Monitoring of Mangrove Area Using Remote Sensing Toward Shoreline Protection

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Abstract. Shoreline is particularly vulnerable to wave action resulting in coastal erosion. The process happens as a result of the shifting of coastal sediments by wave and tidal currents. As shoreline erosion continues, more and more topsoil is drawn into the coastal areas, threatening aquatic life and eventually leading to the need for costly removal or dredging. Several measures such as the use of breakwaters, geotubes, and groynes have been suggested that will provide benefits to the community, and led to a decrease in coastal erosion. The other option is to protect the shoreline by using the natural vegetation resources such as mangrove ecosystem. Remote sensing provides valuable information for mapping vegetation and monitoring mangrove changes. In this research remote sensing technology using Landsat 7ETM+ and ERDAS Imagine version 8.6 were utilized in detecting changes in mangrove areas from Tanjung Piai to Kukup Island within a ten year period. The analysis of the overlay maps showed the changes in mangrove acreage. From the total original acreage of 890.28 hectares in 1995 the mangrove area has decreased to 761.40 hectares in 2005, a decrease of 128.88 hectares or 14 percent. Several factors were responsible for the changes in mangrove acreage. The development of the Port of Tanjung Pelepas in March 2000 has been responsible for the changes in the sea currents and tidal waves. To mitigate the shoreline erosion it is recommended that both the natural and man made structures are combined together. The natural buffer zone can help to reduce the shoreline erosion by propagating and replanting resistant mangrove species. Species such as *Rhizophora apiculata* (Bakau Minyak), *R.mucronata* (Bakau Kurap) and *Sonneratia* (Perepat) can buffer the destructiveness of wave action, wind and tide. However, mangrove areas which are at the front of the big wave energy will not be able to withstand the incessant assault.

Keywords: Shoreline protection, Remote Sensing, Mangrove, Changes

1 Introduction

Shoreline erosion is a natural process that affects all coastal areas with the shoreline moving as part of normal beach behaviour. Typical causes of beach erosion include: change in sediment supply, wave processes of sea level over a range of time scales; windborne sediment transport, formation of updrift littoral barriers (e.g. through a rock fall); loss of headland control (e.g. through erosion of that feature), scouring of beach by storm water discharges; and loss of vegetation. (Auckland Regional Council, undated). As shoreline erosion failure continues, more and more topsoil is drawn into the coastal areas, threatening aquatic life and eventually leading to the need for costly removal or dredging.

Several mitigation impacts have been suggested that will provide benefits to the community, and led to decrease in coastal erosion. They consist of man-made structure and natural factors. Examples of man-made structures are geotubes, groynes, breakwaters, and revetments. There are several coastal structures constructed at Tanjung Piai, Johor National Park. The method used is the application of geotube (sand-filled geotextile tubes) arranged in such a way as to reduce the wave energy that comes with the tide. This then stabilises the soil on the leeward side reducing erosion to an extent. However, although man-made defense structure coastal protection is efficient it is also expensive, not suitable in long terms and not environmental friendly.

The other option is to protect the shoreline by using the natural vegetation resources such as mangrove forest. Mangrove forest can reduce shoreline erosion and protect shoreline against sea storms and floods. Furthermore, instead of having to spend large amount of money for constructing geotubes, breakwaters, groynes, or revetments the mangrove solution is environmental friendly and economical.

One of the methods to detect shoreline erosion is by using satellite image. Remote sensing provides valuable information for mapping vegetation and monitoring mangrove changes. Satellite remote sensing is a useful source of information as it provides timely and complete coverage better than human workers monitoring on the ground. Remote sensing can provide up-to-date valuable information to monitor changes in shoreline. For these reasons, it is economical to carry out studies on shoreline erosion using aerial photography (Guebas, 2002).

2 Research Questions

Three research questions will be posed for this study. First, “How remote sensing technology can be utilized in shoreline detection of mangrove area?” Second, “Can mangrove species protect the shoreline from any possible erosion potential?” Third, “What are the measures to mitigate the shoreline erosion?”

3 Objectives of the Study

1) To interpret data in monitoring changes in shoreline area from Tanjung Piai to Kukup Island within a ten year period from 1995 to 2005.

2) To map changes in mangrove vegetation within the same period along the study area using Remote Sensing technique.

3) To suggest mitigation measures for shoreline protection.

4 Study Area

The study area covers the shoreline Tanjung Piai to Kukup Island consisting of coastal mangrove and intertidal mudflats (Figure 1). The mangroves of Tanjung Piai have been conserved as part of the Johor National Park for protection of the shoreline as the immediate hinterlands are all cultivated farmlands. It is a haven for a diverse species of flora and fauna, including those unique to mangrove areas such as mangrove crabs, beady-eyed mudskippers and crab-eating macaques.

Source: (***World atlas, Microsoft MapPoint*, 2006)**

Figure 1: Location of the study area

5 Literature Review

Parish (2000) found that mangrove provides coastline protection. Mangrove serves an important ecological function in mitigating coastal erosion by reducing the energy of waves, tidal currents and storms that would otherwise erode the coastline. Without mangrove buffer areas, bunds that are built by farmers to protect farmlands are easily beached by wave attracts. As tidal flooding penetrates inland, it results in the destruction of crops. Based on a study by Tomlinson (1986), mangrove forests can help protect coastlines from erosion, storm damage, and wave action. The stability mangroves provide is of immense importance. They prevent shoreline erosion by acting as buffers and catch alluvial materials, thus stabilizing land elevation by sediment accretion that balances sediment loss.

Bird et al. (2004) found that the mangrove from Sungei Buluh wetland reserve to Kranji Dam represented the largest intact mangrove forest left on mainland Singapore. Four aerial photographs for the periods 1946, 1969, 1980 and 2001 were selected for the analysis of mangrove change, with a time interval between successive images ranging from 11 to 23 years. The analysis of photograph covering the period from 1946 to 2001 has revealed major changes in the distribution of mangroves in the area resulting from development induced changes. Following 1980, a reduction in sediment supply possibly due to the construction of the Kranji Dam, immediately east of the study area, led to the initiation of erosion along much of the coastline, with the mangrove fringe having retreated by up to 50 meters in 2001. The result from aerial photograph suggested that the course of the major creek, Sungei Buloh, changed several times prior to 1946. The creek originally discharged to the west of what is now the Island of Pulau Buloh, by coastal erosion and or channel migration.

A study by Wang et al. (2003) found that, the most important factor regarding mangrove ecosystem is the location boundaries area of clearances and mangrove density. Studies about the structure, ecology, coverage and extent of Tanzanian mangrove have been conducted by analysis of field photographs and ground surveys. Landsat and SPOT imageries have been applied to mangrove studies through visual interpretation. The f**ieldwork was supported by interpretation of Landsat data from 1988 to 1990 TM and 2000 ETM+ image and delineation of general cover types and mangroves area with attention to location where the landscape had been altered and land use had been changed over the past years** .

6 Methodology

The methodology for this research is organized in five stages (Figure 2). The research sequence is as follows:

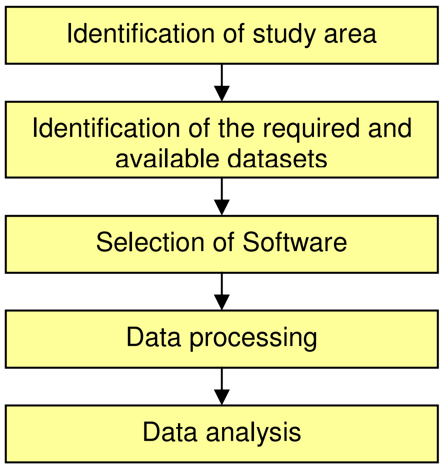


Figure 2: Research sequence

7 Identification of Study Area

The study area selected is the coastal area from Tanjung Piai to Kukup Island Johor National Park. Remote sensing technique will be used to monitor changes in the shoreline and mangrove vegetation.

8 Identification of the Required and Available Datasets

Three datasets of the image in three different time periods shall be compared to monitor the changes within the study area. In this research three main dataset of Landsat 7 Enhanced Thematic Mapper (ETM+) image obtained from Malaysian Centre for Remote Sensing (MACRES) were used. The first set of images was taken by Landsat 7 ETM+ system on 26 June 1995. The second dataset of image was taken on 28 April 2000 and third dataset was taken on 28 January 2005. Datasets were geo-referenced to Universal Traverse Mercator (UTM) projection and World Geodetic Survey (WGS 84) coordinate. Therefore, some adjustments were made using digital image processing.

9 Selection of Software

The main type of software used for this research is Digital Image Processing (DIP) software. The ERDAS Imagine version 8.6 Digital Image Processing software was used for image rectification, image classification, and data conversion and processing of satellite image (Landsat).

10 Data Processing

The data pre-processing stage was conducted before the real processing and analysis of the images can be carried out. Data pre-processing involves two main steps, i.e. image rectification (including collection of Ground Control Points-GCPs) and image subsets.

10.1 Image Rectification

Image rectification involves manipulation of raw dataset so that the spatial arrangement of objects in the data corresponds to a specific geo-coding (or geodetic coordinate) system. Since all landsat image acquired from MACRES are geo-referenced, image rectification or geometric correction is required.

10.2 Ground truthing

The collection of ground-truth data was collected to enable the calibration of remote-sensing data, and aids in the interpretation and analysis.

The field observation was conducted Tanjung Piai to Kukup Island. Since the ground truth data are mainly used for interpretation by Landsat satellites image special attention was paid to location where the mangrove area had been altered and changed over the past years.

The research design is organized in three stages (Figure 3).

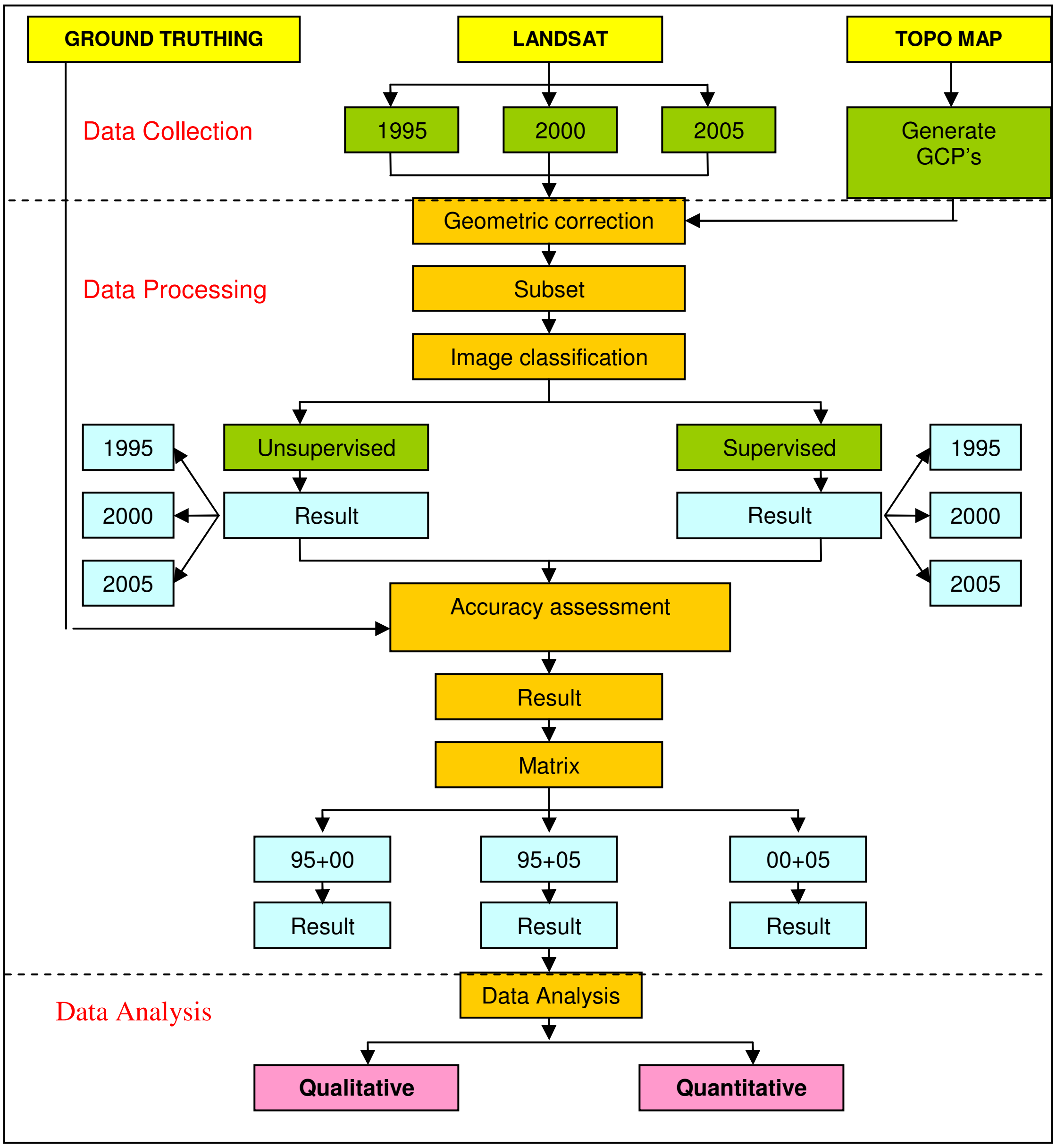


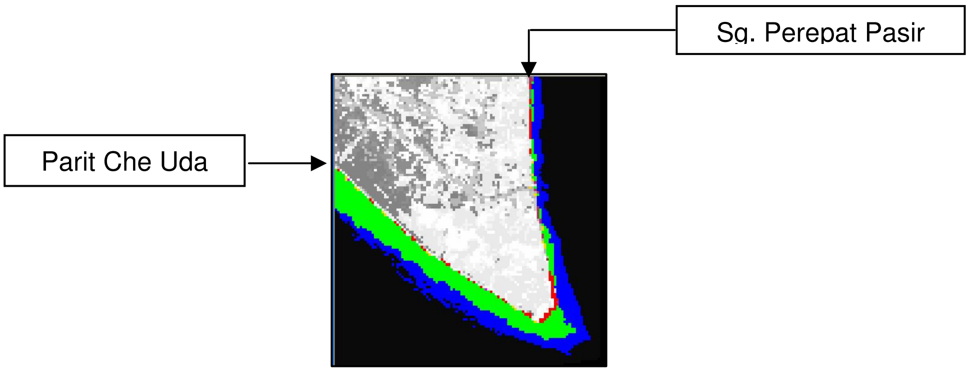
Figure 3: Flow Chart of Research Design

11 Results And Discussions

To compare the changes in the mangrove area within a ten year period two images was overlaid for each area using matrix process.

The 1995 and 2000 images of Tanjung Piai area were overlaid to map the changes within a five year period. Consequently the 2000 and 2005 images were also overlaid for the same purpose. This matrix analysis combines the two input raster files and produces a new file. The new file contained new class values indicating the changes from the original file.

Overlay 1995 with 2005 of Tanjung Piai area



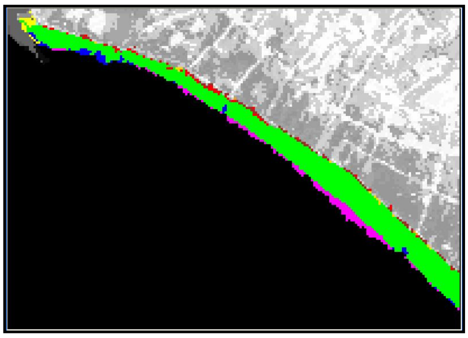
Legend

Row	Color	Class Names		
	Study area	Tanjung Piai (1995)	Tanjung Piai (2005)	Area (Hectare)
1		Mangrove	Water	87.48
2		Mangrove	Mangrove	90.45
3		Mangrove	Non-mangrove veg.	1.89
4		Non-mangrove veg.	Mangrove	1.53
5		Non-mangrove veg.	Mangrove	7.83

Figure 4: Image of the matrix of unsupervised classification of changes between 1995 and 2005 at Tanjung Piai area

Figure 4 is visualisation of the matrix of the unsupervised classification of changes between 1995 and 2005. From the original acreage of 180.09 hectares in 1995, it has decreased to 99.81 hectares, a decrease of 80.28 hectares or 45 percent. Based from, the legend in Figure 4 several changes in vegetative cover were detected. The mangrove area of 87.48 hectares has changed to water while the non-mangrove vegetation has changed to mangrove for a total of 9.36 hectares. However, the overall acreage of mangrove has decreased to 99.81 hectare. The major decrease in mangrove area was located between the Sg. Perepat Pasir to Parit Che Uda. This is the area where mangrove has been replaced with water.

Overlay 1995 with 2005 along the coastal area



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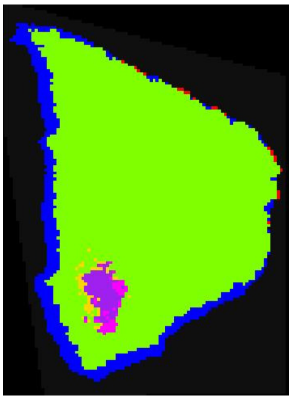
Row	Color	Class Names		
	Study area	Coastal area (1995)	Coastal area (2005)	Area (Hectare)
1		Water	Mangrove	17.73
2		Mangrove	Water	6.48
3		Mangrove	Mangrove	154.26
4		Mangrove	Sand	2.61
5		Mangrove	Veg. Non-mangrove	1.26
8		Veg. Non-mangrove	Mangrove	5.67
9		Veg. Non-mangrove	Mangrove	7.65

Figure 5: Image of the matrix of unsupervised classification of changes between 1995 and 2005 along the coastal area

Figure 5 is imaging of the matrix of the unsupervised classification of changes between 1995 and 2005. From the original acreage of 164.97 hectares in 1995, it has increased to 185.31 hectares in 2005, an increase of 20.34 hectares or 12 percent. Based from the legend in Figure 5, several changes in vegetative cover were detected. Some areas of water have changed to mangrove. Some areas of mangrove have changed to non-mangrove vegetation and vice versa. The major increase in mangrove area was located along the coastal area. The increase in mangrove area was significant along the coastal area. This is the area where non-mangrove vegetation has been replaced with mangrove.

Map overlay 1995 with 2005 of Kukup Island



Legend

Row	Color	Class Names		
	Study area	Kukup Island (1995)	Kukup Island (2005)	Area (Hectare)
1		Water	Mangrove	1.98
2		Mangrove	Water	71.10
3		Mangrove	Mangrove	469.53
4		Mangrove	Non-mangrove	4.59
5		Non-mangrove	Mangrove	4.77
6		Non-mangrove	Non-mangrove	12.24

Figure 6: Image of the matrix of unsupervised classification of changes between 1995 and 2005 of Kukup Island

Figure 6 shows imagery based on the matrix of the unsupervised classification of changes of 1995 and 2005. Based from the legend in Figure 6, several changes were detected. 1.98 hectares of water has changed to mangrove. 4.59 hectares of mangrove has changed to non-mangrove species while 4.77 hectares of non-mangrove have changed to mangrove. The major decrease in mangrove area was detected around the shoreline area from the southeastern part and the whole of the western fringe of Kukup Island. This is the area where 71.10 hectares of mangrove have disappeared and had been replaced with water. However, about 4.77 hectares of non-mangrove species have been replaced with mangrove species at the inland area of the south western edge of the Kukup Island. From the original mangrove acreage of 545.22 hectares in 1995 have decreased to 476.28 hectares; a loss of 68.94 hectares form 13 per cent.

11.1 Ground Truthing

There has been a decrease in acreage of mangrove areas. From the observation and interview it was found that the decrease has been due to several factors. The development of Port of Tanjung Pelepas has changed the water course resulting in some areas within the area being eroded (reformulate). The dredging and channeling of water ways for ships to enter the Port of Tanjung Pelepas has resulted in further shoreline erosion. Waves from passing of ships along the Straits of Malacca have eroded the shoreline near Tanjung Pelepas. Being the busiest ships passage way in the world, it is estimated that 50 thousand ships pass along this area yearly. Oil spill from the passing ships has incurred death and destruction to the mangrove species along the shoreline and the natural shoreline has been adversely impacted. The natural process of high tide and low tide also affected the coastal shoreline and changes in the acreage of the mangrove areas. The accretion process has deposited mudflats along the coastal area and Kukup Island. This has resulted in the increase and decrease of mangrove acreage along the shoreline.

11.2 Research Question 1: How remote sensing technology can be utilized in shoreline detection of mangrove area?

Remote Sensing has been utilized in the shoreline detection of mangrove area and established beyond doubt its potential and important role in providing vital inputs in monitoring the mangrove area. In this research Landsat 7ETM+ data was used to detect the mangrove in the study area. The data was obtained using spectral reflectance consisting of wavelengths which reflected, absorbed, and transmitted energy. The spectral reflectance will identify the size, shape, and site of the mangrove area based on spectral characteristics. The spectral reflectance will curve out three basic types of earth features: vegetation, dry soil and clear water. The mangrove trees will be reflected in a “peak and valley” configuration as dictated by the pigment of the mangrove leaf or through the wavelength band known as chlorophyll absorption band. Therefore the reflectance measurement in this band range will be able to discriminate between species in the same visible wavelength.

11.3 Research question 2: Can mangrove species protect the shoreline from any possible erosion potential?

Figure 7 (A) and (B) show the situation of the mangrove area at Tanjung Piai in 1995 and 2005. In 1995 the mangrove area in image (A) **is shown to be located at** the coastal part of the study area. However, in 2005 that is within a ten year period the mangrove along the coastal area from the tip of Tanjung Piai and moving northward to Sg. Perepat Pasir has disappeared. This is due to extreme erosion and damage by tidal surges, swift currents and storm energy.

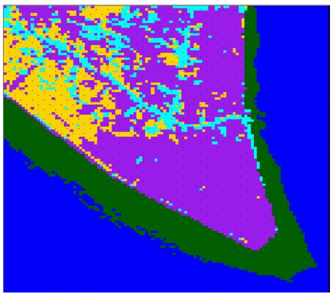


Figure 7:

Color	Class Names
Study area	Kukup Island (1995)
	Water
	Mangrove
	Mangrove
	Mangrove
	Non-mangrove
	Non-mangrove

Satellite image showing a time series of restored mangrove at Tanjung Piai area. Image (A) showed the mangrove area on 1995 and image (B) showed the mangrove area after the 10 year-old period. Color legend is necessary

However, the mangroves from the tip of Tanjung Piai moving southwestward to Parit Che Uda have increased in acreage. This was due to the accretion process and sediments produced by erosion from the tip of Tanjung Piai to Sg. Perepat Pasir. As the accretion process and sediments accumulate new mangrove species grown on the mudflats. This mangrove species help to stabilize the sediments with their tangled root systems. Their growth and physical stability helps to reduce shoreline erosion, shielding inland areas from severe damage from the waves of the ships and tidal waves. The mangrove causes the waves to dampen and break, thus dissipating much of the wave-energy. As long as the trees are sufficiently close together the trees will attenuate the waves. However, when the mud level around the mangrove trees are lowered due to erosion, their roots will be exposed to the sea. The trees will collapse and the erosion will continue further into the mangrove belt. The seeds of the trees will be washed away by the waves as there is no barrier to hold them and help them grow.

Therefore it can be concluded that most of the mangrove species are not able to protect coastal erosion if the waves are bigger and the accretion process and accumulation of sediments are not in place. However, other researches had found that mangrove buffer with a width of 20 meters can reduce the shoreline erosion. Mangrove species such as *Rhizophora apiculata* (Bakau Minyak), *Rhizophora mucronata* (Bakau Kurap) *Sonneratia* (Perepat) are known to be able to reduce shoreline erosion to a certain extent only.

11.4 Research question 3: What are the measures to mitigate the shoreline erosion?

It has been shown that mangrove vegetation alone is not able to prevent shoreline erosion. The ability of the mangrove vegetation to prevent shoreline erosion will depend on several factors. They depend on the type of soil in which the mangrove species are occupying, the types of mangrove species and the topography of the land. The buffering and stabilizing of land by sediment accretion where mangroves are growing will contribute to reducing shoreline erosion. *Rhizophora apiculata* (Bakau

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