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Mapping the Mangrove Vulnerability Index Using Geographical Information System

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***Abstract*—A mangrove vulnerability assessment's goal is to generate recommendations for reducing vulnerability. Mangrove forests, which grow in the intertidal zones and estuary mouths between land and sea, exist in two worlds at once. Mangroves provide crucial stability for preventing shoreline erosion. It helps to maintain land level by sediment accretion while balancing sediment loss by serving as buffers catching materials washed downstream. Climate change, especially the associated increase in sea level, poses a serious threat to mangrove coastal areas, and it is critical to devise strategies to mitigate vulnerability through strategic management planning. Experts are attempting to determine how mangroves have been affected by climate change and rising sea levels. How do we forecast the consequences and effect of rising sea levels on mangroves, and then adjust and mitigate them accordingly? Vulnerability implies the risk of being assaulted or hurt, whether physically or emotionally. Environmental vulnerability is a feature of impact exposure as well as ecological systems' susceptibility and adaptive potential to environmental tensors. Researchers in this study ranked mangrove vulnerability on a scale of 1 to 5, with 1 indicating very low vulnerability and 5 indicating very high vulnerability. The Physical Mangrove Index (PMI), Biological Mangrove Index (BMI), and Threat Mangrove Index (HMI) are the three major groups of the Mangrove Vulnerability Index (MVI)). The study's main objective is to develop an accurate and efficient GIS database system that has been formulated and tested or implemented in three (3) separate areas, namely, Kukup Island, Tanjung Piai, and Sungai Pulai. The study develops a GIS-based Mangrove Vulnerability Index (MVI) Model for a selected ecosystem, and highlights mangrove vulnerability by ranking them from least to most vulnerable using parameters. The study also provides a forecast for the mangrove loss in the next 50 and 100 years, as well as to classify areas where mangroves are most vulnerable.**

***Keywords*—GIS, geographical information system, vulnerable, mangrove vulnerability index, mangrove, ranking, parameter**

I. INTRODUCTION

Mangrove trees are salt-tolerant trees that provide protection to tropical shores, islands, and estuaries (Ellison J. C., 2000). Southeast Asia has the world's largest mangrove area at 6.8 million hectares. Indonesia, Malaysia, Myanmar, Papua New Guinea, and Thailand have the largest mangrove areas. Malaysia is home to about 12% of Southeast Asia's mangroves, which are mostly found along the coast of Sabah (57 percent) (Faridah Hanum and colleagues, 2012). The mangrove stabilisation helps to keep the shoreline from eroding maintains land level based on accretion of sediments to counter loss of sediment by acting as buffers collecting downstream washed objects (Gomez *et al.*, 2019). Mangroves can also be used to treat effluent because they absorb nutrients like nitrates and phosphates. Filtration of sediments and pollutants can help to improve water quality. Aside from that, mangroves absorb carbon dioxide, which helps to mitigate the effects of global warming. It also serves as a buffer zone in the event of severe weather, such as storms and hurricanes, protecting and shielding the coastline from property damage and loss of life (Bell and Lovelock, 2013).

Fisheries, aquaculture, and other sources of income for coastal residents, such as eco-tourism and agriculture, are all dependent on healthy mangroves. They also provide medicine, fuel, food, and building materials to the local population (Mohammad, 2018). For thousands of years, mangrove has been a source of building materials, charcoal, medicines, firewood fibres and dyes, food, and other resources. Mangroves act as salt filters and have aerial roots that allow them to occupy mineral salt watering areas where other plants cannot (Kathiresan and Bingham, 2001).

Mangroves have evolved to accommodate the variety of species that may thrive in their environment. It provides habitat for flora and fauna, including nursery grounds, shelter, as well as food, and it is home to 75 percent of tropical fish. High tide raises water salinity; as the tide falls, heat evaporation occurs, and salinity rises. Meanwhile, the sea will wash these soils away, bringing them back to water salinity levels. Temperature and desiccation increases are also experienced by mangroves, which are then cooled and flooded by the low tide (Kathiresan and Bingham, 2001). Mangroves must be able to withstand rainfall, salinity, and temperatures, as well as other environmental factors, to thrive in this climate (Mildred, E, 2012).

Mangrove forests are significant for the ecological and socio-economic production of coastal land. Harada *et al*. (2002) conducted a hydraulic tsunami impact assessment using five different models, including mangrove, coastal and wave-dissipating structures, breakwater rock, and buildings. It indicates that mangrove is an effective solution for the other four versions. Mazda *et al*. (1997a) estimated that six-year-old mud forests of 1.5 kilometers in diameter decrease tidal waves from one meter of high open sea to 0.05 meters on the coast by twenty times.

II. Objectives of the Study

The study's objective is to create an accurate and efficient GIS database system that will be formulated, tested, and applied in three (3) different research areas: Kukup Island, Tanjung Piai, and Sungai Pulai. The second objective is to create a Mangrove Vulnerability Index (MVI) Model for a specific ecosystem using GIS. The final objective is to highlight mangroves by using parameters to rank them from least to most vulnerable.

III. Data Capture

Data for each of the variables describes various agencies develop a GIS database for assessing coastal vulnerabilities. Base Map – JUPEM, WorldView-2, IFSAR image, SPOT Images, Geomorphology, Geologic Material, Regional Coastal Slope and Shoreline Changes are all used to compile spatial data. Mangrove Species, Mangrove Height, Mangrove Diameter at Breast Height (DBH), Tidal Range, Relative Sea Level Change, Coastal Slope, Sea Level Change, Mean Tidal Range, Mean Significant Wave Height, Shoreline Changes Rate, Population, Land use, Economic Activities, Infrastructure, Heritage, Vegetation, and Mangrove Species are examples of the attribute data.

IV. Spatial Analysis of Study Area

A set of techniques for analysing spatial data is known as spatial analysis. The location of the objects being analysed affects the results of spatial analysis. Access to both the locations of objects and attributes is required by software that uses spatial analysis techniques. Spatial analytics is how we map study area, how they relate, what it all means, and what actions to take to understand what we are predicting. Spatial analysis is at the heart of geographic information system (GIS) technology, from computational analysis of geographic patterns to finding optimum routes, site selection, and advanced predictive modelling. Pulau Kukup, Sungai Pulai, and Tanjung Piai are the study areas in this research. Fig. 1.1 illustrates the maps of the Pulai Kukup, Sungai Pulai and Tanjung Pilai respectively.

Kukup Island is a Malaysian island off the coast of Johor which is entirely covered byMangroves and mudflats. Pulau Kukup was designated as a RAMSAR site on January 31, 2003, to promote the preservation of this unique mangrove habitat. The largest riverine mangrove system in Johore is the Sungai Pulai Mangrove Forest Reserve. The Sungai Pulai mangrove was also designated as a RAMSAR site in 2003, covering approximately 9,126 hectares (Goh, 2016). Tanjung Piai is the southernmost point of continental Asia, with 5.2 km2 of mangroves and nearly four km2 of intertidal mudflats. Tanjung Piai is situated in the southernmost part of the Asian mainland, which is located at the southernmost part of Malaysian peninsula. Tanjung Piai was designated as a National Park on February 26, 2004, under the Johore State Park Corporation Enactment, and as a Wetland of International Importance on January 31, 2003, under the RAMSAR Convention 1971 (Mehra, N. and Lye, L.H, 2015).

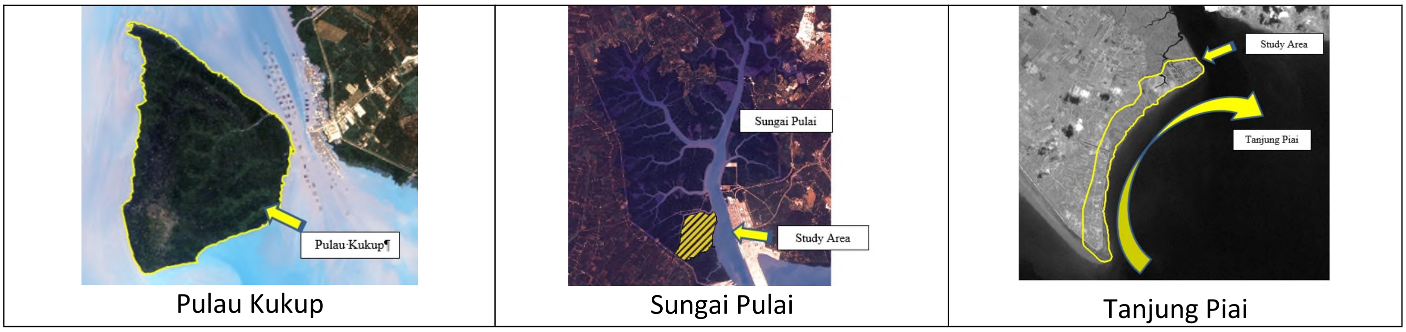

Fig. 1.1. Study Area – Pulau Kukup, Sungai Pulai and Tanjung Piai

V. MANGROVE VULNERABILITY INDEX

The Mangrove Vulnerability Index (MVI) is a comprehensive framework for assessing combined social-ecological responses to environmental change. Physical Mangrove Index (PMI), Biological Mangrove Index (BMI), and Hazard Mangrove Index (HMI) are the three variables that make up MVI. In PMI, three parameters are considered: mangrove roots, mangrove growth, and mangrove height. Distance to Coastline, Soil Type, Tidal Range, Elevation, Salinity, and Mangrove Canopy Density are some of the important examples of the BMI parameters, while Wind, Wave, Erosion / Accretion, Sea Level Rise, Rainfall, and Human Activity are among the HMI parameters . The Physical Mangrove Index (PMI) describes the mangrove's physical characteristics. In this study, the author identified two main characters that must be discovered to consider vulnerability: Mangrove Species and Mangrove Height. While The Biological Mangrove (BMI), is a set of factors that influence whether a mangrove tree is protected or destroyed.

In general, natural factors such as climate and weather can cause BMI to fluctuate. In this study, specifically, distance to coastline, soil type, tidal range, elevation, salinity, mangrove canopy, and NDVI were all determined for BMI parameter. HMI considers both common conditions that can cause gradual 'slow-onset' events and rare high-impact events that can cause massive damage. It should be noted that not all HMI parameters occur at the same time. In this study, the authors consider six factors, namely, Wind, Wave, Erosion / Accretion, Sea Level Change, Rainfall, and Human Activity. Table 1.1 demonstrates the parameter information along with a list of references, whereas Table 1.2 shows parameter rankings.

TABLE 1.1. Parameter with list of reference

Mangrove Vulnerable Index	Parameters	Source
Physical Mangrove Index (PMI)	1. Mangrove Species	(Ng and Sivasothi, 2001)
	2. Mangrove Height	(Ng and Sivasothi, 2001)
Biological Mangrove Index (BMI)	3. Distance to coastline	(Spalding, 2014, Tran Quang Bao, 2011)
	4. Soil and Geomorphology	(Pendleton et. al, 2004 and Gornitz *et al*., 1977)
	5. Tidal Range	(Ellison, 2015)
	6. Elevation	(McIvor, *et al*., 2013)
	7. Mangrove Canopy Density	(Shadow Index (SSI), Spalding, 2014)
	8. NDVI	(Bisrat and Berhanu, 2018)
	9. Salinity/Temperature	(Duke *et al*, 2010 , Robertson and Alongi, 1992)
Hazard Mangrove Index (HMI)	10. Wind	(Beaufort Scale, Spalding, 2014)
	11. Wave	(Beaufort Scale, Spalding, 2014)
	12. Sea Level Change	(IPCC, 2013)
	13. Rainfall	(Lau, 2011)
	14. Human Activity • Industrial Threats • Shipping • Villages	(Jabatan Perancang Bandar dan Desa Negeri Selangor, 2012) (The Nautical Institute and The World Ocean Council, 2017) (IMO, 2017)

TABLE 1.2. Parameter Ranking

Parameter		1	2	3	4	5
		Very Low	Low	Moderate	High	Very High
Mangrove Species		Prop Roots / Stilt Roots (Rhizophora group)	Knee roots (Bruguiera group)	Pneumatophores/ pencil roots Plank Roots (Avicennia group)	Cone Root (Xylocarpus group and Sonneratia group)	buttress roots (Heritiera littoralis Pelliciera rhizophorae)
Mangrove Height	Rhizophora mucronata	16-30m	11-15m	6-10m	3-5m	0-2m
	Rhizophora apiculata	21-25m	11-20m	6-10m	3-5m	0-2m
	Sonneratia alba	21-25m	11-20m	6-10m	3-5m	0-2m
	Bruguiera parviflora	16-17m	11-15m	6-10m	3-5m	0-2m
	Brugueira cylindrical	16-17m	11-15m	6-10m	3-5m	0-2m
	Xylocarpus muluccensis	17-25m	11-16m	6-10m	3-5m	0-2m
	Rhizophora mucronata	15-30m	31-32m	33-34m	35-38m	>38m
	Rhizophora apiculata	20-25m	26-27m	28-29m	30-31m	>31m
	Sonneratia alba	20-25m	26-27m	28-29m	30-31m	>31m
	Bruguiera parviflora	15-17m	18-19m	20-21m	22-23m	>23m
	Brugueira cylindrical	15-17m	18-19m	20-21m	22-23m	>23m

Parameter		1	2	3	4	5
		Very Low	Low	Moderate	High	Very High
	Xylocarpus muluccensis	16-25m	26-27m	28-29m	30-31m	>31m
Distance to coastline		240-600m	120m-240m	80m-120m	40m-80m	0m-40m
Geomorphology		Barrier beaches, sand, beaches, mudflat, delta, coral	Cobbles, beach, estuary, lagoon.	Low cliff, alluvial plan	Medium cliff indented coast	Rocky cliff coast
Geologic		Coral reef	Volcanic ash, composite	Unconsolidated sediments (loose, uncemented),Mud, clay, silt, sand, conglomerate, glacial till, calcareous sediments and mixed or varied lithology	Sedimentary rock (cemented, grabular, weak minerals) and weak metamorphic rock	Old erosion resistant rock and stronger metamorphic rock
Tidal Range Ranking		>3m	2-3m	1.5-2m	1-1.5m	<1m
Elevation Ranking		>4.57m	3.96-4.57m	3.35-3.96m	2.44-3.35m	<2.44m
Canopy Density		> 80% density	50-80% density	25-50% density	1-25% density	Less than 1 density
NDVI		Dense green leafy vegetation (0.500-1.000)	Medium green leafy vegetation (0.140-0.500)	Light green leafy vegetation (0.090-0.140)	Bare soil (0.025-0.090)	Swampy areas/wet lands, water body (-1.000 – 0.025)
Salinity	Rhizophora mucronata	8-33 ppt	34-35 ppt	36-37 ppt	38-40 ppt	> 41 ppt
	Rhizophora apiculata	8-15 ppt	16-20 ppt	21-30 ppt	30-60 ppt	> 61 ppt
	Sonneratia alba	11-20 ppt	21-25 ppt	26-28 ppt	29-32 ppt	> 33 ppt
	Bruguiera parviflora	8-34 ppt	35-40 ppt	41-50 ppt	51-66 ppt	>67 ppt
	Bruguiera cylindrical	8-34 ppt	35-40 ppt	41-45 ppt	46-50 ppt	>51 ppt
	Xylocarpus muluccensis	11-23 ppt	24-28 ppt	29-30 ppt	31-32 ppt	> 33 ppt
	Ceriops Tagal	10-15 ppt	15-35 ppt	35-40 ppt	40-45 ppt	>45ppt
	Rhizophora Stylosa	10-15 ppt	15-35 ppt	35-40 ppt	40-45 ppt	>45ppt
	Rhizophora mucronata	8-33 ppt	34-35 ppt	36-37 ppt	38-40 ppt	> 41 ppt
	Rhizophora apiculata	8-15 ppt	16-20 ppt	21-30 ppt	30-60 ppt	> 61 ppt
	Sonneratia alba	11-20 ppt	21-25 ppt	26-28 ppt	29-32 ppt	> 33 ppt
	Bruguiera parviflora	8-34 ppt	35-40 ppt	41-50 ppt	51-66 ppt	>67 ppt
	Bruguiera cylindrical	8-34 ppt	35-40 ppt	41-45 ppt	46-50 ppt	>51 ppt
	Xylocarpus muluccensis	11-23 ppt	24-28 ppt	29-30 ppt	31-32 ppt	> 33 ppt
	Ceriops Tagal	10-15 ppt	15-35 ppt	35-40 ppt	40-45 ppt	>45ppt
	Rhizophora Stylosa	10-15 ppt	15-35 ppt	35-40 ppt	40-45 ppt	>45ppt
Wind Speed (m/s)		> 11km/h	12-19 km/h	20-28 km/h	29-49km/h	>49km/h
Wave Height		>0.2m	0.2-0.6m	0.6-1m	1-3m	>3m
Sea Level Change		<1.8mm/yr	1.8-2.5 mm/yr	2.5-3.0 mm/yr	3.0-3.4 mm/yr	>3.4 mm/yr
Rainfall measurement by three hours period		≤ 100 mm/h	100-150 mm/h	150-250 mm/h	250-500 mm/h	≥500mm/h
Continuously raining over 24 hours that can contribute to flood		≤ 20 mm/d	20-50 mm/d	50-100 mm/d	100-150 mm/d	≥150mm/d
Human Activity	Buffering Zone for Industrial	1250m	1000m	750m	500m	250m
	Main Shipping Route	9000m	7,200m	5,400m	3,600m	1800m
	Secondary Shipping Route	2,500m	2,000m	1,500m	1,600m	800m
	Villages	1250m	1000m	750m	500m	250m

VI. Analysis of Mangrove

For the classification of the Physical Vulnerability Index (PVI) for Mangrove Species. IFSAR (Interferometric Synthetic Aperture Radar) data is used.. It is great for making large-area elevation datasets that are accurate. In a simple form, it is like radio detection ranging classification of manipulation in ArcGIS Mangrove Species based on attribute calculation. The Multivariate toolset includes tools for both supervised and unsupervised classification, thanks to the ArcGIS Spatial Analyst extension. The most common technique for quantitative analysis of remote sensing image data is supervised classification. The concept of segmenting the spectral domain into regions that can be associated with the ground cover classes of interest to a specific application is at the heart of it. The training sample data follows a normal distribution, and the classification analysis is based on the ground truth data.

Unsupervised classification (Fig. 1.2) is a type of pixel-based classification that is essentially computerised. The number of classes is determined by the user, and the spectral classes are created solely based on numerical data in the data (the pixel values for each of the bands or indices). To determine the natural, statistical grouping of the data, clustering algorithms are used. Unsupervised classification employs the Maximum Likelihood Classifier (MLC) and the ISO cluster techniques, an original mechanism, which is quick and simple to implement.

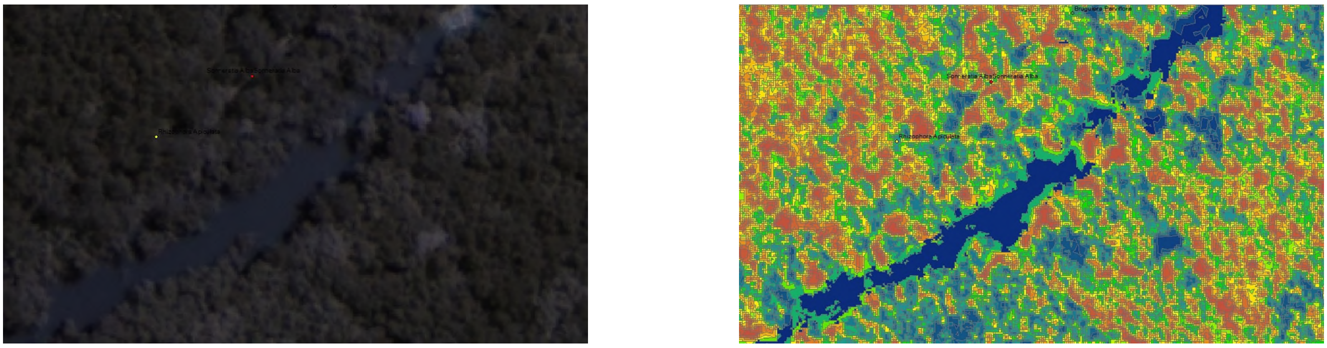

Fig. 1.2. Comparison Original Image and Unsupervised result

To evaluate the final product in a GIS mapping study, accuracy assessment is essentially used. The goal of the evaluation is to provide an assurance of classification quality and user confidence in the item. Steps for assessing accuracy with ArcGIS 10.3. The overall accuracy of supervised classification as can be observed in Fig. 1.3 is higher than that of unsupervised classification, with supervised producing 91.5% compared to 78% for the unsupervised method in terms of accuracy. This shows that the supervised classification is more accurate than unsupervised classification. Table 1.3 and Table 1.4 present the confusion matrix for the supervised and unsupervised classification in terms of the accuracy.

TABLE 1.3. Confusion matrix of the supervised classification image

SPECIES	Sonneratia Alba	Rhizophora Mucronata	Rhizophora Apiculata	Bruguiera Parviflora	Bruguiera Cylindrica	Xylocarpus Moluccensis	User's Accuracy (%)
Sonneratia Alba	3	0	0	0	0	0	100
Rhizophora Mucronata	0	24	0	0	0	1	96
Rhizophora Apiculata	0	0	69	0	0	3	95.83
Bruguiera Parviflora	0	2	2	6	0	1	54.55
Bruguiera Cylindrica	0	0	1	0	16	1	88.89
Xylocarpus Moluccensis	0	1	0	1	0	11	84.62
Producer's accuracy (%)	100	88.89	95.83	85.71	100	64.71	Overall Accuracy 91.5

TABLE 1.4. Confusion matrix of the unsupervised classification image

SPECIES	Sonneratia Alba	Rhizophora Mucronata	Rhizophora Apiculata	Bruguiera Parviflora	Bruguiera Cylindrica	Xylocarpus Moluccensis	User's Accuracy (%)
Sonneratia Alba	3	0	0	0	0	0	100
Rhizophora Mucronata	0	23	0	1	2	3	79.31
Rhizophora Apiculata	0	1	64	0	3	7	85.33
Bruguiera Parviflora	0	2	3	6	0	3	42.86
Bruguiera Cylindrica	0	1	5	0	11	1	61.11
Xylocarpus Moluccensis	0	0	0	0	0	3	100
Producer's accuracy (%)	100	85.19	88.89	85.71	68.75	17.65	Overall Accuracy 78

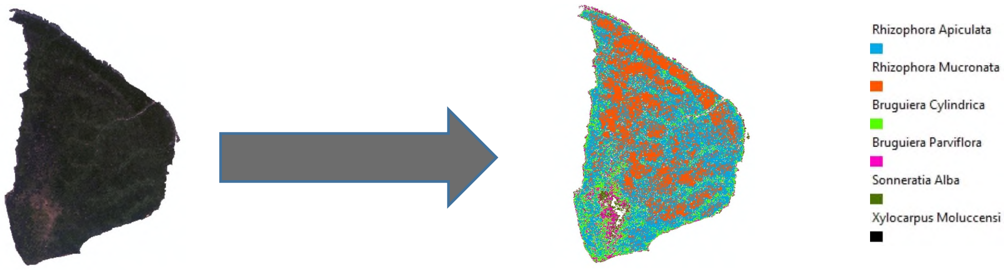

Fig. 1.3. Pulau Kukup Mangrove Species

To calculate the tree height IFSAR data is used and to study . the Earth's surface, two types of Digital Elevation Models (DEM) are created: A Digital Surface Model (DSM) that corresponds to the first returns of the LiDAR three-dimensional points cloud containing all the features of the Earth's surface (ground, vegetation, and constructions), except for abnormal registers; and a Digital Terrain Model (DTM) that takes into account the underlying terrain. To create and execute a map algebra (Fig. 1.4) expression for generating raster data as an output, the raster calculator toll is used in this study. The datasets and variables to use in the expression are selected from the layers and variables list. Select the datasets and variables to use in the expression from the Layers and variables list. By selecting the appropriate buttons in the tool dialogue box, numerical values and mathematical operators can be added to the expression.

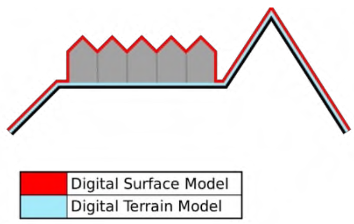

Fig. 1.4. DSM and DTM animation

Ground truth information from mangrove tree height is used to correct the Z value. Pulau Kukup's mangroves reach a maximum height of 25.25 metres. Using the Raster to Polygon tool, an integer type raster is converted to a polygon feature class. Height Map and Species Overlay Process Mangroves create a height map called Mangrove Height Map as shown in Fig. 1.5. To convert a raster to a polygon, the Arc Toolbox is used.

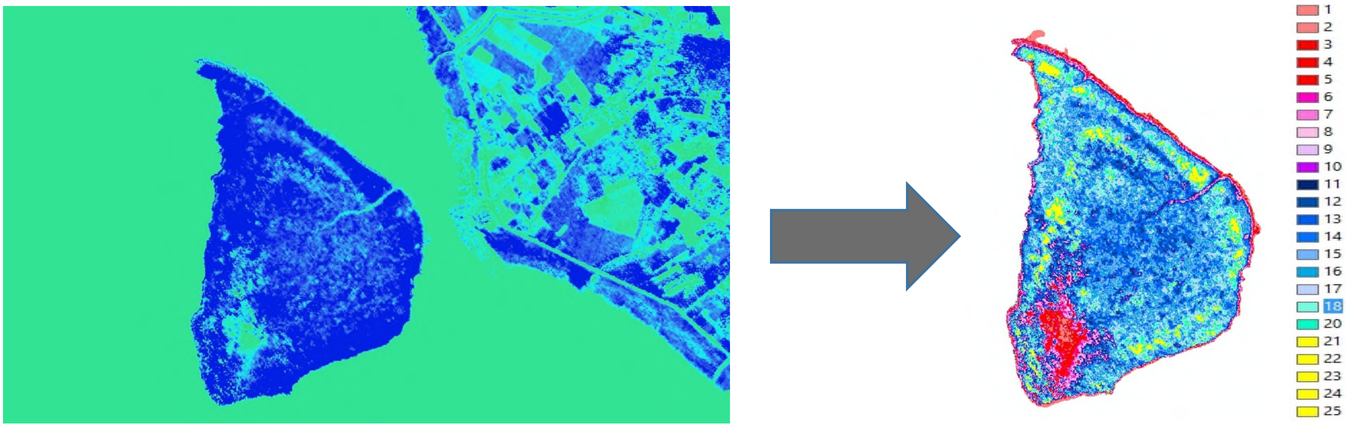

Fig. 1.5. Mangrove Map based on height of mangrove

The buffer tool was used to calculate distances to coastlines. The buffer distance used to buffer each linear unit (X-axis) of the Coastline coordinate system which is stored in the BUFF DIST field of the output feature class. Fig. 1.6 shows the distance to the coastline buffer as a result. Fig. 1.7 which is from the Department of Agriculture, Malaysia (DOA) depicts the major soil types in Johor. Sedentary soils are the most common type of soil in Johor which cover 53% of the total land area.

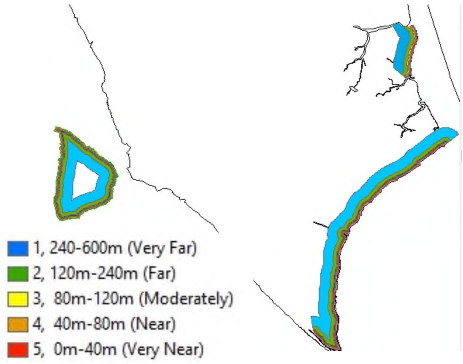

Fig. 1.6. Buffer distance to Coastline

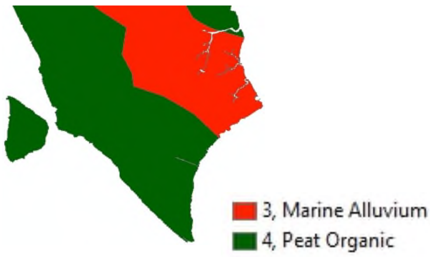

Fig. 1.7. Soil Type (source: Department of Agriculture, Malaysia (DOA))

The type of rock that makes up a rocky cliff and unconsolidated sediments that make up beaches are examples of geologic materials that form coastal landforms (Fig. 1.8). When exposed to erosion, these materials are ranked according to their erodibilities. Fig. 1.8 depicts BMI geology.

Table 1.1. Parameter with list of reference

Ellison, (2015) used a DTM data and slope along the coastline with height to calculate the tidal range (Y-axis) parameter. To manipulate a raster image, the author uses the reclassify as shown in the Fig. 1.9 tool. VI classes were extracted using the Classify statistics method.

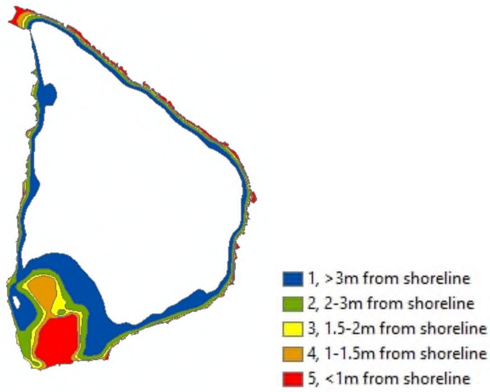

Fig. 1.9. Pulai Kukup Tidal Range

In ArcGIS, the elevation is derived from the DTM contour data (Fig. 1.10). Sea level is 0 and heights are orthometric. This is the foundational service from which all other services are built. DTM sources have a smaller data volume, making them easier to manipulate and display.

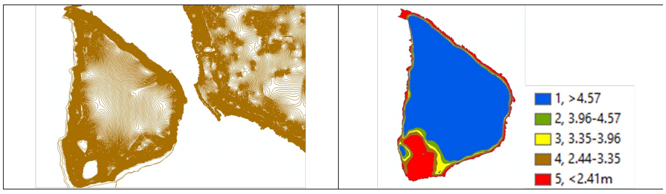

Fig. 1.10. DTM Contour data

Several environmental applications, such as biomass estimation, vegetation coverage, and biodiversity determination, use forest canopy density and height as variables (Mutanga and Adam, 2012). The ratio of vegetation to ground as seen from the air is known as canopy density, or canopy cover. IFSAR data is used to determine these variables. Canopy height refers to how high the top of the canopy is above the ground (ArcGIS 10.3 help). On each of the input cells of an input raster, performs a conditional (con) if/else evaluation. In this case, the researcher used a raster calculation with a Map Algebra Expression, and the height of the mangroves which was calculated from the result (Fig. 1.11).

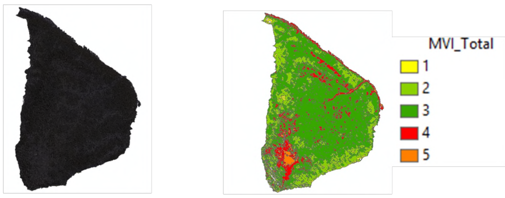

Fig. 1.11. Kukup Island Canopy Density

NDVI uses the spectral reflectivity of solar radiation to calculate differential reflection in the red and infrared (IR) bands, allowing researchers to track the density and intensity of green vegetation growth. In the near-infrared wavelength range, green leaves often reflect better than in visible wavelength ranges. When leaves are water stressed, diseased, or dead, they turn yellow and reflect less in the near-infrared spectrum (refer Fig. 1.12). The default NDVI equation is given as follows:

NDVI = ((IR - R)/(IR + R))
IR = pixel values from the infrared band
R = pixel values from the red band

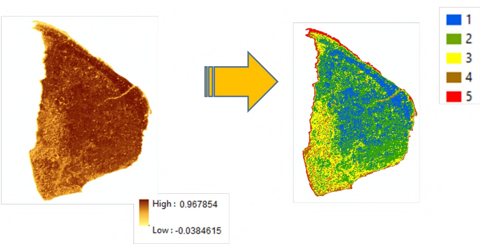

Fig. 1.12. NDVI Map Pulau Kukup

In ArcGIS, the Inverse Distance Weighted (IDW) method is an automatic and relatively simple technique. This is an interpolation technique in which the interpolation is estimated based on values in the closest location, which are only measured by distance from the interpolation location (Garnero and Godone, 2013; Naoum, andTsanis, 2004). Salinity, wind and wave, rainfall, and temperature parameters are used to determine the point of mangrove vulnerability. Using a linearly weighted combination of a set of sample points, IDW interpolation determines cell values. The weight is inversely proportional to the distance. The surface to be interpolated should be a location-dependent variable's surface. This method assumes that the influence of the variable being mapped decreases as the distance from the sampled location increases(ArcGIS assistance). The interpolated values start to approach the nearest sample point's value. By setting the power to a lower value, more influence will be given to nearby points that are further away, resulting in a smoother surface. Six stations were used to collect salinity data (Fig. 1.13 and Fig. 1.14).

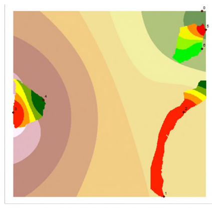

Figure 1.13 IDW using Salinity Data

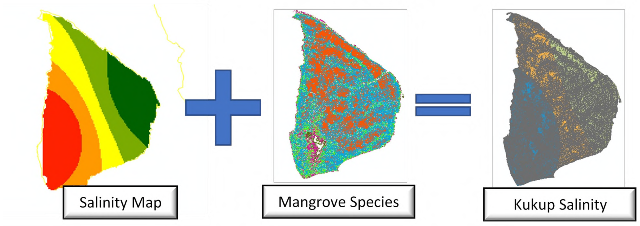

Fig. 1.14. Salinity Result

For the areas without meteorological stations, interpolation techniques are used to estimate wind speed and direction values. The interpolation method chosen is important, and it will be determined by the nature of the variables and the number of points. Because of the limited number of point stations in this study, we used the IDW method. To generate raster data, this method interpolates the values of speed and direction (Figs. 1.15 and 1.16).

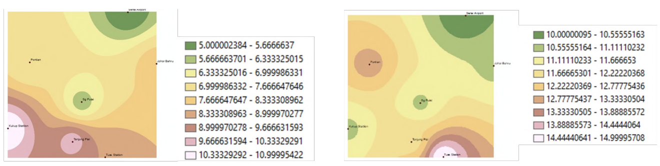

Fig. 1.15. Direction Map and Speed Map

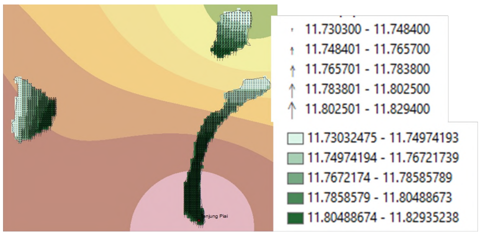

Fig. 1.16. Direction Map and Speed Map of Study Area

Researcher is using the IDW method to determine values by weighting temperature points in order to predict temperature flow in this study area (Fig. 1.17).

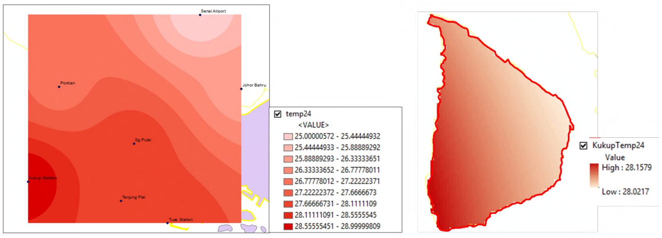

Fig. 1.17. Temperature Map

Rainfall is a significant aspect of hydrologic information. Through well-designed rainfall station networks, sample data is recorded as observational data. Each measured point, according to IDW, has a local influence that decreases with distance. It gives higher weights to points that are closest to the prediction location, and the weights decrease as distance increases, thus the name inverse distance weighted. This can be illustrated as given in Fig. 1.18

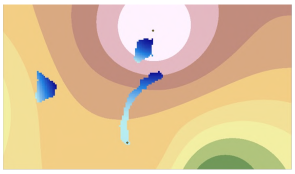

Fig. 1.18. Rainfall Map

In this study area, industrial activities are the most serious threat to mangroves. ATB Oil Terminal, Pelabuhan Tanjung Pelepas, and Tanjung Bin are the three main industrial zones that are developed here. To define this industrial threat, buffer tools (Fig. 1.19) are used. Choose outside polygon(s) and include inside using the buffer wizard from the Create buffers Tools.

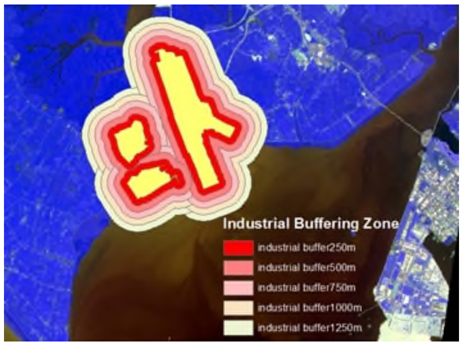

Fig. 1.19. Industrial Buffered result

There are main and secondary shipping routes that have been identified (IMO, 2017). In terms of buffer area, the two shipping routes differed. The Shipping Route Map was created using buffering tools. Data was taken from the Lembaga Pelabuhan Johor, which was published on the 28th of October 2015. Fig. 1.19 depicts the main and secondary shipping routes). Polyline/line buffer creates a polygon feature around a polyline feature in a map at a specified parameter distance. When the primary feature geometry is a polyline, the builder is available with polygon component templates.

There are nearly 35 residential area points. Feature builder with multiple Coincident points creates a point feature that is identical to one created in the map. When the primary feature geometry is a point, the builder is available with the point component (Fig. 1.20).

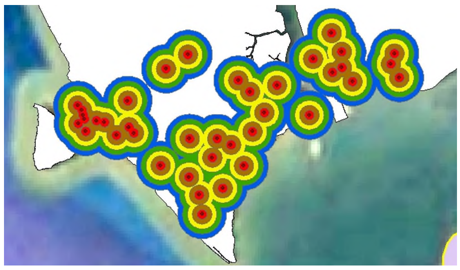

Fig. 1.20. Villages buffering

VII. Final Mangrove Vulnerability Index Map

The Pulau Kukup - Tg. Piai - Sg. Pulai Estuary has been classified as vulnerable, with a rating ranging from 1 (extremely low) to 5 (extremely high). The rankings are generally high, indicating the sensitivity of the coastal area, according to an analysis. These locations are near the shoreline and human activities, resulting in a high classification for the relevant parameters. Fig. 1.22 depicts the Process of overlaying a GIS.

The Physical Mangrove Index is a measure of how healthy a mangrove is. Within each category, the classification was graded from 1 to 5 as shown in Fig. 1.21. The following grades are used to indicate the species and height quality:

1 : very slightly affected (or very low vulnerability)

2 : slightly affected (or low vulnerability)
3 : moderately affected (or moderate vulnerability)
4 : highly affected (or high vulnerability)
5 : severely affected (or very high vulnerability)

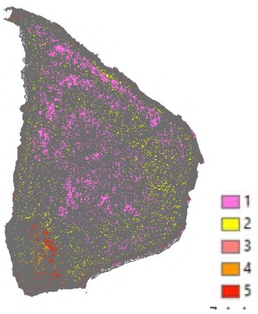

Fig. 1.21. Biological Mangrove

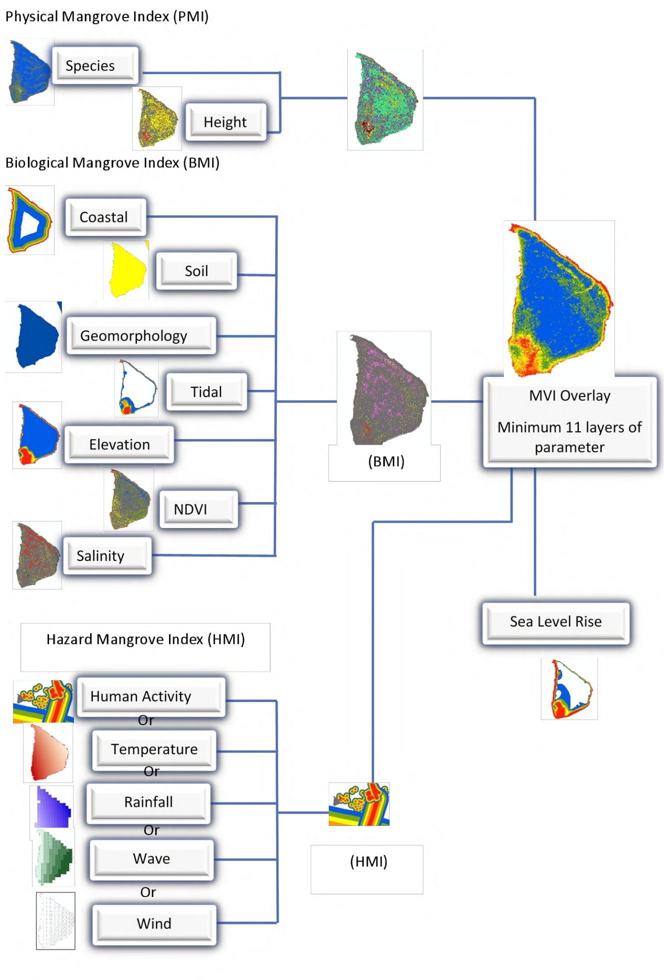

Fig. 1.22. Overlay Process

VIII. MVI Score

Results of the statistical analysis of the calculated MVI values gave the following distribution characteristics. Fig. 1.23, Fig. 1.24 and Fig. 1.26 depict statistics for the for Pulau Kukup, Sg Pulai and Tanjung Piai respectively. The Figs are automatically produced by ArcGIS.

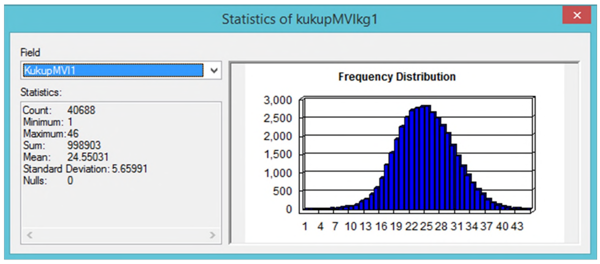

Fig. 1.23. Statistics of Mangrove

Hence, the physical vulnerability of the shoreline can be categorized according to the MVI Scores within the range of the percentiles given in Table 1.5 and Table 1.6 (Kukup Island), Table 1.7 and Table 1.8 (Sungai Pulai) and Table 1.9 and 1.10 (Tanjung Piai).

TABLE 1.5. Percentile Result MVI for Kukup Island

Mean MVI		Std. Deviation	
24.55031		5.65991	
20th percentile	40th percentile	60th percentile	80th percentile
19.78	23.11	25.98	29.31

TABLE 1.6. Range of MVI Scores for Categorisation at Kukup Island

VERY LOW	≤ 19.80
LOW	19.80 < x ≤ 23.1
MODERATE	23.1 < x ≤ 26
HIGH	26 < x ≤ 29.3
VERY HIGH	> 29.3

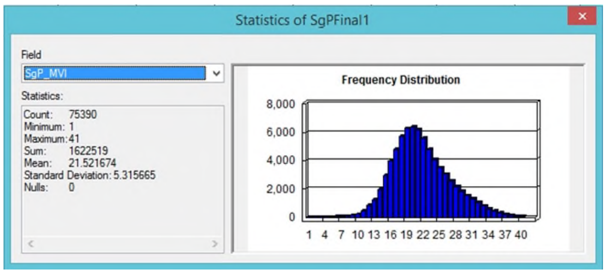

Fig. 1. 24. Statistic for Sg Pulai.

TABLE 1.7. Percentile Result MVI Sg Pulai

Mean MVI		Std. Deviation	
21.521674		5.315665	
20th percentile	40th percentile	60th percentile	80th percentile
17.1	20.17	22.87	26

TABLE 1.8. Range of MVI Scores for Categorisation at Sg Pulai

VERY LOW	≤ 17.1
LOW	17.1 < x ≤ 20.17
MODERATE	20.17 < x ≤ 22.87
HIGH	22.87 < x ≤ 26
VERY HIGH	> 26

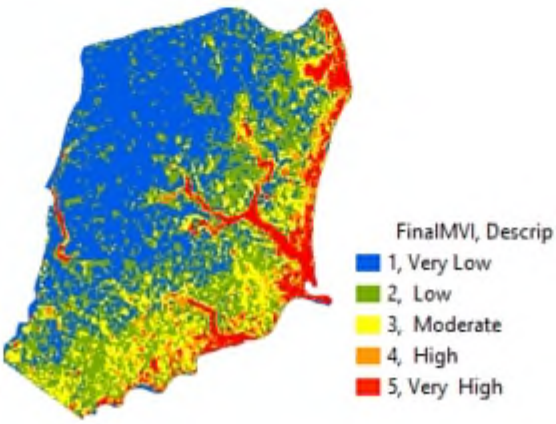

Fig. 1.25. MVI for Sg Pulai

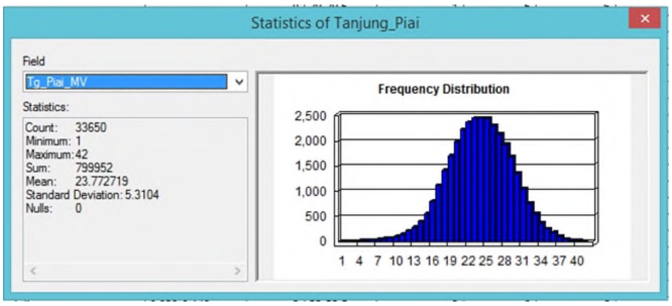

Fig. 1.26. Statistics of Mangrove

TABLE 1.9. Percentile Result MVI for Tanjung Piai

Mean MVI		Std. Deviation	
23.772		5.3114	
20th percentile	40th percentile	60th percentile	80th percentile
19.78681	23.11639	25.98423	29.31381

Where x is the relative or calculated MVI, which is calculated by adding the index values of the physical, biological, and hazard variables. MVI is obtained using Union Tools. [SpeciesMI] + [HeightMI] + [CoastalMI] + [SoilMI] + [GeomoMI] + [Tidal] + [EleMI] + [CanopyMI] + [NDVIMI] + [SalinityMI] + [kg VI] = MVI (using Field Calculator) (result Fig. 1.25, 1.27 and 1.28).

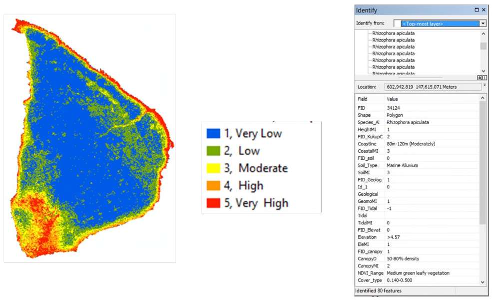

Fig. 1.29. Result MVI

TABLE 1.10. Range of MVI Scores for Categorisation at Tanjung Piai

VERY LOW	≤ 19.80
LOW	19.80 < x ≤ 23.1
MODERATE	23.1 < x ≤ 25.9
HIGH	25.9 < x ≤ 29.3
VERY HIGH	> 29.3

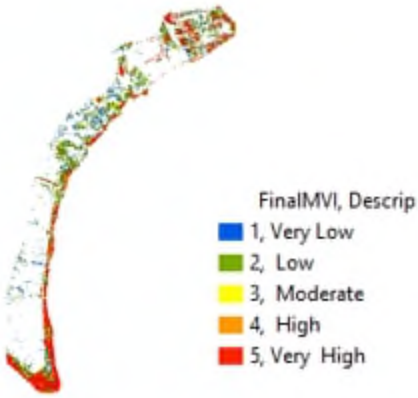

Fig. 1.31. MVI for Tanjung Piai

IX. CONCLUSIONS

This study proposed an approach for mapping the mangrove vulnerability index using geographical information system. The study presented an accurate and efficient GIS database system that has been formulated and tested in three (3) separate areas, namely, Kukup Island, Tanjung Piai, and Sungai Pulai. The study developed a GIS-based Mangrove Vulnerability Index (MVI) for a selected ecosystem, and highlighted mangrove vulnerability by ranking them from least to most vulnerable. The study also provided a forecast for the mangrove loss and classified areas where mangroves are most vulnerable. To validate the proposed approach the supervised and unsupervised techniques, the study used confusion matrix for summarizing the classification performance. The results are the collection of Mangrove Vulnerability Index (MVI) classification and the potential impact assessment. The MVI is the product of average Physical Mangrove Index (PMI), Biological Mangrove Index (BMI) and Hazard Mangrove Index (HMI). Input Data to

ArcGIS software comprise species, height, distance, soil, tidal etc. Unsupervised and supervised techniques are used to segregate Mangrove Species.

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