DETECTION OF SHORELINE CHANGES AT KUALA TERENGGANU, MALAYSIA FROM MULTI-TEMPORAL SATELLITE SENSOR IMAGERY

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Abstract − A large percentage of the world's population and industrial activity is concentrated along the coastal zone. These environmentally sensitive areas are under intense pressure from natural processes, urban growth, resources development, and pollution. These threats have made the coastal zone a priority for shoreline monitoring programs. This research utilizes multi-temporal satellite imagery to monitor shoreline changes from 1992 to 2009 at Seberang Takir, Terengganu, Malaysia through the use of image processing algorithm and statistical analysis. All the imagery was geo-rectified to the Malaysian Rectified Skew Orthomorphic (MRSO) projection and analysis was done to detect spatially significant areas with erosion and accretion along the shoreline and detect potential sources of the changes. The shoreline was divided into 16 sited and shoreline changes at the sites were determined based on satellite sensor imagery. Preliminary result show erosion occurring near to human activities Northeast of Kuala Terengganu shoreline while southwest of Kuala Terengganu was subjected more to accretion.

Keywords: Shoreline change, aerial photo, sub-pixel classification, multi-resolution imagery.

1. INTRODUCTION

Shoreline can be defined as the intersections of the land with the water surface at a selected tidal elevation level (Camfield & Morang, 1996). The shoreline is a dynamic environment and an important component in research such as sea level rise, shore protection, tidal inundation, land subsidence and erosion-sedimentation process (Scott, 2005; Shcwarzer, 2009). Due to this constant shoreline monitoring is important requiring multi-year shoreline maps for coastal monitoring and assessment (M-Muslim *et al.*, 2007)

Conventionally shoreline monitoring were conducted using aerial photo and ground survey technique which were expensive, requires trained staff and time consuming (Bohnestiehl, 2001). In normal process, the preparation of these maps required month to years, and considered as outdated (Muslim, 2004).

Recently, remote sensing and geographical information system (GIS) have been widely used as another option than conventional method for monitoring shoreline position (Ryu *et al.*, 2002; Yamano *et al.*, 2006). Remote sensing provides the capability monitor the shoreline in a cost effective manner. Various techniques were developed for change detection study. Previous study done by Zimmerman and Bijker (2004), Shrestha (2005), Ozdarici and Turker (2006), Xiaodong*et al* (2006) using different spatial and temporal resolution of satellite imagery for change detection.

Remote sensing satellite sensor imagery has been used widely to monitor coastal areas and offer the potential of updating maps frequently (Clark, 1983; Balopoulos et al., 1986; Dekker et al., 1992; Elraey et al., 1995; Cendrero and Fischer, 1997; LaValle and Lakhan, 2000; Lemmens, 2001; Stauble, 2003). Early research in the application of satellite sensor images for shoreline mapping relied on coarse spatial resolution satellite sensor images (Blodget and Taylor, 1990; Dwivedi, 1997; Frihy et al., 1998; Byrnes et al., 2003). Despite the coarse spatial resolution, satellite sensor imagery has assisted in understanding small cartographic scale coastal erosion in areas such as the Nile Delta (Blodget et al., 1991; El Asmar, 2002). Mapping from remotely sensed imagery is commonly achieved through the application of a conventional hard image classification analysis. With hard classification, each pixel in the image is allocated to the class with which it has the greatest similarity spectrally (Foody *et al.*, 2005). This pilot study aims to visualize shoreline changes before further analysis using soft classification technique. A variety of data sets and methods have been used, but typically the waterline is mapped through image classification procedures, including density slice analysis(Ryan *et al*. 1991).

Main objectives is to map shoreline of Kuala Terengganu using multi-date and resolution of satellite imagery and identify shoreline erosion and deposition using time series data from 1992 to 2009. Common software packaging was used to analyze, visualize and map continuous shoreline changes from multi date and resolution imagery.

3. STUDY AREA

The study area extends from Teluk Ketapang beach to Kuala Terengganu river mouth for about 12 kilometers. Kuala Terengganu coastal area was characterized by northeast monsoon, with semidiurnal tides and average annual temperature of 25° C to 27° C (Rosnan and Lokman, 1995).

The shoreline in this area is categorized as being critical by the local authorities. Main causes for this problem are the dynamic physical process in the area, change in sea level and human activities. Monsoon and tides are major natural forces which help to shape the shoreline of Kuala Terengganu. Since all activities centered along shoreline, monitoring are necessary to identify area highly affected to erosion/accretion.

4. MATERIALS AND METHOD

Methodology used in this study based on classification technique to delineate land/sea boundary which was introduced by Muslim, 2004. As this study utilized different satellite sensor imagery such as SPOT HRV, IKONOS and RazakSat which have different spatial resolution a sub-pixel mapping techniques were adopted to increase accuracy of the coarser SPOT and RazakSat imagery. The datasets used in this study are shown below.

Table 1: Multi dataset used in this study comparison purposes.

Dataset	Year	Scale	Resolution (m)
AERIAL PHOTO (scanned)	1992	1:5000	-
IKONOS	2000	-	1
IKONOS	2002	-	1
SPOT	2009	-	2.5
SPOT	2009	-	2.5
RAZAKSAT	2010	-	2.5

Figure 1: General methodology

Geometric correction is the most crucial step since it can reduce accuracy of shoreline changes measured..In this study, several dataset are used including scanned aerial photo and satellite imagery. Initially all the imagery were geo-rectified to Malaysian Rectified Skew Orthomorphic (MRSO). 33 ground control points (GCP) were used to rectify all imagery. GCP collected were based on permanent landmark such as road junction, bridge and permanent structure such as airport runaway. The GCP collected were distribute evenly across area of study. Root Mean Square Error (RMSE) during geo-rectification for all images is lower than 0.5 image pixel size.

In this paper two classification techniques were applied to produce the shoreline. For IKONOS sensor images, the hard classification images were used. The imagery were classified into two classes mainly, water and land. The boundary between the two classes was considered as the shoreline.
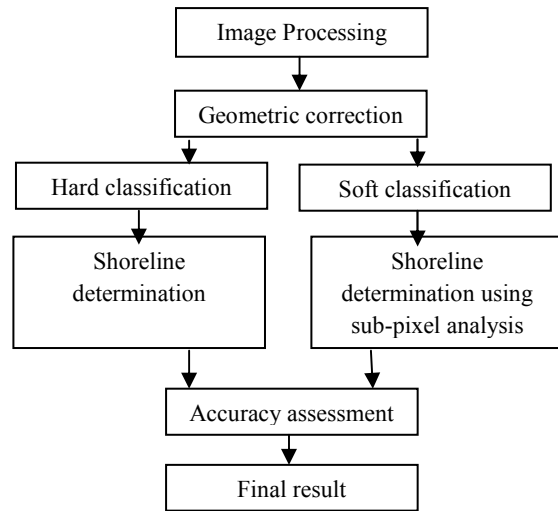
For the coarser RazakSat and SPOT imagery, sub-pixel processing was adopted to increase positional accuracy. This is needed to reduce errors introduced by the difference spatial resolution of the images. Initially the images were classified using a soft classifier that predicts the per class composition of a pixel. This mainly affects the pixels along the shoreline as it would contain a mixture of land and water classes. Using this information a shoreline would be generated using a contouring method. The contour generates a line at positions where the per class composition of land and water is 0.5. This is assumed as the position of the shoreline.

Having generated the shoreline for each imagery analysis was conducted to determine erosion and accretion at selected shoreline positions. In this initial study the shoreline were not corrected for variations in tide levels and it is assumed that these variations are neglect able.
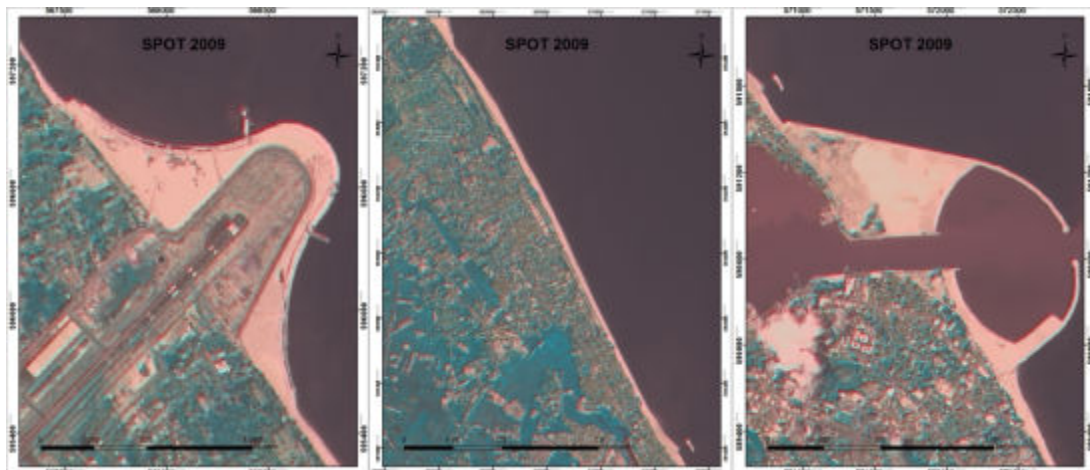

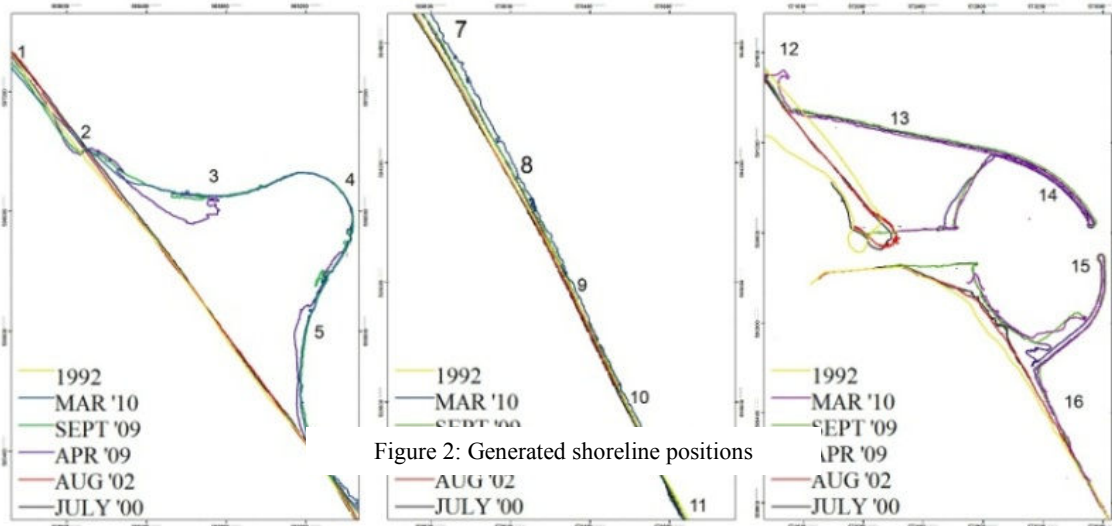Figure 1: SPOT satellite imagery of study area

Figure 2: Generated shoreline positions

The shoreline was divided to 12 sections measuring approximately 800 m each. Changes in the positions were later determined at each site to determine erosion/ accretion at the particular site. The relative changes in shoreline positions are shown in table 1.

Table 1 Shoreline positional changes

Site	7/2000	8/2002	4/2009	9/2009	3/2010
1	8.0	11.0	-8.0	-24.0	-46.0
2	36.0	24.0	-29.0	-19.0	-24.0
3	11.0	-7.6	290.0	290.0	290.0
4	7.8	-5.0	900.0	900.0	900.0
5	7.5	9.2	360.0	275.0	360.0
6	1.0	2.0	3.0	-5.0	12.0
7	8.0	3.0	26.0	33.0	43.0
8	5.0	-6.0	26.0	37.0	42.0
9	-4.0	-12.0	14.0	5.0	23.0
10	-3.0	-3.0	17.0	1.0	11.0
11	-8.0	-11.0	-11.0	2.0	-25.0
12	-22.0	-33.0	-38.0	-4.0	-4.0

5. RESULT AND DISCUSSION

Detection of shoreline changes were quantified by analysis of remote sensing with GIS. From the result, value of erosion and sedimentation from 1992 to 2010 are determined. In site 1 from July 2000 to August 2002 the shoreline experience accretion to an amount of 3 m. But in 2008 work started on the extension to Kuala Terengganu airport and effected the shoreline in this area. in April 2009 erosion was recorded at 8 m and this increased to 24 m in September. The trend continued with a total erosion of 46 m in March 2010. This process was also facilitated by North-East monsoon which blows between November and January (Lokman, 1995).

Site 3 to 5 was located at the Sultan Mahmud airport. This area was reclaimed in 2008 for airport upgrades. Measurement of 290 m, 900 m and 360 m was observed at the selected site surrounding the airport. Such man-made structures are one of major causes of coastal erosion despite of natural tidal inundation and mineral resource mining (Shwarzer, 2010).

From site 7 to 12, erosion with an average of 13 meters occurred. The highest erosion was recorded at 38 meters from July 2000 to August 2002. Instead of erosion, accretion took place during April 2009 to March 2010 with highest value 43 meters. During this period, land reclamation activities were conducted to repair eroded beaches due to airport construction. Site 11 and 12 show erosion during July 2000 until August 2002 and form April 2009 until March 2010. This area was located to the left of Kuala Terengganu river mouth breakwaters. This could be the main reason of erosion due to interruption of sediment transport.

Site 3, 4 and 5 was not taken into consideration because it was part of the airport runaway reconstruction and artificially created Overall sediment and accretion in this area is shown in table 2. Based on the finding, overall the area was dominated by sediment accretion rather than sediment erosion especially at sites 7 - 12.

Table 2: Shoreline changes in comparison to year 1992 aerial photo

Imagery	7/2000	8/2002	4/2009	9/2009	3/2010
Erosion (m)	-46	-107.6	-67.4	-52.5	-99.8
Accretion (m)	173.7	92.0	126.0	121.0	176.3
Total	+54	-15.6	+39.6	+58.6	+76.5

6. CONCLUSION

In general, this study area was most affected by beach nourishment and airport construction which impacts the coastal process and system and indirectly through modification of natural process and events.

In a natural environment erosion and accretion at a certain area are normally balance. If erosion occurs at a particular area, Accretion would also be found. In this study this is not evident, proving that the sediment transport in the area has been disturb. Sediment transport from the south near Kuala Terengganu is disturbed due to the construction of the airport runaway resulting accretion in the south of the site (Site7-11) and erosion occurs to the north near site 1 and 2. This is due to the fact that the area is deprive of sediment flowing from the south.

In order to achieve higher accuracy the shoreline maps generated need to be corrected to a local reference tidal level, which is Mean High Water Spring used by Malaysia authorities

(Muslim, 2004). This correction would remove biases as the satellite imagery obtain in this research was not acquired at a similar tidal elevation. Further work would be conducted to achieve this goal.

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