DEVELOPMENT OF MANGROVE AND SALINITY DISTRIBUTION MAPPING FOR THE ENVIRONMENTAL SUSTAINABILITY IN KUANTAN ESTUARY USING RS-GIS TECHNOLOGY

SENIOR DESIGN 2 (BTV4826)

RESEARCH

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28 JAN 2023

SUPERVISOR's DECLARATION

I/We* hereby declare that I/We* have checked this proposal and in my/our* opinion, this proposal is adequate in terms of scope and quality for the award of the degree of Bachelor of Engineering Technology (Energy & Environmental) …………………………..

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STUDENT'S DECLARATION

I hereby declare that the work in this proposal is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at university Malaysia Pahang or any other institution.

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ABSTRACT

The mangrove ecosystem is one of the most productive ecosystems on earth. Mangrove act as a habitat for various species including fish, birds, and crocodiles. However, massive development activities in the Kuantan areas have given enormous pressure to the coastal ecosystem especially mangrove. Development for residential and industrial uses, followed by aquaculture, are the primary threats to Kuantan's mangrove forest. As a result, continuous monitoring of mangroves is essential to ensure their preservation and the development of a sustainable coastal zone. The objectives of this study are to employ remote sensing and gis, to determine how mangrove distribution is affected by salinity. And to create a mangrove distribution map that illustrates the level of degradation from 2002 to 2018 as a result of development in Kuantan. This study examines the mangrove species distribution, and degradation level between 2002 and 2018. Semi-supervised classification was used to assess changes in mangrove distribution using Landsat 7 and Sentinel-2 satellite images of the Kuantan-Belat estuary. The total mangrove cover in 2018 was 1,541.9 ha, a 34% drop from the total area of 2,335.8 ha in 2002. The Kappa coefficient (K) for classification was 0.95 in 2002 and 0.92 in 2018. The diversity of mangroves was distributed in accordance with salinity in the brackish water. Thus, analytical solutions were used to replicate the estuary's longitudinal salinity distribution. The species were distributed on the three salinity zones observed on Kuantan-Belat estuary, polyhaline, mesohaline and oligohaline. Five mangroves' species were detected dominated by Sonneratia alba and Rhizophora mucronate. This study provided a clear mapping of changes in mangrove cover over the decades to assist environmentalists, researchers, and managers in developing better policies. It also raised awareness, revive interest in mangroves, and create a database that will aid in the preservation of mangroves, as well as revealed the total area of Kuantan mangroves between 2002 and 2018.

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LIST OF ABBREVIATIONS

GIS	Geographic Information System
QGIS	Quantum Geographic Information System
RS	Remote Sensing
USGS	US Geological Survey
HWS	High Water Slack
LWS	Low Water Slack
TA	Tidal Average

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Mangroves are a symbiotic group of shrubs and trees that serve as barriers to protect coastal land from ocean waves, tsunamis, and storms. Mangroves also serve as a natural filter, improving water quality by providing habitat for a variety of aquatic life forms(Zuhairi et al., 2019). Furthermore, mangroves are one of the world's most productive marine ecosystems. Mangroves forests provide food, breeding grounds, and nursery sites for several terrestrial and marine species, including many commercial species and early age reef fish. Furthermore, they are a vital biological and economic resource, as well as a significant renewable source of wood and accumulation sites for sediment, pollutants, carbon, and nutrient as well as provide coastal erosion protection (Murakami et al., 2016). According to Kodikara 2018, mangroves can grow in a variety of harsh environments, including high and fluctuating salinity, low air humidity, and high temperatures. And one of the most critical elements affecting the health, distribution, growth, and productivity of mangroves is salinity. In some investigations it has been documented that water content and salinity are factors that play a role in mangrove distribution, and it influence the mangrove species composition and growth (Atwell et al., 2016). As a result, understanding species-specific salinity reactions is crucial for mangrove growth.

The public, policymakers, and decision-makers in Malaysia have begun to pay more attention to mangroves in recent years due to the variety of benefits they offer to local societies and to humanity. On a regional level, many Malaysian societies rely on mangroves' natural resources for their livelihood and wellbeing as well as to shield their properties from storm damage and erosion. (Otero et al., 2020). Malaysia has taken the approach of conservation, sustainable of mangrove forests decades ago, one example of excellent management of mangrove forest is Matang mangrove forest in Perak. It was first listed in 1901, marking the beginning of Malaya's mangrove forest management regime. Since then, the forest has undergone a succession of methodical cutting and planting, and it has become a major global showcase for mangrove forest within Malaysia and for the world for silviculture as well as the study of numerous elements of mangrove ecology and management (Omar, 2020). Malaysia has established a National Policy on Biological Diversity (2016 – 2025) that will guide the country's efforts to conserve biodiversity and utilize its sustainably in the face of increasingly complex issues currently and in the future. At least 20% of terrestrial and inland waterways, 10% of coastal and marine resources, and other effective area-based conservation measures will have been preserved via a representative system of protected areas. by 2025. Additionally, by 2025, known threatened species will have been saved from extinction, and their conservation status will have improved and been sustained (Ministry of Natural Resources and Environment, 2016).

In 2016 Malaysia had 60 different species of mangroves, with a total area of 629,038 ha and in Pahang which considered to be the largest state in Peninsular Malaysia and located within the coastal range had a mangrove forest cover of 9,000 ha, However, only one-third of the mangrove forest has been designated as a Forest Reserve, falling under the Department of Forestry's jurisdiction (Omar,2016). The tremendous growth and urbanization that is taking place in Kuantan, Pahang is putting a lot of pressure on the coastal habitat, particularly the mangrove ecosystem. The current challenges to Kuantan's mangrove forest are mostly caused by residential and industrial development (Zuhairi et al., 2019). Mangroves provide multiple ecological, economical, and social benefits to the villagers in Kuantan region. Therefore, the preservation of mangroves plants in Kuantan estuary is important. This study aims to develop a mangrove distribution map to contribute to the environmental Sustainability of mangrove in Kuantan estuary as a response to the degradation of mangroves. The map will allow decision-makers to know where restoration should be performed. By identifying locations where mangroves historically thrived and where conditions are still ideal for restoration.

1.2 PROBLEM STATEMENT

Malaysian economic development in the 1960s and 1970s was primarily concentrated on agriculture, residential and industrial development. Most of the forests, including mangroves, were converted to agricultural and commercial land use. By 1990, Malaysia had given up to 5.22 million hectares of land for development such conversions and abuse have caused severe environmental damage and have had a long-term impact on the ecosystem (Watershed et al., 2018). For a primary observation of mangrove degradation in Kuantan estuary two google earth images of the year 1985 and 2020 were captured to show some of the areas of mangrove which had been cut for residential and commercial land uses (see figure 1 and 2). For that reason, this study will establish a mangrove mapping database to determine the degree of degradation of mangroves in Kuantan estuary from 2002 to 2018 using geographical information system (GIS) and remote sensing (RS) technologies as a conservation and sustainable measure.

The physical and chemical variables of water that influence mangrove composition, productivity, and zonation are salinity, oxygen, temperature, light, electrical conductivity, turbidity, and nutrients. Poor water quality like high salinity level, temperature or pH value threatens mangrove forests health, and cause more unstable ecosystems (Mama et al., 2021). One of the most important factors influencing mangrove health, distribution, growth, and productivity is salinity. Water quality involves basic scientific information such as spatial quality metrics and ecologically relevant toxicological threshold values. These are necessary for understanding critical physical and chemical factors influencing mangrove growth (Patale & Tank, 2022). Long-term monitoring of mangrove regions is required to ensure that the water quality of the mangrove estuary does not deteriorate, and that the mangrove ecosystem remains healthy (Iskandar Khalit et al., 2017). As a result, monitoring salinity in Kuantan River is critical for the growth of mangrove species and their preservation. This study aims to determine the effect of salinity on mangrove distribution in Kuantan and Belat estuary.

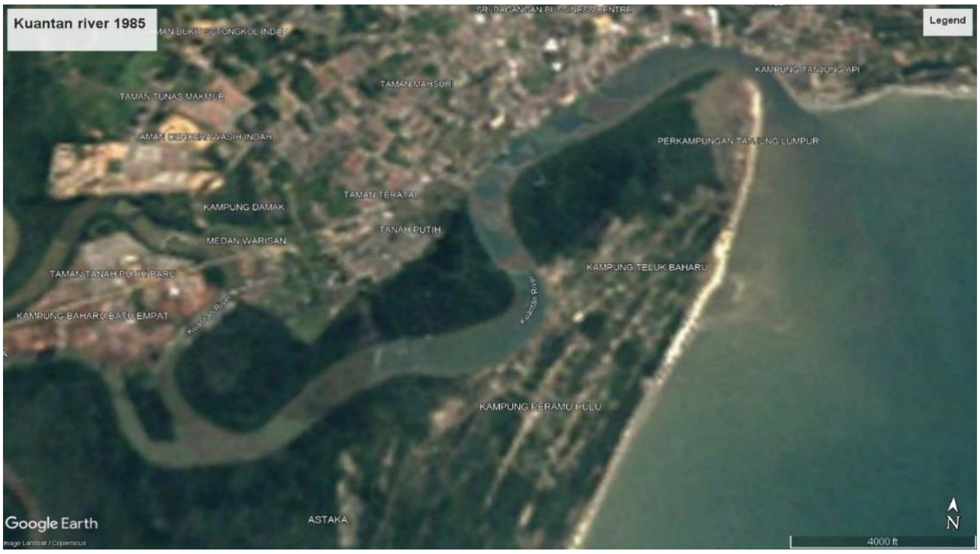

Figure 1: Google earth image for Kuantan River estuary of the year 1985.

Figure 2: Google earth image of Kuantan River estuary of the year 2020.

1.3 OBJECTIVES

The following are the objectives of the proposed study:

I. To evaluate the influence of salinity towards the change of mangrove diversity using supervised approach

II. To develop the mangrove distribution mapping showing the degree of degradation over the decades as a result of development

1.4 SCOPE OF STUDY

The focus of this project is the design of an efficient mapping database of mangrove in the Kuantan and Belat Estuaries for the purpose of conservation of the mangrove ecosystem as well as to investigate the effect of salinity on mangrove species distribution. Salinity data will be acquired from different sources such as Malaysian agencies, literature reviews, reports, and journals. A field investigation will also be carried out using a boat to collect salinity data for the Kuantan estuary. Field measurements will be taken during the dry season, during the spring tide, when salinity travels the farthest with the least amount of freshwater discharge. And A-D 1 analytical salt intrusion model will be used for salinity analysis and data from field measurements will calibrated until the result is valid.

Kuantan is located along the coast, and the development and urbanization taking place there have caused tension on the coastal habitat, particularly the mangrove ecosystem. As a result, monitoring the expansion or degradation of mangroves is critical for the preservation and management of this ecosystem. In recent years, remote sensing has shown to be one of the most accurate approaches for mapping mangrove distribution. The mangrove area in Kuantan will be examined for the years (2000 and 2018) using remote sensing techniques. Sentinel-2 will be used to get 2018 image and Landsat 7 will be used to get 2002 image. Site observation will be conducted to categorize mangrove species based on salinity level at Kuantan estuary.

There are some limitations of this study, first the site observation will not be detailed because most of the data will be obtained from satellite images. However, taking into consideration that satellite data is susceptible to errors such as sensor error, solar, and atmospheric effects, the data will be pre-processed using the desktop version of QGIS software. QGIS is a geographic information system (GIS) tool that allows users to browse, modify, print, and analyze geographical data for free. Second, there are only few studies have been conducted to identify the land status of mangrove and the influence of water salinity of Kuantan estuary on mangrove species distribution. As a result, the lack of recent available salinity data of Kuantan estuary will limit our study to be conducted on 2018 satellite images.

1.5 SIGNIFICANCE OF STUDY

The International Union for Conservation of Nature's (IUCN) Red List of Threatened Species includes a list of mangrove species that are endangered. Even though, mangroves are present in 118 countries around the world, they only make up 1% of the tropical forest and less than 0.4 percent of the world's forests. Yet, they provide a very important ecosystem to both human life and the diversity of life that inhabits it. Additionally, they provide materials such as wood and timber, which help support the livelihoods of thousands of coastal communities. Therefore, mangroves must be recognized as a vital socioeconomic and ecological resource that must be maintained and managed in a sustainable manner. The findings of this study will be valuable in a variety of ways. First, the mangrove distribution map will provide data on the land use change dynamics in the Kuantan estuary and surrounding area from 2002 to 2018. Second, this study will provide sufficient data to help understand the effects of water salinity on the mangrove species distribution. Third, this study can be used as a baseline for Kuantan estuary mangrove forest monitoring and management. The data of this study will support environmentalists, researchers, and managers in developing better policies to prevent further losses of mangrove by implementing efficient conservation techniques, long-term planning, and restoration of previously harmed mangrove ecosystems successfully. Our expectation is that this research will raise awareness, revive interest in mangroves, and create a database that will aid in the preservation of these vital yet underappreciated ecosystems. Finally, the importance of this study is to define the influence of salinity on mangrove distribution and to develop a mangrove map that shows the degradation level at the Kuantan estuary.

CHAPTER 2

2.1 INTRODUCTION

Mangroves have traditionally been used for food, timber, fuel, and medicines (Murakami et al., 2016). Mangrove plants have been used by humans for thousands of years. Many villages use mangrove wood as the foundation for their homes, boats, furniture, fences, bridges, and even poles for fish traps. In the medical field, mangroves are consumed as a medicinal herb to treat wounds, burns, and even serious health problems. The root of mangrove is boiled and combined with milk to treat coughing and asthma illnesses. Mangrove has been used as a traditional medicine for decades (Azli et al., 2021). Mangrove forests are projected to be worth at least US$1.6 billion in 2010 worldwide. For example, mangroves provide numerous ecological, economic, and social benefits to the residents of the Kuantan estuary. According to one study, 36% of the villagers in Sungai Kuantan use the mangrove forest area for income generation, recreation, or as part of daily food supply, and 31.9 percent of their income comes from the Kuantan mangrove forest and nearby coastal areas (Abdullah et al., 2021). As a result, the preservation of mangrove plants in the Kuantan estuary is critical.

In recent years, there has been a growing awareness of the extent to which mangroves perform vital ecosystem tasks. These functions are important not only at the local levels, in fisheries and cultural preservation—but also at the global level, as part of the climate change equation. One of the most essential tasks that mangrove forests play, particularly for coastal cities, is coastal protection by minimizing storm danger. In addition, mangroves play a significant role in climate regulation at the macro level because of their "carbon store and sink" function. Mangrove forests, in fact, are among the most carbon-dense in the tropics, with an average of 1,000 Mg carbon per hectare (See figure 1.1) (Goh, 2016). Malaysia has made a serious plan to reduce its carbon emissions intensity by 45 percent by 2030, compared to 2005 levels (Susskind et al., 2020). As a result, maintaining its mangroves at the local level would go a long way toward achieving this ambitious goal.

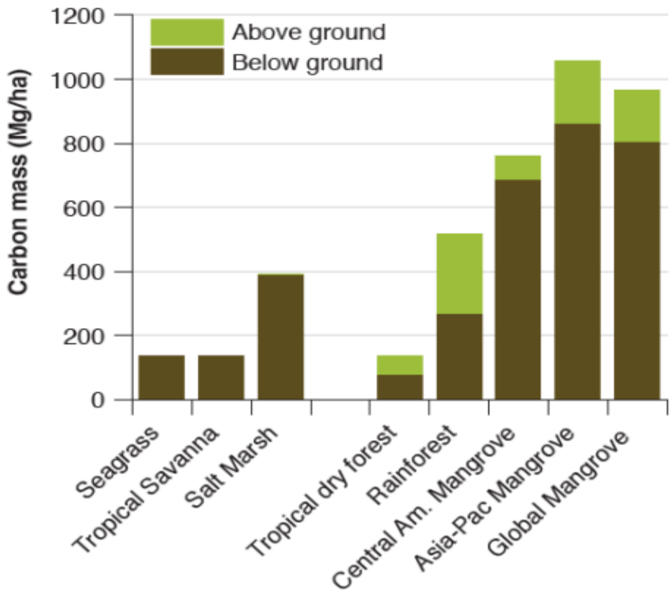

Figure 3: The carbon stores (MG/ha) of a few tropical highland and coastal ecosystems (1 Mg is equal to 1 metric ton) (Goh, 2016).

Despite the great value of mangrove, they are declining at a global rate estimated at 1–8% annually (Xu et al., 2022). Between 1980 and 2005, the global area of mangroves diminished from 18.8 million ha to 15.6 million ha. The Indo-Malay Philippine Archipelago is home to 36 to 46 of the world's 70 known mangrove species, making it the region with the highest mangrove biodiversity. Even though less than 15% of species in this region are endangered, with an estimated 30% decrease in mangrove area since 1980, the Indo-Malay Philippine Archipelago has one of the highest rates of mangrove loss in the world.(Murakami et al., 2016). The Land Acquisition Act of 1960 in Malaysia empowers all state governments to acquire land for economic goals. As a result of such legislation, vast portion of lands that include mangrove forests are being converted to agriculture, residential and commercial land use (Watershed et al., 2018). Malaysia is one of the countries in Southeast Asia with the most extensive mangrove forests. Despite the mangrove ecosystem's widespread distribution in Malaysia, the forest is inevitably threatened by numerous land use activities (Omar et al., 2018). In December 2004, a tsunami hit Malaysia in several states including Perlis, Penang, and Kedah. It was the first tsunami recorded to hit Malaysia, which cause extensive destruction and the death of 68 people. The loss of life and the extreme damage sparked a sudden increase in awareness of the importance of the mangroves (Omar, 2020).

2.2 DETERIORATION OF MANGROVES IN KUANTAN ESTUARY

Development and urbanization taking place in Pahang, which is located along the coast, has put a strain on the coastal ecosystem, specifically the mangrove ecosystem (Zuhairi et al., 2019) And that happened in major cities in Pahang such as Kuantan where the mangrove habitat is at risk (Ahmad et al., 2019). Between 2006 and 2014, urban housing areas and forest areas dominated the land use in the area between Cherating River, Ular River, and Kuantan River. Almost 31% of the area was transformed to industrial and urban development. Kuantan is in the centre, between Cherating, Ular, and Penor. Thus, the new development has created employment opportunities and growth of beach resorts and tourism areas which led in a shift in urban housing density from medium to high. Furthermore, agricultural plantations such as coconut and oil palm, as well as the development of new urban housing, were found to dominate the landscape between Kuantan and Pekan, putting immense stress on the coastal ecosystem in Kuantan (Hamzah et al., 2020).

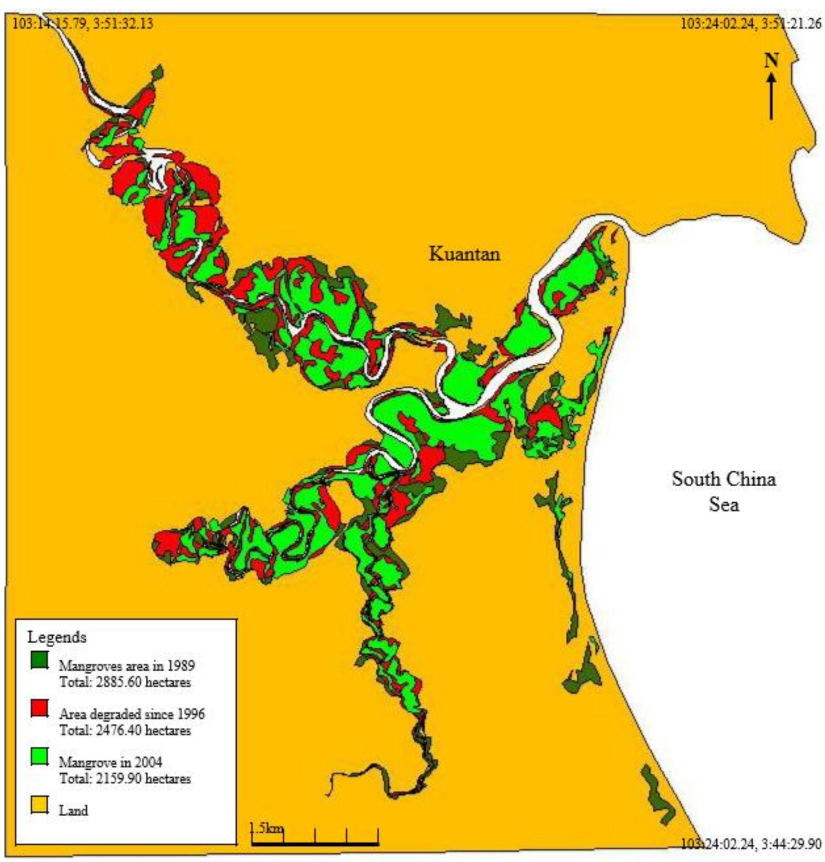

Figure 4: Mangrove distribution and degradation map in Kuantan, Pahang (Shahbudin et al., 2009).

2.3 IMPACT OF WATER QUALITY PARAMETERS TO MANGROVES

Kuantan's mangroves are surrounded by rivers and brackish water, which change depending on the season and geographical domain. Basic scientific data regarding spatial quality parameters and ecologically relevant toxicological threshold values is provided by water quality parameters. Understanding the important physical and chemical factors that affect the aquatic environment is critical. Temperature, rainfall, pH, salinity, dissolved oxygen, and carbon dioxide are just a few of the elements that might affect how vigorously mangroves develop. Salinity is one of the key elements affecting mangrove distribution, growth, and production (Kodiara et al., 2017). Some studies have found that water content and salinity are factors that influence mangrove species composition and growth (Atwell et al., 2016). According to Yunus et al. (2017), higher salinity was recorded in Kuantan estuary because of sea water intruding and moving further into the freshwater region during the dry season.

2.4 SALINE INTRUSION PROCESS

The inflow of seawater affects how salinity is distributed in estuaries. The estuary location where the difference between river salinity and seawater is below a small amount determines the seawater intrusion limit. Sea intrusion is caused by tides, the density difference between river and seawater, currents, and turbulence. It is evened out by the freshwater inflow from rivers, groundwater, and other sources. For both man and nature, seawater intrusion in estuaries is a major phenomenon because it limits the amount of freshwater that can be used for drinking and agriculture, as well as the types of ecosystems and species that can survive in an estuary environment. The processes of sedimentation and turbidity in estuaries are also influenced by salinity and density-driven currents. Figure 2.4 below provides an illustration of the saline intrusion process. Figure 5 below provides an illustration of the saline intrusion process (Syuhaida Adnan & Anak Gisen, 2021).

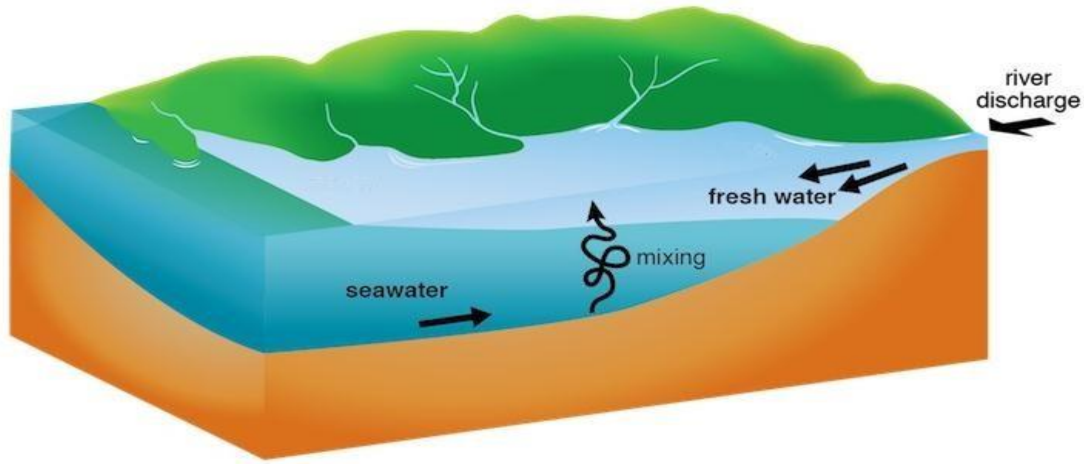

Figure 5: Illustration of saline intrusion process (Syuhaida Adnan & Anak Gisen, 2021).

2.5 MANGROVES SPECIES DISTRIBUTION BASED ON SALINITY RANGE

Insufficient understanding of the critical ecological factors that influence mangrove health, such as the ecological requirements for salinity, suitable hydrology and topography, and an appropriate species composition, is one of the main reasons that mangrove restoration efforts have failed. Salinity is one of the most important factors determining the growth, dispersion, production, and health of mangroves. It has been shown in investigations of mangrove restoration operations in a number of sites that it impacts the survival and growth of planted mangrove seedlings. Due to freshwater and saltwater inflow, inundation, groundwater seepage, and evaporation, it frequently displays substantial geographical and temporal changes. Therefore, understanding species-specific reactions to salt is crucial for mangrove planting initiatives. According to some studies, seedlings of at least some species thrive most effectively when exposed to moderate salinity, such as 17 ppt. Other research, however, claim that water with a significantly lower salinity boosts production, growth, and survival. Each species of mangrove plant has a different tolerance range for salinity, and it depends on the plant's capacity to maintain a high-water usage efficiency (Kodikara et al., 2018). Table 2 presents the mangrove species' probability of occurrence along with their percentages. Table cells with no values indicate '0' probability of occurrence, as observed or reported. A tick mark (✓) shows that earlier research confirms the presence of that species in that area.An asterisk (*) Mark identifies the zone-specific anticipated indicator plants by (Barik et al., 2018) study.

Table 1: Ranges and zonation of salinity

Zone	Zone code	Salinity range (ppt)
Low salinity (Oligohaline) zone	1	5-15
Medium salinity (Mesohaline) Zone	2	15.1-25
High salinity (Polyhaline) zone	3	>25

Table 2: probability of mangroves occurrence in salinity zones based on past studies

	Low salinity zone		Medium salinity zone		High salinity zone	
	Present	Referred	Present	Referred	Present	Referred
Heritiera	21.05*	✓	0	Nil	0	Nil
Nypa	21.05*	✓	0	Nil	0	Nil
Sonneratia	52.63	✓	13.33	Nil	0	Nil
Lumnitzera	10.53	✓	13.33	Nil	0	Nil
Phonix	5.26	✓	13.33	Nil	0	Nil
Ceriops	5.26	✓	13.33	✓	66.67*	✓
Aegiceros	0	✓	6.67	✓	0	Nil
Kandelia	5.26	✓	6.67	✓	0	Nil
Aegialitis	0	Nil	13.33	✓	0	Nil
Xylocarpus	10.53	✓	6.67	✓	0	Nil
Bruguira	0	✓	33.33*	✓	0	✓
Avicennia	21.05	✓	40.00	✓	66.67*	✓
Exoecaria	47.37	✓	53.33*	✓	33.33	✓
Rhizophora	0	✓	20.00	✓	0	✓

(Barik et al., 2018)

2.6 MONITORING OF MANGROVES USING RS-GIS TECHNOLOGY

Monitoring mangrove degradation is crucial to access the degree of degradation due to development and land use change since they are being extinct in the world throughout the years. However, the huge and inaccessible areas covered by mangrove forests make field assessments difficult, time-consuming which make monitoring mangroves by conventional methods expensive and inefficient (Muhammad et al., 2021). Considering the situation, time and cost-effective mapping approaches for monitoring mangroves are required, which can be obtained using remote sensing. One of the mangrove advantages is having a clear spectral and spatial characteristic that are easily identifiable on satellite pictures, making remote sensing an effective technique of mapping and monitoring. Hence, remote sensing techniques can be used to estimate the mangrove forest cover that extends over a broad area and is inaccessible to field surveys (Maurya et al., 2021). The ability to capture information over broad areas, produce repeated measurements over a location, and make full use of the electromagnetic spectrum for quantitative and qualitative measurements over mangroves are the main reasons why remote sensing is the ideal technology for monitoring mangroves (Geographic Information Systems and Science, 2019). Furthermore, applying various classification approaches to remote sensing data acquired through various sensors is useful for extracting various parameters of the mangrove ecosystem, including tree height, canopy height, above-ground biomass, species structure and types, mangrove health, leaf area index, and leaf chlorophyll content (Maurya et al., 2021).

Remote sensing and GIS were used to conduct several analyses on the mangrove forests in Pahang. According to one study, between 1997 and 2016, 26.32 hectares of mangrove areas along the Cherating river estuary were lost with a significant drop in mangrove cover from 2013 to 2016, with the loss of 9.156 hectares of mangrove forest which represent 34.76 % decline in mangrove from 1997 to 2016 (Ahmed, 2017). Another study found that the overall mangrove cover in the Pahang River estuary is reducing. Between 1990 and 2017, 43.7 % or 670.80 ha of mangrove had been destroyed (Zuhairi et al., 2019). And a different study showed that Ular River and Penor River in Pahang had lost 8.7% and 7.2% of their mangrove forest respectively between 2006 and 2014 (Hamzah et al., 2020).

However, many of the recent studies of mangrove in Pahang have focused on districts such as Cherating and pekan other than Kuantan. There has been only few research on the degradation level of mangrove in Kuantan. Consequently, there is no reliable data on mangrove cover and the effect of salinity on mangrove species distribution in Kuantan. Considering that, this study will be conducted to monitor the state of mangrove deterioration as well as the distribution of mangrove species as a response of water salinty in Kuantan estuary using a combination of a new method (Drone Technology) with remote sensing and GIS. This study establishes a mangrove mapping database to determine the degree of degradation of mangroves from 2000 to 2018 and to provide in-depth study of the effect of water salinity on mangrove species distribution for the purpose of conservation and sustainability of mangrove forests in Kuantan city. To manage and restore such important ecosystems, to assure the supply of goods and services, as well as the associated ecological and economic benefits that mangroves offer to Malaysia's economy and to the villagers in Kuantan city.

Table 3: Summary of mangrove cover in Pahang Estuary

Year	**Pahang State Total Area (ha)**	**Pahang River Estuary Total Area (ha)***	**Percentage***
1990	11,467.03	2,206.20*	19.24%
1995	11,129.23	-	-
2000	10,791.42	-	-
2005	9,915.34	-	-
2010	9,039.26	-	-
2014	8,513.61	-	-
2017	-	1,535.40	-

Source: (Zuhairi et al., 2019)

Table 4: Summary of previous research used methods

Author & Year	Method Used	Outcome Performance
Shahbudin, 2009	The study showed the total mangrove cover at Kuantan estuary by using Landsat-5 TM.	The reliability of the method classification's accuracy for each year was determined (1989 = 85.1%, 1996 = 92.7%, and 2004 = 76.6%) which were reliable.
Zuhairi, 2019	This research identified the effects of development and urbanization to the mangrove cover along Pahang River pekan sub-district using Landsat- 8 and Landsat- 5.	The Kappa coefficient (K) for supervised categorization of images in 1990 and 2017 ranged between the value of 0.67 and 0.72 and accuracy ranged from 77% to 81% which is reliable.
Ahmed, 2017	This study examined the effects of different coastal developments on the number of mangroves along the Cherating Estuary, Pahang, Malaysia between 1997 and 2016 using Landsat 4-5 TM, Landsat 7 and Landsat 8 OLI.	Over 19.99% (26.275 ha) of mangrove cover was degraded along the Cherating estuary from its total area of 131.642 ha during the past 20 years. The confusion matrix for supervised classification was varied between 77 and 87 percent. The range of the supervised classification's kappa coefficient was between 0.6 and 0.8.

Sources: (Shahbudin et al., 2009), (Zuhairi et al., 2019), (Ahmed, 2017).

2.7 SALINITY MONITORING

One-dimensional (1-D), two-dimensional (2-D), and three-dimensional (3-D) models of salt intrusion are all available. These models have been widely applied to simulate the salinity distribution in estuaries around the globe. When high accuracy in modelling results is required, 2-D and 3-D models are preferred. Meanwhile, for cases requiring moderate accuracy, a 1-D analytical solution suffices. A 1-D model has the advantage of being simpler and more adaptable to contexts with less data over 2-D and 3-D models. This model is particularly economical because it just needs characteristics that can be measured immediately, such as geometry, freshwater flow, and tide (Savenjie, 1986). Numerous estuaries across the world have evaluated the 1-D analytical salt intrusion model, and it has shown to be reliable, especially in minimally gauged estuaries (Nyugen, 2012). Researchers confirmed that 1-D salt intrusion model can be applied to both multi-branch and single reach estuaries.

Since salinity travels the farthest during the dry season at spring tidal high-water slack, this is the time of year when it is most crucial to measure it. The following equation is used to calculate the salt intrusion length L:

$$L^{TA} = aln\,(\frac{1}{\beta_0} + 1) \quad \text{(Equation 1)}$$

To maintain consistency throughout the computation, Equation (1) refers to the average tidal salt incursion (TA). The results of the intrusion length are then converted to the high-water slack (HWS) condition. The maximum salt intrusion length is then calculated using the conversion equation:

$$L^{HWS} = aln\,(\frac{1}{\beta_0^{HWS}} + 1) \quad \text{(Equation 2)}$$

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

The data collection activities for this study, which were broken down into three phases: primary data, secondary data, and tertiary data. Primary data included all the satellite data collected from United States Geological Survey USGS while secondary data focused on the data obtained from previous literatures and tertiary data involved all the data from site observation. Sentinel-2 satellite image (10m) resolution and Landsat 7 satellite image (30m) resolution from the United States Geological Survey (USGS) website, while Kuantan estuary salinity data were collected from previous literature and site observation. Mangrove species distribution based on salinity range data was collected from field observations.

3.2 STUDY AREA

Mangroves in Kuantan is located in the east coast of Pahang state, Malaysia. The study area of mangrove covering the banks along Kuantan River and its tributary downstream. Kuantan mangroves range between 3°51.32.13'N to 3°52.21.26'N in latitudes and 103°14.15.79'E to 103°24.02.24'E in longitudes. Figure 6 below shows the Kuantan estuary.

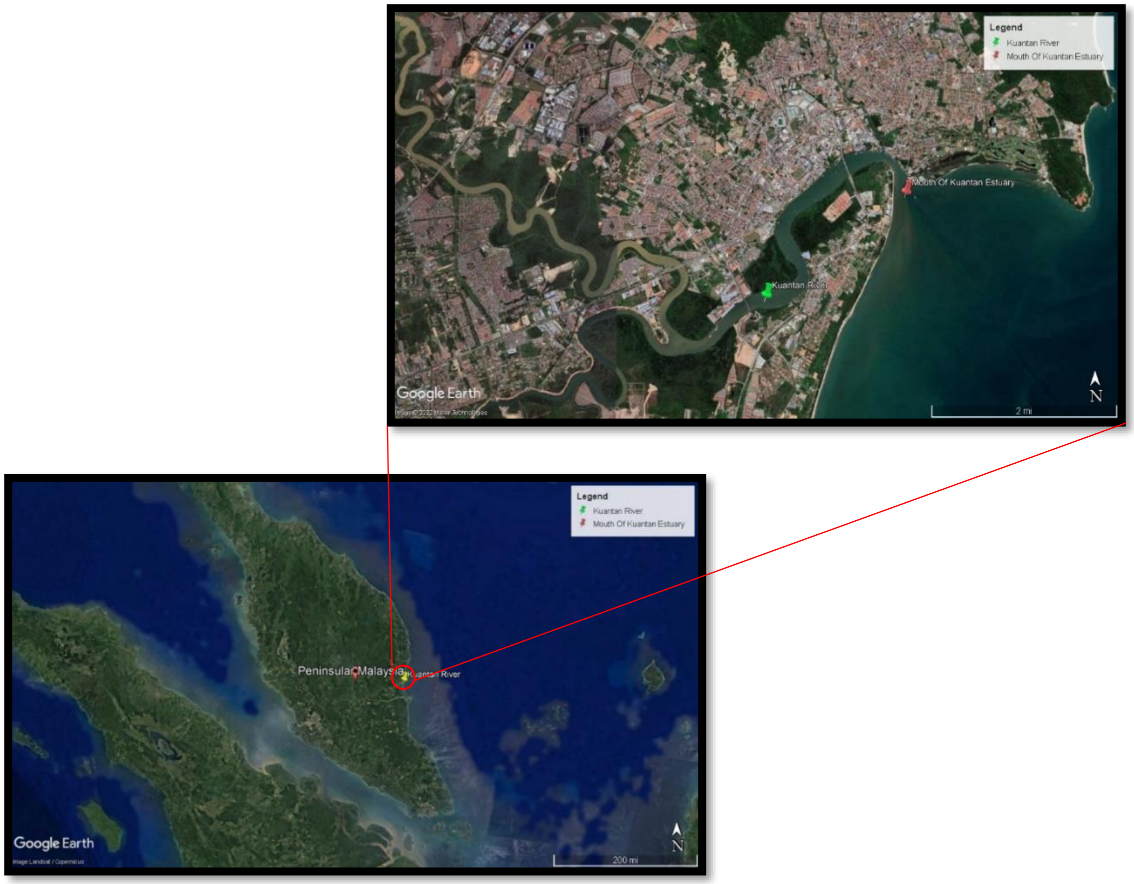

Figure 6: Kuantan Estuary

3.3 DATA COLLECTION

Data is the primary and most important step for the research, there are two types of data in this research, available data and collected data. Available data were requested from previous researchers for the water salinity of Kuantan and Belat Rivers. And collected data was through United States Geological Survey USGS, and field observation.

3.3.1 SATELLITE DATA

Satellite data were downloaded from the United States Geological Survey (USGS) website for the year 2000 and 2018. Sentinel-2 satellite image has 10m resolution and was used to extract the mangrove area of Kuantan estuary in 2018. While Landsat 7 satellite image has 30m resolution and was used to extract the mangrove cover area of Kuantan estuary in 2000.

3.3.2 SALINITY DATA

Data for the salt intrusion study was collected from previous literature. A couple of salinity field surveys was conducted in that literature for the Kuantan and Belat estuaries as the dry season began. because the dry season and the spring tide are when salt intrusion is most severe. The field survey was carried out when the water was at zero velocity and at both high and low water slacks (HWS and LWS). To test the workability of the methodology three site visits were conducted on 14 July 2022, 25 August 2022, and 27 September 2022. Starting at the mouth of the estuary and proceeding forward until the salinity level reached 0.1 ppt, the salinity measurements were obtained using a boat. The waypoints for each measurement were recorded using a GPS, and the water depth at each salinity measurement location was recorded using a portable handheld depth equipment. Then a Multi-Parameter Water Quality Meter with a 30 m cord was used to test salinity. The water quality meter's cable was weighted, allowing the measuring probe to remain submerged in water throughout the measurement. This instrument was used to measure salinity of the river water.

3.3.3 MANGROVE SPECIES DATA

Mangrove species distribution data were collected from previous study of mangrove in Kuantan estuary and through field observation. A GPS was used to record each salinity measurement's waypoint of Kuantan estuary and those waypoints were also used to determine the mangrove species distribution based on salinity range.

3.4 SATELLITE IMAGE PROCESSING

The USGS provided satellite images of the Kuantan River Estuary. Two satellite images were examined: on July 5, 2018, by Sentinel-2, and on October 18, 2002, by Landsat 7. The satellite images were pre-processed using Qgis software. The images have undergone standard geometric and atmospheric correction processes. Maximum Likelihood was used for semi-supervised classification based on the specified Region of Interest (ROI). Four (4) classes have been determined, which are: Mangroves, Vegetation, Built-up, and Water. The classifications' accuracy was evaluated using the Kappa coefficient (K) and the proportion of the confusion matrix. On semi-supervised classification, the Kappa coefficient was used to compare the error between classifications produced by the producer and by the users. The Kappa coefficient expresses the proportionate decrease in error caused by a classification procedure in comparison to the error caused by a classification that was made at random. Confusion matrices show a list of class values for the pixels in the classified picture file and the class values for the associated reference pixels, primarily field data. To track changes in mangrove covers over the last 16 years, the supervised images were digitalized.

3.5 SALINITY ANALYSIS

3.5.1 SALT INTRUSION MODELLING

Using a 1-d dimensional analytical salt intrusion model, the salinity condition in both Kuantan and Belat estuaries were evaluated. It was effectively used in the spring tide with high water slack (HWS) and low water slack (LWS) conditions. Geometry and salinity analyses were the two types of analyses that were performed. Kuantan Estuary underwent five field surveys on March 27 and 29, 2017, October 3, 2017, March 7, 2018, and April 15, 2018. By using the moving boat technique, the study for the estuary covered from the mouth of the estuary until the reading reached 0.1ppt but restricted until the Kobat barrage. To validate the model and examine the potential of the tributary, the study was further expanded to the Belat Estuary. Thus, four surveys in the Belat Estuary were carried out on April 26, 2017, October 2, 2017, March 6, 2018, and April 14, 2018.

3.5.2 MODEL CALIBRATION

For both estuaries, the Van der Burgh's coefficient K, dispersion D0, tidal excursion E, and sea salinity S0 parameters were calibrated during the initial survey and confirmed by the subsequent survey. K is the "shape factor" that affects the toe salt intrusion curve's shape. It is reliant on modifications in channel topography. It is difficult to manually quantify dispersion since it is a mathematical artefact. The mixing number, which reflects the ratio between the dispersion D and discharge Q, is used to calibrate the dispersion. This is because the discharge, for which the statistics are never available, has a significant impact on D.

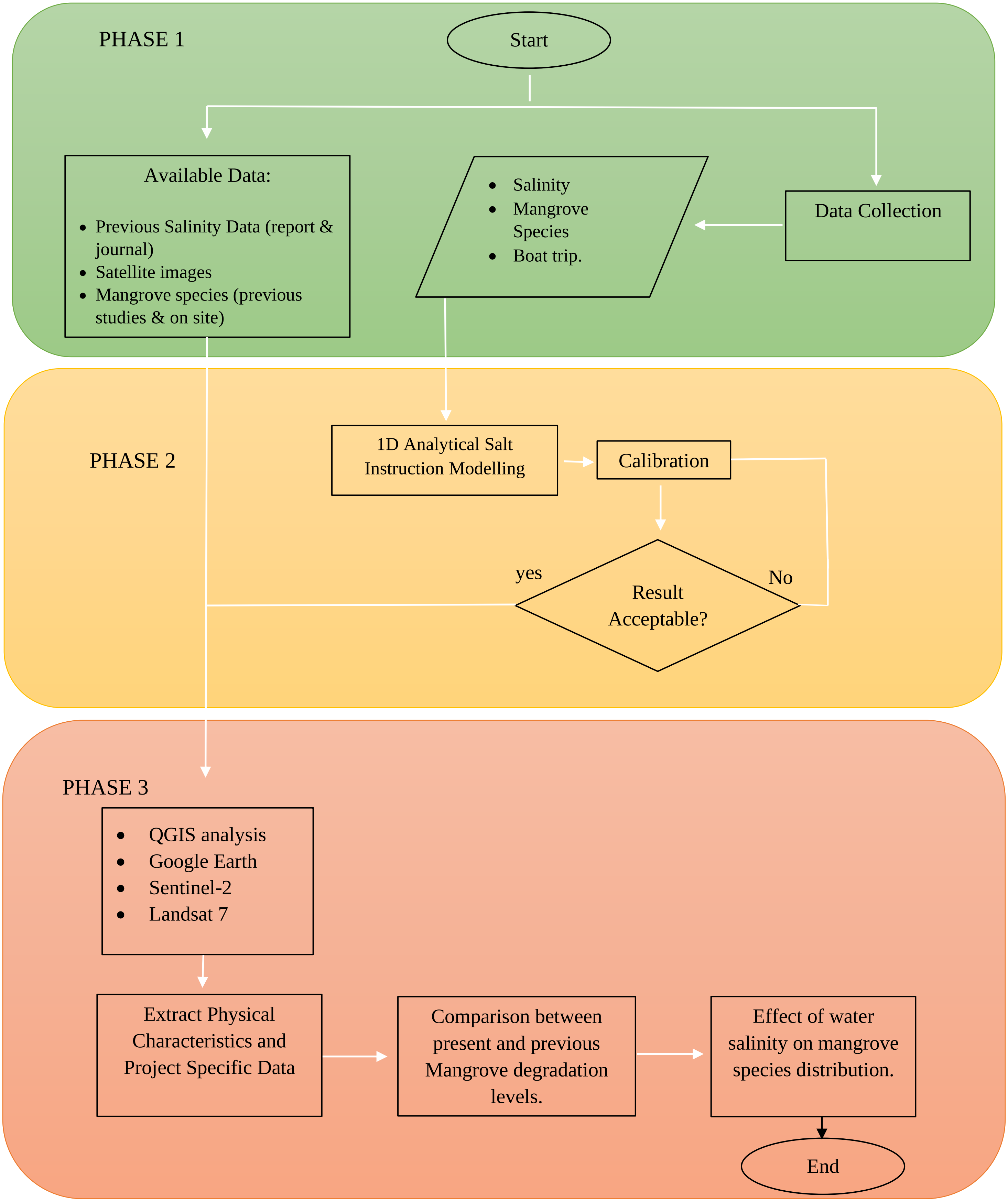

Figure 7: Methodology graph

3.6 FLOW CHART

This study was completed in three phases, as shown in the flow chart above. The first phase was data collection. Water salinity data was collected using readily available data, such as previous salinity data from journals and reports. The United States Geological Survey provided the satellite data (USGS). And a site visit was also conducted to determine mangrove species distribution in the Kuantan and Belat River.

The second phase was salinity analysis. The salinity analysis in the Kuantan estuary was conducted using Savenjie's 1-D analytical salt intrusion solution model. The salinity was measured just before the flow direction changes from High Water Slack (HWS) to Low Water Slack (LWS). During tidal cycles, the HWS and LWS represent the vertical salinity variation envelope. To capture the slack moment, the field survey employed a moving boat technique, in which the boat travels at the pace of a tidal wave. Salinity fluctuations were recorded throughout the cycle, commencing at the estuary's mouth, and progressing through the course. Following the collection of field survey measurements, the data was calibrated until the Kuantan estuary calibration result was valid.

Image processing was the third phase and final phase. Satellite Landsat 7 image of 2002 and sentinel 2 image of 2018 of the land use and land cover of Kuantan and belat estuaries were processed using Qgis software and classified using maximum likelihood to determine the degradation level of mangroves from 2002 to 2018. And isoline map of Kuantan and belat estuaries salinity level were processed to show the distribution of mangrove species based on salinity level in both estuaries.

CHAPTER 4

RESULT AND DISCUSSION

4.1 INTRODUCTION

The QGIS application in collaborating with USGS satellite images for Kuantan city have been successfully processed to determine the level of mangrove degradation due to land use landcover changes for 16 years. Furthermore, several salinity measurements were considered for Kuantan and Belat estuary to examine mangrove species durability to different salinity levels.

4.2 SALINITY ANALYSES

Salinity analyses was extracted from a previous study that was conducted in 2017 and 2018 for Kuantan and Belat estuaries. The longitudinal salinity distribution data for the Kuantan Estuary at HWS and LWS for the measurement on 3rd October 2017, 7th March 2018 and 15th April 2018 were considered. Meanwhile, another four surveys considered for the Belat Estuary on 26th April 2017, 2nd October 2017, and 6th March 2018.

4.2.1 KUANTAN ESTUARY

The Kuantan Estuary's longitudinal salinity profile for all surveys is shown in Figure 8 to Figure 10. Because of the stratification pattern, all data measurements showed a slightly lower salinity level at 2 and 4 kilometers from the estuary mouth. At the confluence of the Belat-Kuantan Estuary for the LWS, several outliers were seen. At the confluence, the flows that convey saltwater back toward the ocean from the Belat and Kuantan Estuaries' upstream to downstream met at the ebb tide. As a result, the gathering spot has a higher concentration of salinity. In addition, there were a number of outliers for the LWS and HWS conditions in the vital zone between 16 and 20 kilometres, which is close to the Kobat barrage area. The uneven salinity distribution and morphological changes in this region were the causes of these outliers. As a result, the saline water in this location becomes unstable.

The data measurements show that the natural hydrodynamic process in the Kuantan Estuary is not in equilibrium condition and is unstable. Hence, these changes required the most attention as they may give a serious impact on the ecology. This supported by a report by Ahmad (2021) where the local residents admitted on the significant changes in the natural condition habitat. This condition leads to the declining of Nipah Crab due to habitat changes in mangrove swamps and riverbanks. It is also worrying that if it continues, it will have an impact on aquatic life such as lobsters which have 12 life stages, and each stage requires a certain salinity and water quality (Badrul Kamal Zakaria, 2015).

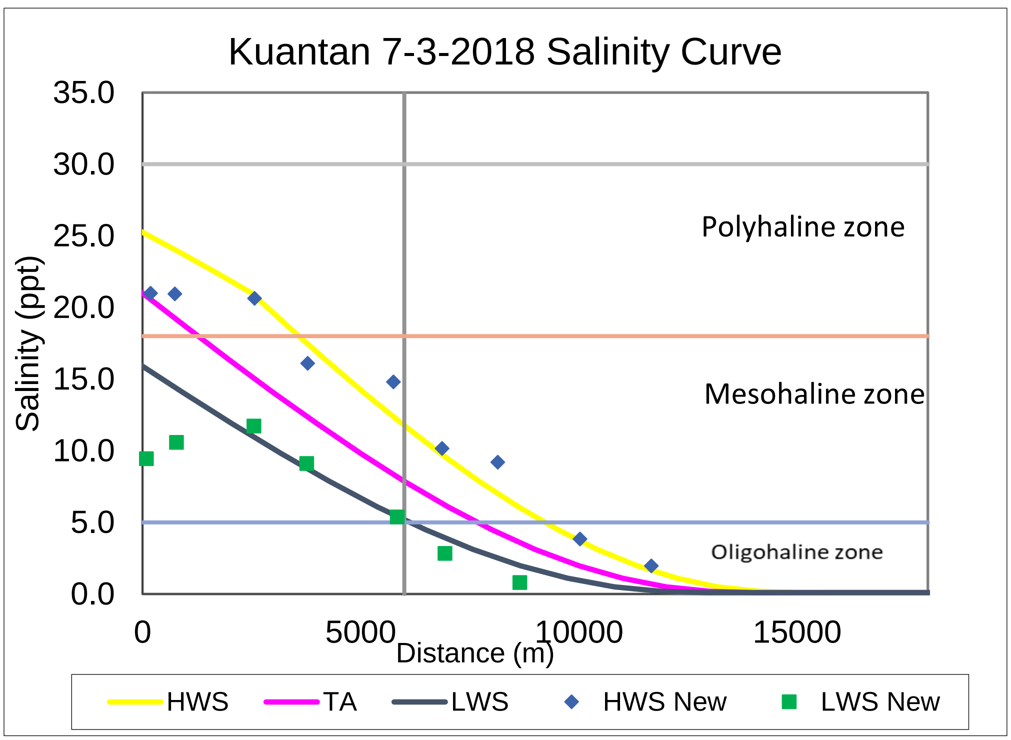

Figure 8 The longitudinal salinity distribution for Kuantan Estuary on 7th March 2018.

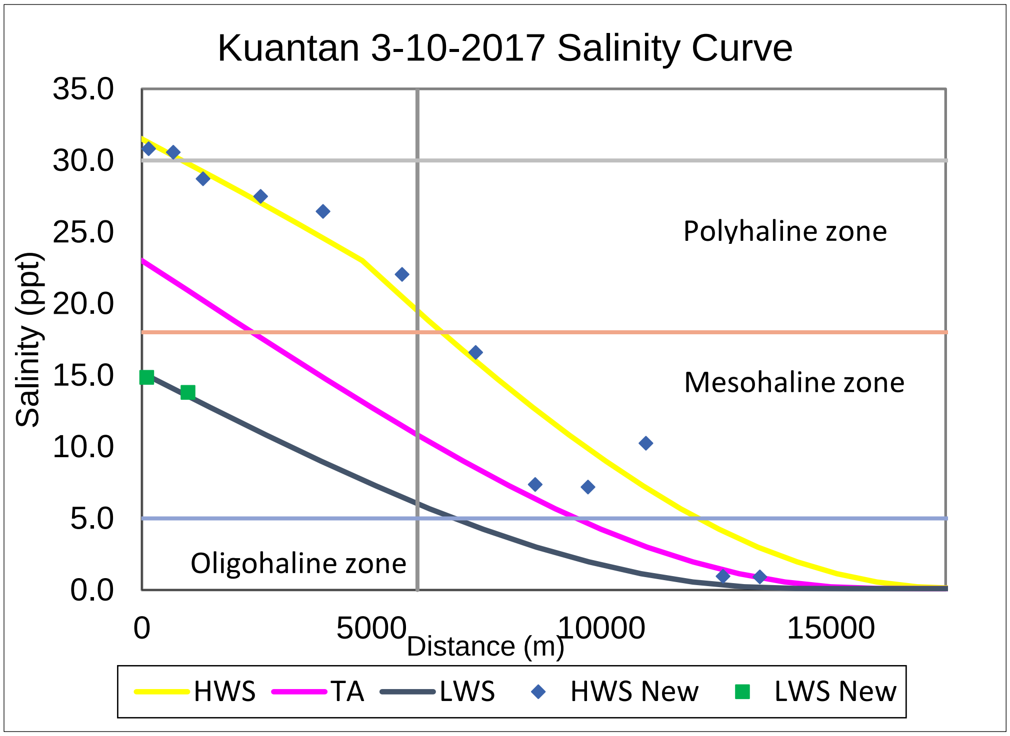

Figure 9 The longitudinal salinity distribution for Kuantan Estuary on 3rd October 2017.

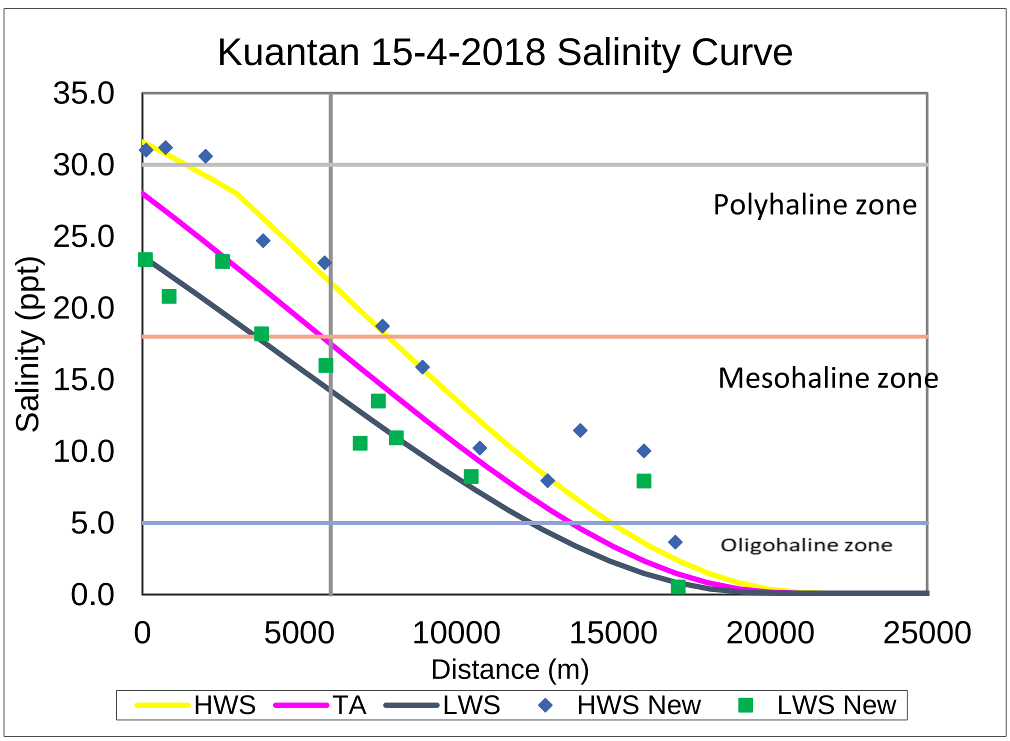

Figure 10 The longitudinal salinity distribution for Kuantan Estuary on 15th April 2018.

Table 5 Calibrated parameters in Kuantan salinity curve.

	Van der Burgh Coefficient, K	**Mixing Coefficient, α_0 [1/m]**	**Tidal excursion, E [m]**	**Dispersion, D [m2/s]**
3rd October 2017	0.45	9.0	9000	203.4
7th March 2018	0.45	6.8	5000	192.4
15th April 2018	0.45	14	4800	116.2

The salinity length for Kuantan estuary was determined by using Equation 1. Table 6 summarises the total salinity length at HWS for the dates of 3 October 2017, 7 March 2018, and 15 April 2018 as 21, 16, 24, and 24 kilometres, respectively.

Thus, the equation for salt incursion length is:

$$Ls^{HWS} = a_1 ln\left(\frac{1}{\beta_0^{HWS}} + 1\right) \quad (1)$$

Where, a_1 = Cross-sectional convergence length of the seaward reach of estuary, m

β_0 = Dispersion reduction rate at the estuary mouth (dimensionless)

Ls = Salt intrusion length, km

Table 6 The total salinity length at HWS results in the Kuantan Estuary.

Survey date	**Total salinity length at HWS (L_{HWS}) , km**
27th March 2017	21.00
29th March 2017	18.82
3rd October 2017	21.05
7th March 2018	16.24
15th April 2018	24.00

4.2.2 BELAT ESTUARY

The simulated longitudinal profile for all Belat Estuary measurements is illustrated in Figure 4.24 to Figure 4.27. The majority of the observations demonstrate good consistency between the simulated and observed data. However, due to the splitting in the Kuantan River (Belat - Kuantan), there are still some outliers at 6.5 kilometers. The salinity distributions for the area downstream of the mouth display some discrepancies. This was due to the Kuantan River which is no longer in an equilibrium condition after the construction of the Kobat Barrage owning a portion of the Belat Estuary downstream. The measurement from Figure 4.25, taken on October 2, 2017, during the early rainy season, shows an excellent fit for the HWS simulation, while there were several variations around the estuary for the LWS. This resulted from the measurements' delayed time.

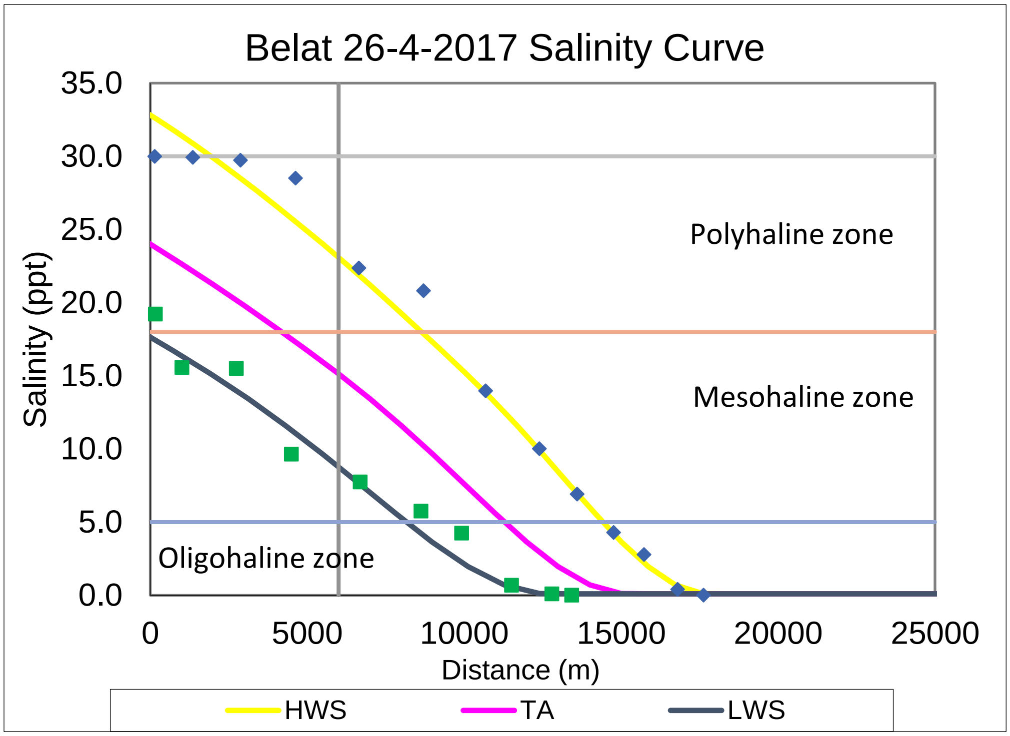

Figure 11 The longitudinal salinity distribution for Belat Estuary on 2nd October 2017.

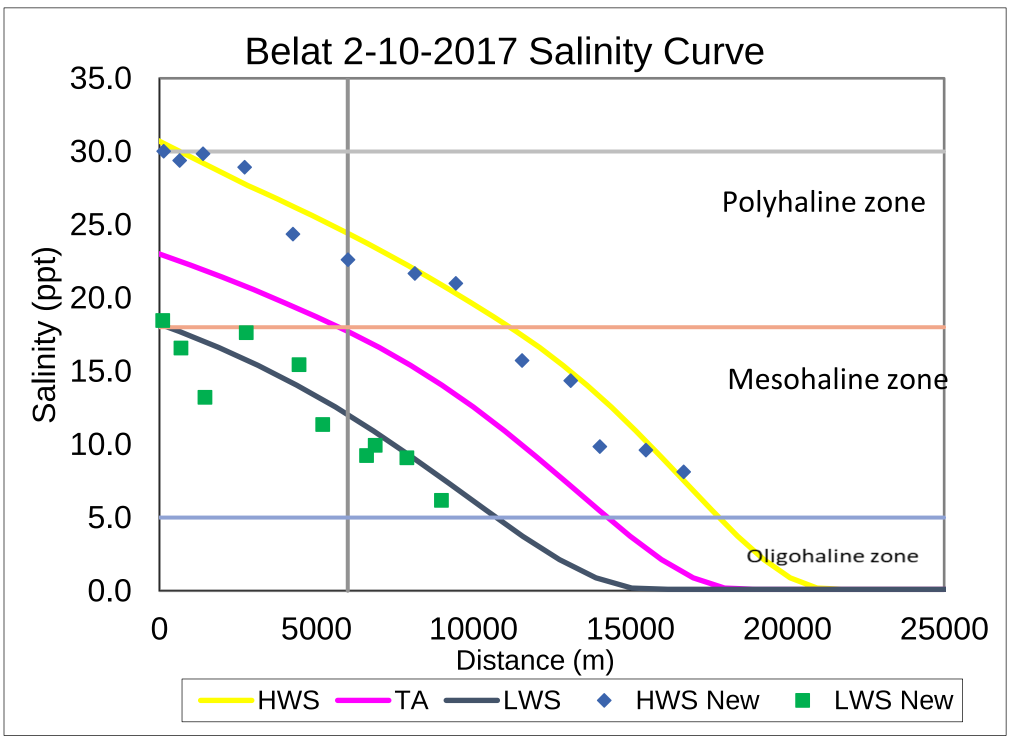

Figure 12 The longitudinal salinity distribution for Belat Estuary on 26th April 2017.

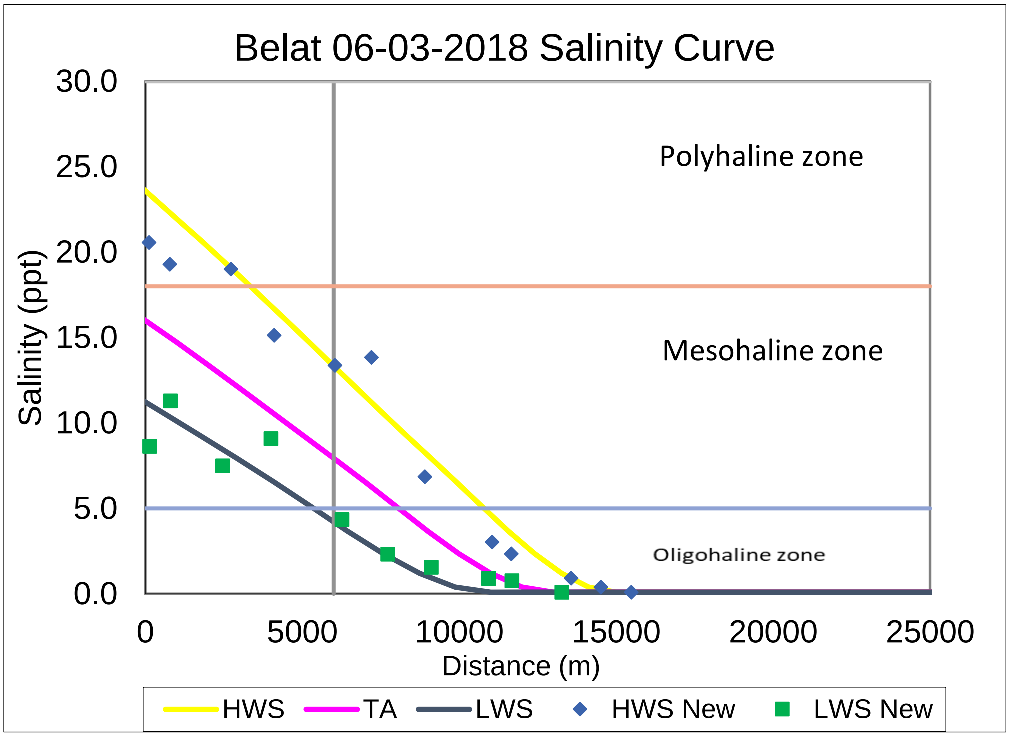

Figure 13 The longitudinal salinity distribution for Belat Estuary on 6th March 2018.

From the calibration parameters summarized in Table 7 below, the Van der Burgh's coefficient K obtained is 0.5 and this coefficient is fit for all surveys.

Table 7 Calibration parameters for Belat Estuary salinity curve.

	Van der Burgh Coefficient, K	**Mixing Coefficient, α [1/m]**	**Tidal excursion at mouth, E_0 [m]**	**Tidal excursion inflection point, E_1 [m]**	**Convergence length, e [m]**
26th April 2017	0.50	14.00	4500	129.8	18000
2nd October 2017	0.50	20.50	6000	176.3	19500
6th March 2018	0.50	9.50	5000	192.4	13000

Using Equation 1, the salinity length for the Belat Estuary was calculated. Table 4.10 provides an overview of the total salinity length at HWS as measured on the 26th of April

2017, the 2nd of October 2017, and the 6th of March 2018. The total salinity length measured at HWS varies between 17 and 24 km, and the discharges range between 2.0 and 11.6 m3/s.

Table 8 The Belat Estuary's total salinity length at HWS.

Survey date	Total salinity length at HWS (L_{HWS}), km
26th April 2017	20.85
2nd October 2017	24.20
6th March 2018	17.00

4.3 SALINITY IN DIFFERENT ZONES OF AN ESTUARY

The salinity of an estuary often changes gradually as fresh water flowing in from rivers mixes with seawater streaming in from the ocean along the length of the estuary. Based on salinity distribution five salinity zones can theoretically be recognized in estuaries. The zones are Euhaline, Polyhaline, Mesohaline, Oligohaline and Limnatic zones. There are only three salinity zones have been identified in the estuary which are Polyhaline, Mesohaline, and Oligohaline zones. A list of these zones' salinity ranges in parts per thousand (ppt) is shown in Table 9.

Table 9 range of salinity in different zones of an estuary.

Zone	Range of salinity
Euhaline zone	30 to 40 ppt and more
Polyhaline zone	18 to 30ppt
Mesohaline zone	5 to 18ppt
Oligohaline zone	0.5 to 5ppt
Limnatic zone	0.5ppt (Fresh water)

4.3.1 SALINITY DISTRIBUTION PATTERN THROUGHOUT KUANTAN AND BELAT ESTUARIES

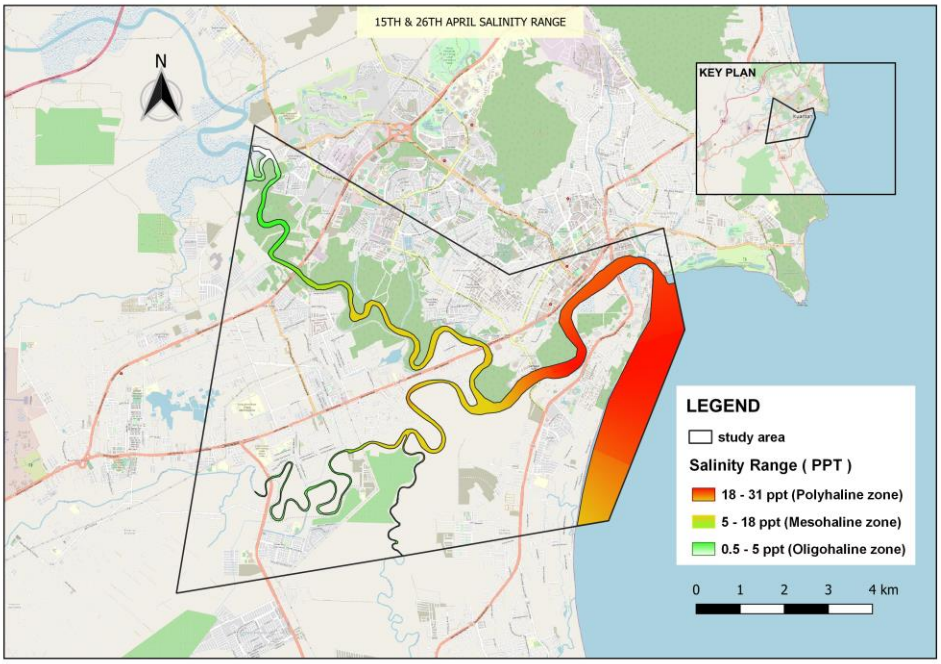

Figure 14 Distribution pattern of salinity for 15th & 26th March in low tides.

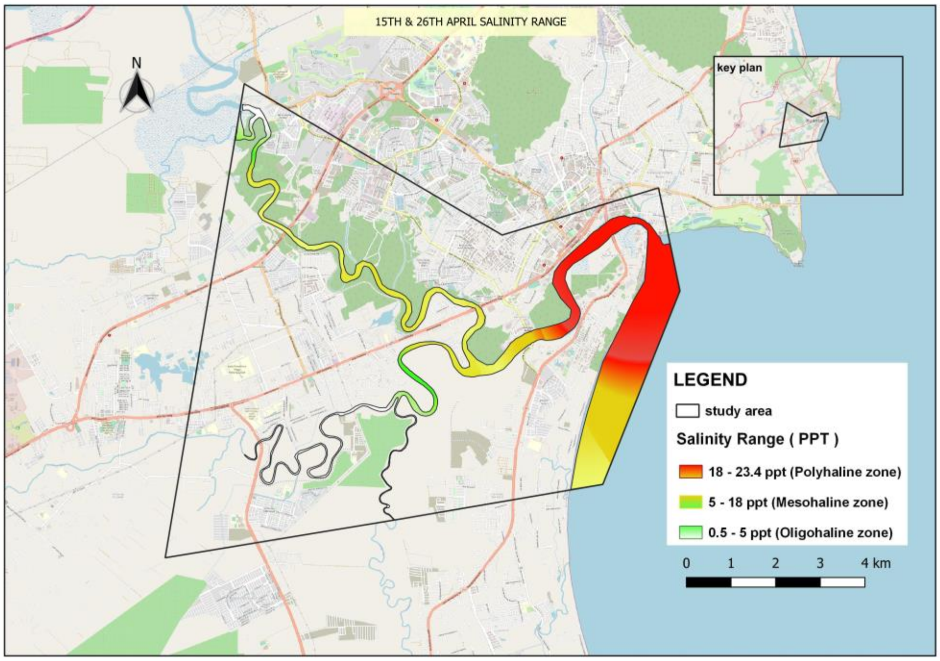

Figure 15 Distribution pattern of salinity for 15th & 26th March in low tides.

Based on Figure 14 and 15, both high and low tides on 16th & 26th had three salinity zones which are polyhaline, mesohaline and oligohaline. However, there was a slightly difference between the value of salinity distribution in high tide and low tide conditions. In high tides the salinity distribution ranges from 0.5 ppt to 31 ppt with the highest salinity at the mouth. While in low tides the salinity of the river ranges from 0.5 ppt to 23.4 ppt.

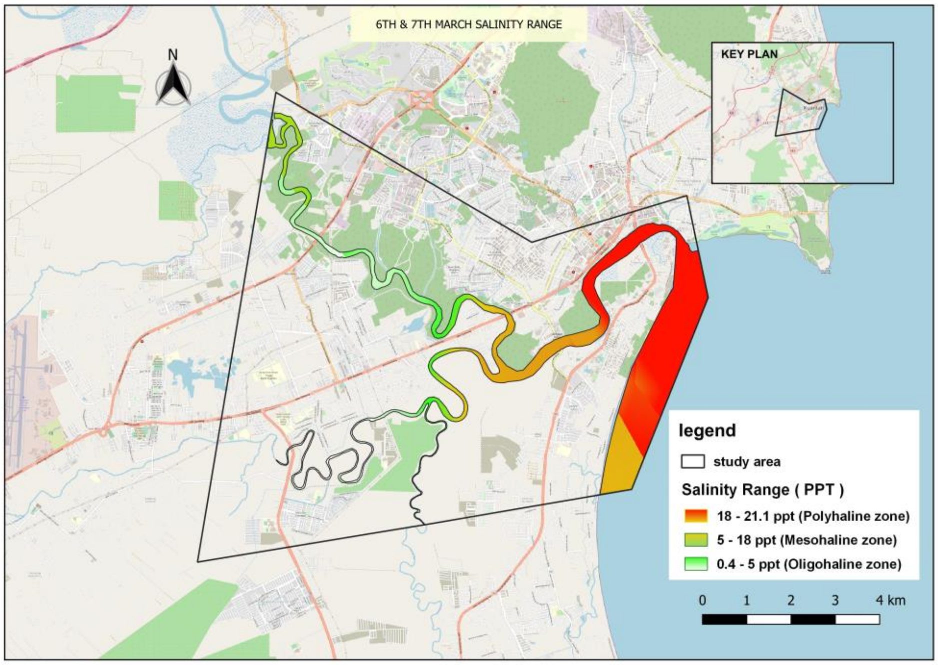

Figure 16 Distribution pattern of salinity for 6th & 7th March in high tides.

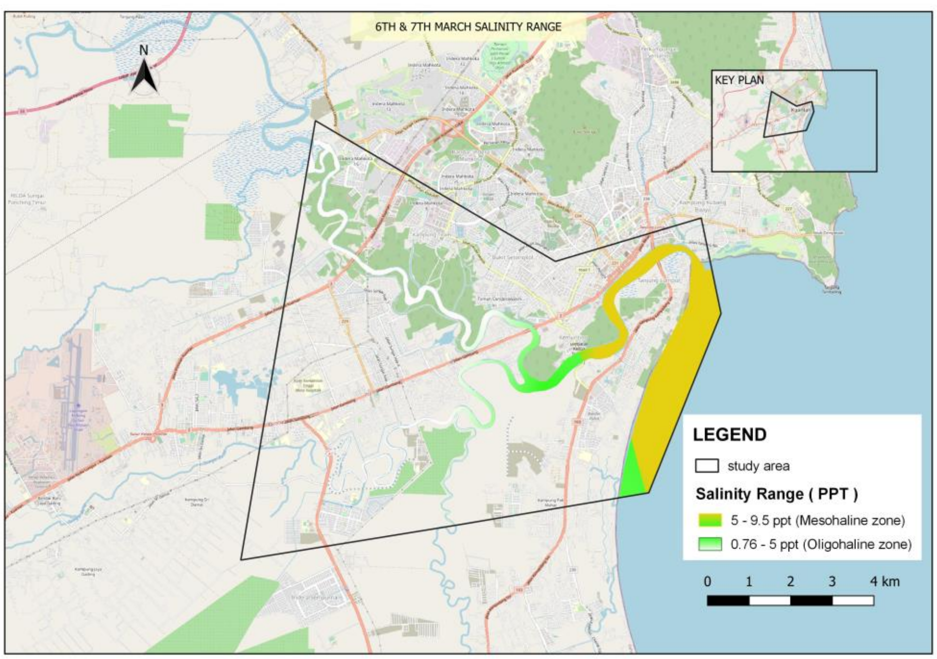

Figure 17 Distribution pattern of salinity for 6th & 7th March in low tides.

Based on Figure 16 and 17, there is a significant difference between the value of salinity distribution in high tide and low tide conditions. In high tides the salinity distribution ranges from 0.5 ppt to 20.1 ppt with the highest salinity at the mouth. It also had three salinity zones which are polyhaline, mesohaline and oligohaline. While in low tides the salinity of the river ranges from 0.76 ppt to 9.5 ppt which include only two salinity zones mesohaline and oligohaline.

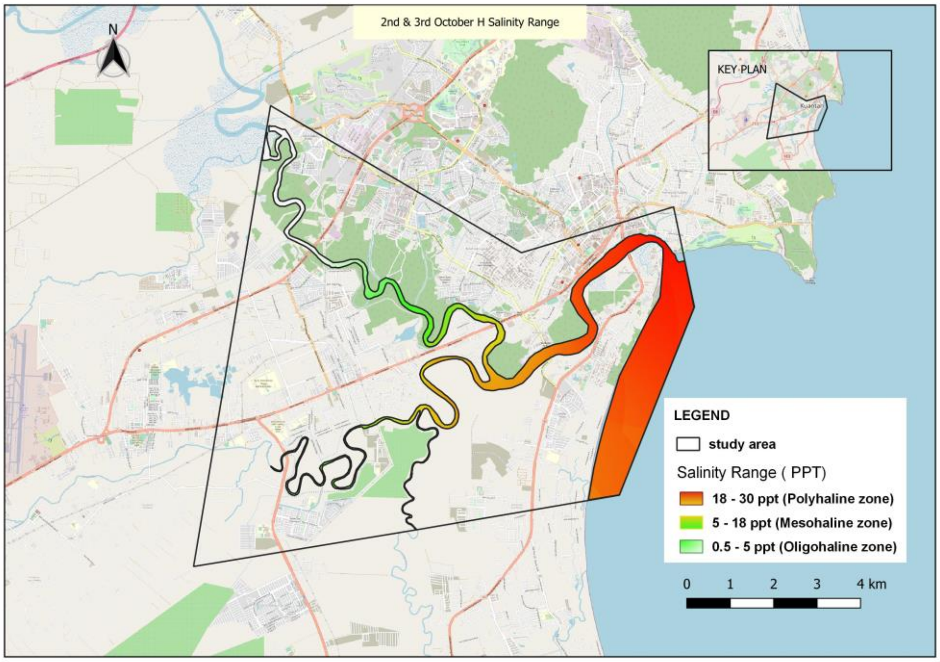

Figure 18 Distribution pattern of salinity for 2nd & 3rd October in high tides.

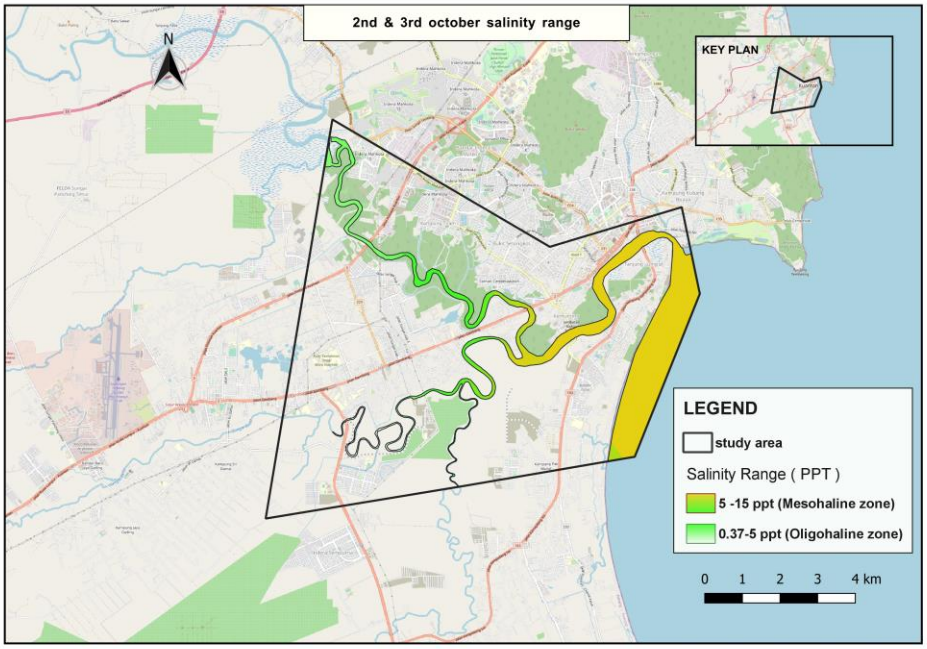

Figure 19 Distribution pattern of salinity for 2nd & 3rd October in Low tides.

Based on Figure 16, 17, 18 and 19, the salinity zone distribution of 2nd & 3rd October showed a similar pattern as 6th & 7th March distribution pattern. However, there was a slightly difference in the salinity range between them. On 2nd & 3rd October the value of salinity in both high tides and low tides were higher. In high tides the salinity ranges from 0.5 ppt to 30 ppt. while in low tides the salinity of the river ranges from 0.37 ppt to 15 ppt.

4.4 INFLUENCE OF SALINITY ON MANGROVE SPECIES DISTRIBUTION

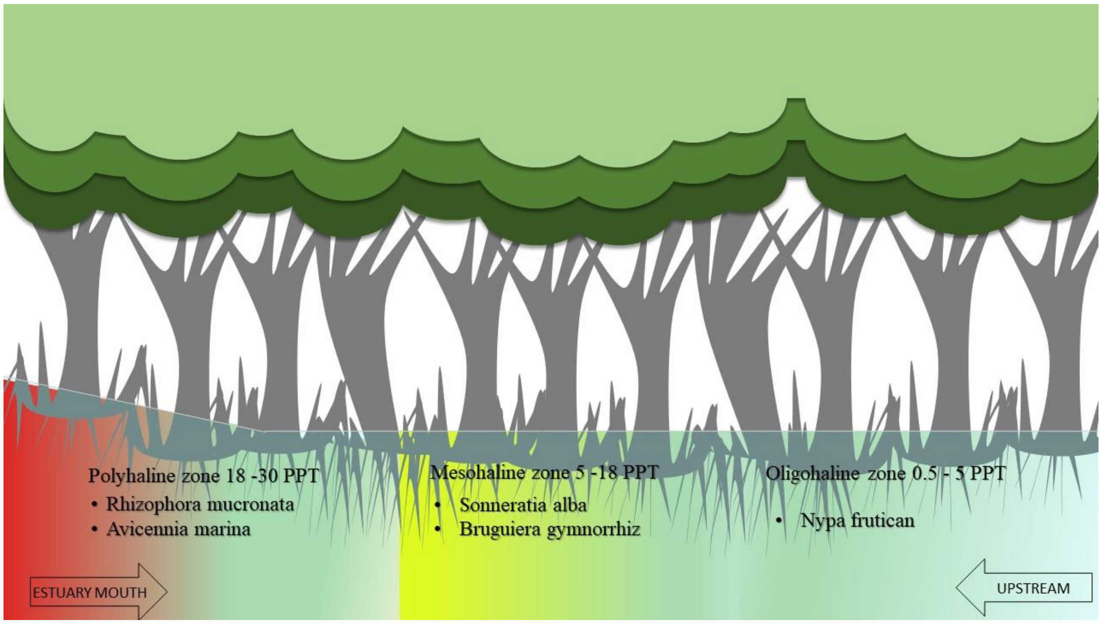

Figure 20 Distribution of mangrove species in different salinity range.

Salinity levels largely control the kinds of plants and animals that can survive in different estuarine zones. The upper portions of the estuary may be inhabited only by freshwater species, whereas the estuarine outlet is habitat to marine animals. Some species can only withstand moderate salinities, whereas widely adaptable species can adapt to salinities ranging from fresh water to seawater. Mangrove plants can withstand salinities of between 2 to 90 ppt. However, laboratory research demonstrate that mangrove plants only develop to their maximum potential in conditions with moderate salinity (v. Selvam, 2019). In Kuantan River there are 5 species of mangroves. The mangrove species were distributed based on the three salinity zones polyhaline, mesohaline and oligohaline. The species found are Avicennia marina, Sonneratia alba, Rhizophora mucronate, Bruguiera gymnorrhiza and Nypa frutican. The dominant species found in Kuantan were Sonneratia alba and Rhizophora mucronate. However, various species found mixing in small portions with other species in all areas. Most of the mangroves in Kuantan are distributed along riverbanks, and tall mangroves like Sonneratia alba are not only found in the back mangrove area but also in the front mangrove region. The occurrence of mangrove species in different salinity range and zonation in Kuantan River are listed in Table 10.

Table 10 the occurrence of mangrove species in different salinity zones.

Polyhaline zone	**Mesohaline zone**	**Oligohaline zone**
Rhizophora mucronate 18 - 30 ppt	Sonneratia alba 13 - 19 ppt	Nypa frutican 0.5 – 5 ppt
		
Avicennia marina 15 ppt – 30 ppt	Bruguiera gymnorrhiza 5 - 15 ppt	
		

4.5 MANGROVE DEGRADATION MAPPING

4.5.1 CLASSIFICATION AND ACCURACY ASSESSMENT

Based on the supervised analysis maximum likelihood 4 categories of landuse land cover were analyzed, Mangroves, built-up, vegetation and water. The producer and user accuracy for each category was obtained as well as the Kappa coefficient and overall accuracy. The values of accuracy assessments and Kappa coefficient is listed in table 5. For both 2002, and 2018 images, the accuracy evaluations and the supervised classification's Kappa coefficient (K) were satisfactory.

Table 11 summary of accuracy assessment.

		Supervised classification (maximum likelihood)			
Satellite	Category	producer accuracy (%)	user accuracy (%)	Kappa coefficient	overall accuracy (%)
2002 Landsat 7	Waterbody	98.1	100	0.95	96.7
	Mangroves	93.3	95.4		
	Build-Up	100	100		
	Vegetation	96.1	89.2		
2018 Sentinel-2	Waterbody	99.9	97.9	0.92	97
	Mangroves	93.5	95.3		
	Build-Up	76.8	96.3		
	Vegetation	89.6	89.3		

4.5.2 MANGROVE COVER

The degradation of the mangroves along the Kuantan River was identified by several types of coastal developments as the main cause of degradation. Land clearing for commercial and residential building as well as agriculture were the main reason of mangrove degradation in Kuantan between 2002 and 2018. Moreover, other developments such as jetty for fisheries landing and facilities like highways and flyovers have been constructed to connect places, mostly situated along the riverbank and coastline. Figure 21 and 22 shows how agriculture and build-up land use that affected the mangrove cover. As a result, Kuantan mangroves decreased from its total area of 2335.8 ha in 2002 to its total area of 1541.91 ha in 2018, the mangrove cover declined by 34% or 793.89 ha. Figure 23 depicts the decline in mangrove areas of the years 2002 and 2018.

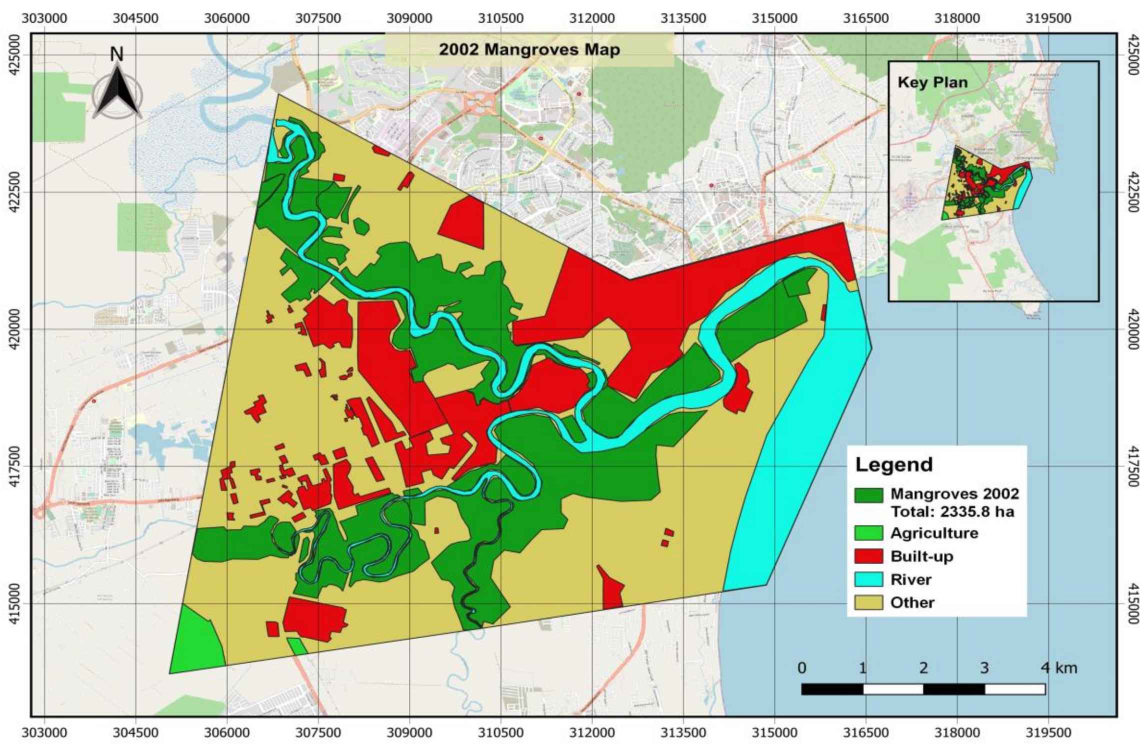

Figure 21 Mangrove cover area in 2018.

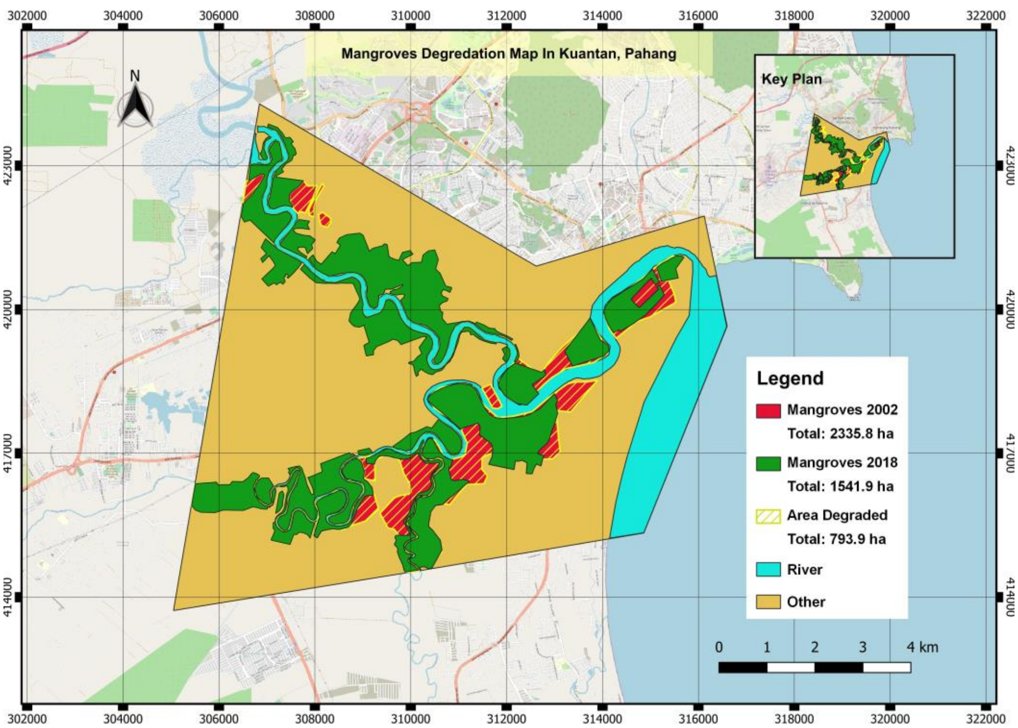

Figure 22 Mangrove cover area in 2002.

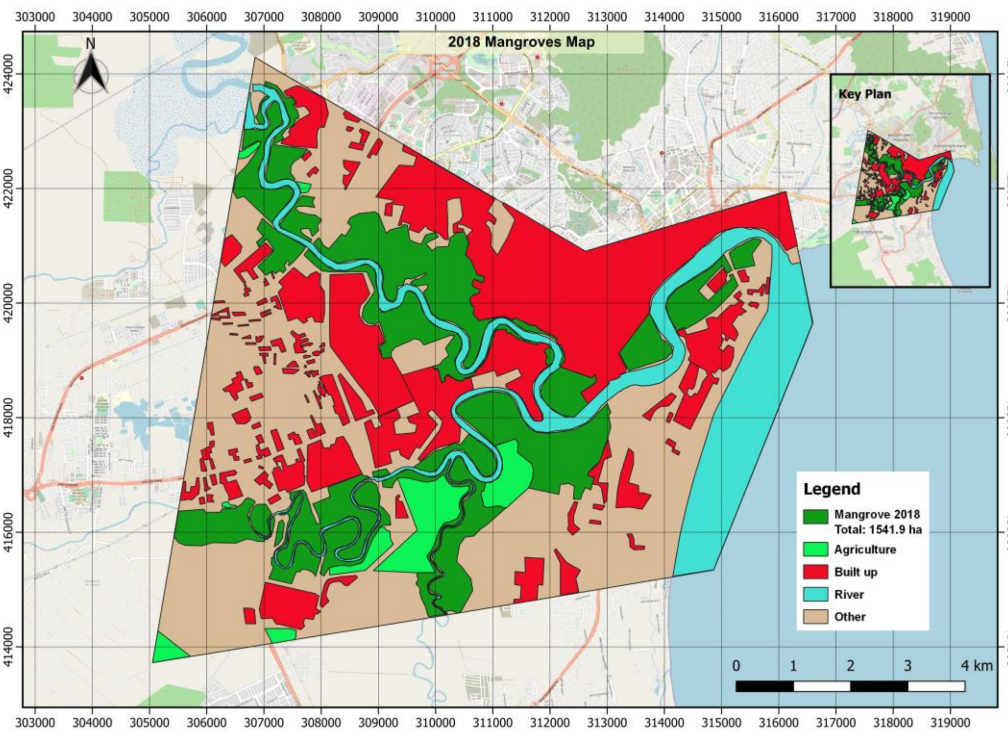

Figure 23 Changes in mangrove cover from 2002 to 2018.

4.5.2.1 AREA WHERE MANGROVE DEGRADED IN KUANTAN.

.**Figure 24** degraded areas of Kuantan mangroves.

Chapter 5

CONCLUSION AND RECOMMENDATIONS

5.1 INTRODUCTION

The objective of this study was to evaluate the influence of salinity towards the change of mangrove diversity using supervised approach and to develop the mangrove distribution mapping showing the degree of degradation between 2002 and 2018 as a result of development. The salinity condition in both Kuantan and Belat estuaries have been collected from previous study. high and low water slack data had been used to show the salinity distribution over Kuantan and Belat estuaries using Qgis software. The study for the estuary covered from the mouth of estuary until the reading reached 1ppt but restricted until the Kobat barrage. three of the field surveys data had been used in this study for Kuantan Estuary on 3rd October 2017, 7th March, and 15th April 2018. In addition to another three surveys for Belat Estuary on 26th April 2nd October 2017, and 6th March. The result showed that Kuantan River includes three salinity zones polyhaline, mesohaline and oligohaline. And it also showed that the highest salinity was recorded is 31 ppt at the mouth of the estuary.

Five mangroves' species were found in Kuantan River which are Avicennia marina, Sonneratia alba, Rhizophora mucronate, Bruguiera gymnorrhiza and Nypa frutican. The dominant species found to be Sonneratia alba and Rhizophora mucronate. The species were distributed based on the three salinity zones. Polyhaline zone contains Rhizophora mucronate and Avicennia marina. And Mesohaline zone contains Sonneratia alba and Bruguiera gymnorrhiza. Finally, Oligohaline zone contains Nypa frutican.

However, mangroves in Kuantan River had been degrading over the years. By using sentinel-2 and Landsat 7 satellite images with the aid of Qgis software the total degraded area of Kuantan mangroves between 2002 and 2018 had been found to be 793.89 ha or 34% mainly because of commercial and residential development as well as agriculture activities.

5.2 RECOMMENDATION

Further research can be done to evaluate the trend of future mangrove zonation assessing their ability to adapt in different environmental conditions. Additionally, more research should be conducted to understand how salinity fluctuations affect the zonation of different mangrove species. Furthermore, for better mangroves mapping, hyperspectral data usage must be considered to identify mangrove species and their degradation level properly and precisely. It is advised that ongoing mangrove monitoring studies be conducted in Kuantan as the rate of degradation is alarming.

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