict the impact of projected future sea level rise (SLR) to mangrove habitat

1.4 Scope of Study

The study involves the uses of geospatial technology in assessing the mangrove habitat and riverbank erosion. The integrated geospatial technology that are used in this study consist of the use of satellite temporal images, orthophoto, unmanned aerial system (UAS) and geographical information system (GIS). The scope of studies is best describe as following:

i. There are two type of data collection, which can be differentiate into primary data and secondary data. The primary data consist of on ground data collection that include soil sampling, water sampling, tidal reading, mangrove inventory data, Unmanned Aerial Vehicle (UAV) data and detail of natural and man-made features along Kilim River. The secondary data consist of satellite images, which is QuickBird, WorldView II, Pleaides and SPOT 7 images. Other secondary data obtained from Department of Surveying and Mapping Malaysia (DSMM) is Topography Map and MyGeoid application. While other supported data obtained from various agencies.

ii. Data collected in two different years in year 2016 and 2017. Unmanned aerial vehicle (UAV) data collected in two epochs, which is on year 2016 and 2017. The data are processed through different type of data processing. There is several software involve in data processing which is Envi in processing satellite image of WorldView2, Quick Bird, Pleaides and Spot images. The different of satellite images in temporal resolution is analyze using ArcGIS. The rate of riverbank changes is identified using Digital Shoreline Analysis System (DSAS) version 4.0. This software is an extension tools in ArcGIS Desktop software that help in calculating statistical data of shoreline changes. This software is also used in simulating prediction of sea level rise inundation through different period of time and different scenarios for the studied area.

iii. The prediction in riverbank erosion along Sungai Kilim, Langkawi in this study is limited to temporal resolution of satellite data and tidal data prediction. The final output for this study is inundation map due to different sea-level rise scenarios and simulation of sea-level rise affecting mangrove area in predicted year of 2030, 2050 and 2100. And its effect to mangrove area for projected year

iv. Geographic Information System (GIS), Remote Sensing (RS), and Global Positioning System (GPS) are all examples of geospatial technology (GPS). Geospatial technology collects data with a geographic reference and uses it for analysis, modelling, simulations, and visualization. Geospatial technology allows people to make conscious decisions based on the value and priority of limited resources. To analyze riverbank erosion, geospatial technology may be utilized to construct intelligent maps and models that can be interactively queried to get the appropriate findings. It may be used to discover spatial patterns hidden in enormous amounts of data that can't be accessed or mapped in any other way. Geospatial technology has been integrated in our daily lives.

1.5 Significance of Study

The importance of the study conducted in Kilim River, Langkawi, is the area's status, which has been gazette as one of the UNESCO heritages as Kilim Karst Geoforest Park. The sustainability of the ecosystem there is essential to maintaining the UNESCO status. Apart from that, Sungai Kilim is also a tourist attraction. There is a diversity of flora and fauna, one of the tourist attractions to visit the area by taking a tourist boat provided by the local community there. Due to the large influx of visitors every year, there are issues involving the mangrove area's sustainability.

The site is threatened by alarming river erosion. The importance of this study is to identify the parameters that can be used to analyze the causes of river erosion. In addition, this study is also vital to locate mangrove trees that have fallen because of erosion. The size and age of the mangrove trees there can help identify areas that threaten the growth of mangrove trees in the area. Identifying the characteristics of mangrove trees in the Sungai Kilim area is important for river erosion prevention measures because we know the function of mangrove trees as a wall erosion of rivers or beaches. Strong mangrove trees grip the ground and grow closely together, forming a solid defense preventing the river fortifications from eroding.

1.6 Organization of the Thesis

The structure of this thesis as follows:-

I. Chapter 1 introduce the background study, scopes of research, research significance and the study objectives.

II. Chapter 2 focus on the literature review of sea level rise impact on mangrove migration. This chapter compiled the definition, general concepts and related issues on the coastal inundation caused by the sea-level rise that effect the mangrove and caused of riverbank erosion. The compilation of related studies are obtained from the previous research on sea-level rise, and mangrove inundation.

III. Chapter 3 explain the method used in carried out the research of mangrove migration due to sea level rise and its effect in riverbank erosion. In this

chapter also explain about the description of software use which is ENVI 4.8, ArcGIS, and SNAP. Method of collecting ground data and secondary data.

IV. Chapter 4 analyzing on the data and discussing the results. The analysis involves river physical properties, riverbank erosion and sea level rise scenario.

V. Chapter 5 conclude the finding contributed from the study and suggestion for future works

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