INTEGRATED REMOTE SENSING AND GIS FOR CALCULATING SHORELINE CHANGE IN PHAN-THIET COASTAL AREA

Pham Thi Phuong Thao[1], Ho Dinh Duan[2], Dang Van To[3]

[1]Institute of Oceanography, Nha Trang. Email: pthaopt@gmail.com
[2]Vietnam Academy of Science and Technology. Email: duanhd@gmail.com
[3]University of Natural Sciences, HCMC. Email: dangvanto@hcmuns.edu.vn

ABSTRACT

Shoreline evolution is one of the most concerns of coastal engineers and managers. There are several approaches to calculate the rates of shoreline change such as numerical models and remote sensing technique. By integrating modern techniques of remote sensing and GIS, the rates of shoreline change would be easily and quickly determined for a regional area. In this paper, improved methods based on the spectral band characteristics for extracting the waterline from various Landsat images over 30 years from 1973 to 2002 in Phan Thiet bay are presented. The waterline data then is corrected and adjusted for serving as an input for GIS tool to estimate the erosion and deposition rates. Many statistical methods such as EPR (End Point Rate), LRR (Linear Regression Rate) and AOR (Average of Rates) in DSAS (Digital Shoreline Analysis System), which is an extension for ArcView, are used in this study. On average, from 1973 to 2002, the shoreline of Phan Thiet bay advances 0.5-3.1m/yr and the shoreline of Mui Ne area, in contrast, retreats 0.1-0.3m/yr for the same period.

Keywords: Waterline, Spectral Bands, Landsat, Phan Thiet Bay, DSAS.

1. INTRODUCTION

With the rapid development of remote sensing and GIS technology, some useful applications would be obtained in oceanography, especially in shoreline change. Besides some traditional computation from modeling, the integrated remote sensing and GIS also support effective results to coastal engineers and managers. By the input data from waterline information extracted automatically or semi-automatically from satellite image, GIS tool would calculate long-term shoreline change rate. This approach would help us save money, time, and human power.

To discriminate water pixel from land pixel, there are several methods. The band ratio between B5 and B2 is used (Jensen, 1996; US Army Corps of Engineers, 2003). Other approach is to use single band thresholds such as band 3 or band 4 of Landsat MSS, and band 5 or band 7 of Landsat TM and ETM+ to extract water-land interface because they are useful in clear water conditions (Jensen, 2000; Bagli and Soille, 2003). For Landsat TM and ETM+, the combination of histogram threshold and band ratio techniques is proposed by using band 2, 4, and 5 to separate water and land directly (Alesheikh *et al*., 2007). Based on the physical characteristics of spectral band, a new ratio of (B3+B4)/B2 is proposed for Landsat MSS, and the combination between histogram threshold of band 7 with improved band ratio (B5+B7)/B2 is used for Landsat TM and ETM+ to determine water-land interface in this paper.

With shoreline data input, the rate of shoreline change can be calculated by DSAS, an extension for ArcView. DSAS is a useful tool to build transects automatically and to give statistical results from the baseline and historical shoreline data. Some results derived from DSAS are compared with measured data (Doukakis, 2007); other shows that they are well fit to existing data results from numerical modeling (To D.V. and Thao P.T.P., 2008).

Phan Thiet is one of the regions which have developed dramatically after the solar ellipse event occurred in 1995. Many resorts were built for tourism. Along with that, several artificial coastal structures such as groin, jetties were constructed for developing local economic targets. Consequently, the beach erosion has been happening. It is necessary to collect historic images for monitoring the shoreline evolution in this region. As a result, the study area in this paper is selected as Phan Thiet region and it stretched from $10^{o}44'55.44''$N, $108^{o}0'59.26''$E to $10^{o}59'58.53''$N, $108^{o}20'52.82''$E. The coastline of Phan Thiet is about 60km. To facilitate the computational efforts, Phan Thiet coastline is divided into 3 regions as shown in Figure 1. In region 3, there are 2 sub-regions, 3A and 3B. Region 3B is Mui Ne area.

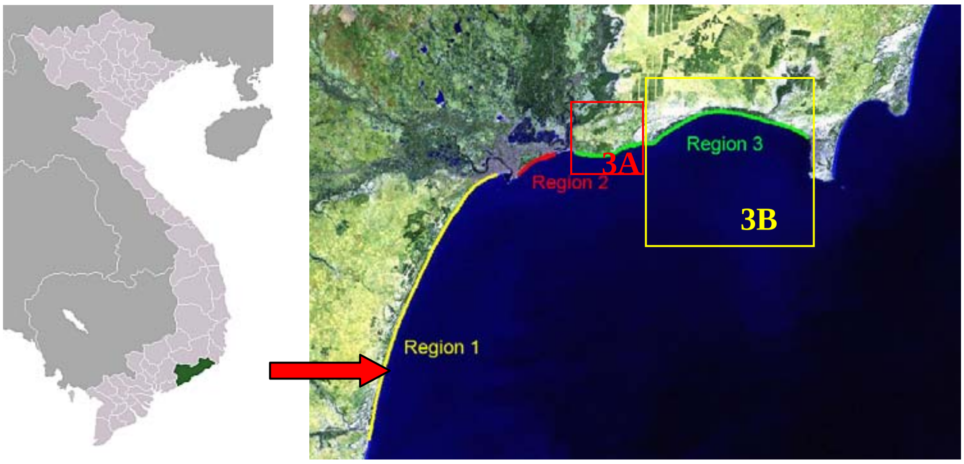


Figure 1. The study area.

2. THE NATURAL CONDITIONS IN PHAN THIET

Meteorologically, Phan Thiet region is affected by two windy seasons. The winter season is north-east monsoon and the summer season is south-west monsoon. The former begins from November and lasts until March next year; the mean wind speed is about 5-7m/s. The latter begins from June to August; the mean wind speed is about 4-6m/s. From April to May is the transfer period between the winter to summer season and vice versa from September to October. The mean wind speed is approximate 3-5m/s (Bui Hong Long *et al*., 2000).

Hydrologically, the wave regime is similarly affected by two seasons. In winter, the north-east and east directions dominate and the mean wave period is 5-7s. The mean wave height is about 0.4-0.5m and the maximum height is approximate 1-1.3m. In summer, the south-west and south directions dominate and the mean wave period is 5.25s. The mean wave height is about 0.3m. However, the wind wave is not stable and steady since storms frequently attack the beach in this season. In addition, tides are quite complicated since Phan Thiet is located in the transition region between the diurnal tide at the north (Qui Nhon) and the semi-diurnal tide at the south (Vung Tau). The tidal range is approximate 2m. The tides also induce strong currents near the coast which can be up to 50-70cm/s (Bui Hong Long *et al*., 2000).

3. METHODOLOGY

3.1 Remote sensing

Because all images are orthoretified, preprocessing is omitted. The images are divided into 2 classes, water and land, based on the classification technique. The original band ratio for separating water from land is B5/B2 for Landsat TM and ETM+. In addition, band 3 and band 4 of Landsat MSS, or band 5 of Landsat TM and band 7 of Landsat ETM+ are of good resolutions for discriminating water from land. Consequently, the combination of two bands is substituted by just only band 5 in the original band ratio. For Landsat MSS, (B3+B4)/B1 is proposed. For Landsat TM and ETM+, along with the improved band ratio (B5+B7)/B2, the histogram threshold of band 7 is combined for eliminating some interference.

After classification, raster images would be converted to vector images. The final step is to export into shapefile format for processing in GIS tool.

3.2 GIS

In general, the waterline would be corrected and adjusted as the shorelines before calculating shoreline change. In this paper, the tidal adjustment is neglected. As a result, the shoreline data is the waterline just extracted. With DSAS, an extension for ArcView, shoreline changes are calculated following 3 steps:

- To set up baseline
- To choose parameter for transects
- To calculate shoreline change

Three statistical methods are chosen to present the computational results. They are EPR (End Point Rate), AOR (Average of Rate), and LRR (Linear Regression). The EPR is calculated by dividing the distance of shoreline movement by the time elapsed between the earliest and latest measurements. Consequently, it is easy to compute. However, some data which are different to the initial and final shorelines are neglected. The AOR involves calculating separate end-point rates for all combinations of shorelines when more than two shorelines are available. The LRR can be determined by fitting a least squares regression line to all shoreline points for a particular transect (Thieler, 2003).

4. DATA

The image source is from University of Maryland, USA. All images which are orthorectified are captured at the same time 02:40 GMT over about 30 years from 1973 to 2002. The WGS-84 UTM projection, zone 49 was set up. The scenes for the study aera of Phan Thiet are listed in Table 1.

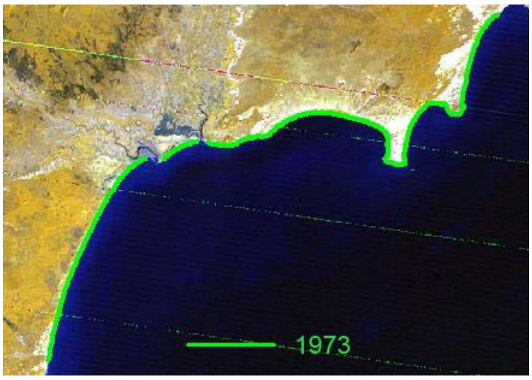
Table 1. List of Landsat scenes used for Phan Thiet shorelines.

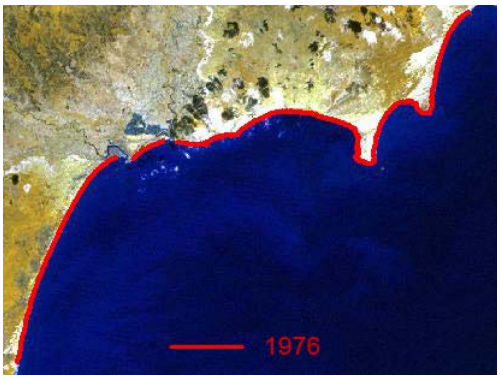
Sensor	Pixel Size (m)	Date
Landsat 1 MSS	57	01/01/1973
Landsat 2 MSS	57	31/01/1976
Landsat 5 TM	28.5	30/12/1990
Landsat 7 ETM+	28.5	05/01/2002

5. RESULTS AND DISCUSSION

5.1 Extracting waterline

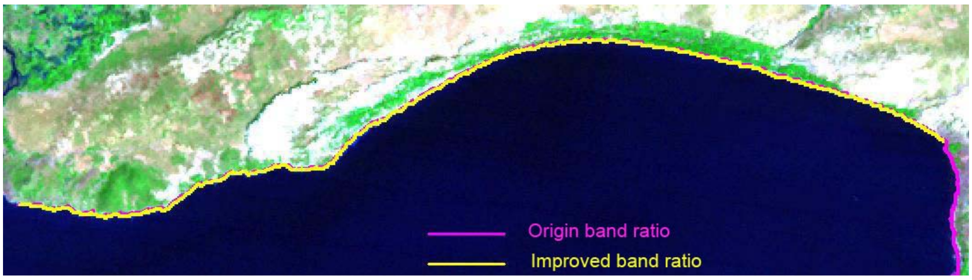
Waterlines extracted from Landsat MSS by the band ratio (B3+B4)/B1 are quite fit with the shoreline on images as shown in Figure 2. The extracted waterline by using the original band ratio for Landsat TM is almost similar to the waterline extracted by the improved band ratio (Fig. 3a). However, when using the origin band ratio for Landsat ETM+, the extracted waterline encounters mis-matches in certain areas such as Phu Hai and Mui Ne beaches. For example, some disagreement in Mui Ne area as in Figure 3b can be seen. Thus, the combination between (B5+B7)/B2 and the second peak spectral value of band 7 is proposed and chosen to determine the waterline.



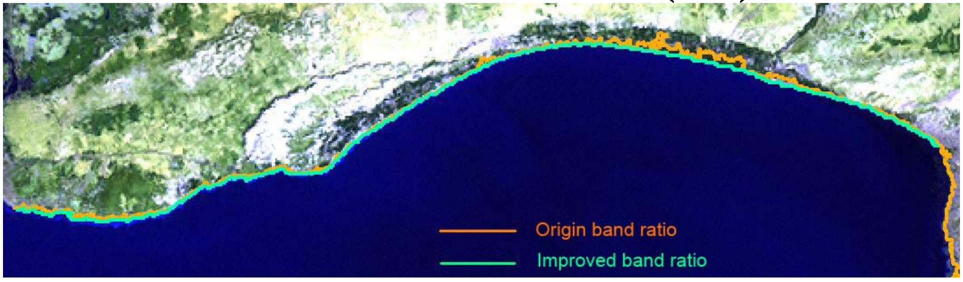


a. Waterline extracted from Landsat 1MSS b. Waterline extracted from Landsat 2MSS

Figure 2. Compararison between extracted waterline and shoreline on images



a. Waterline extracted from origin band ratio and from improved one in Mui Ne area on Landsat 5TM (1990)



b. Waterline extracted from origin band ratio and from improved one in Mui Ne area on Landsat 7ETM+ (2002)

Figure 3. Comparison between waterline extracted from origin band ratio and improved band ratio

5.2 Shoreline change analysis

Based on the established transects in Figure 4, the computed rates of shoreline change in three regions can be illustrated in Figure 5 and Table 2, respectively. There are 403 transects established in region 1, 60 in region 2, 102 in region 3A, and 222 in region 3B. It can be seen that the positive and negative rates of change in Figure 5 show the beach accretion and beach erosion correspondingly. As a result, both region 1 and region 2, with sub-region 3A tend to deposit approximately 05-3.1m/yr within 30 years from 1973 to 2002. In contrast, Mui Ne has the rate of erosion from 0.1-0.3m/yr for the same period. While the computing results of EPR and LRR are almost the same, the computing result of AOR is relatively higher than these two. These computing results agree with the measured data in Binh Thuan (Bui Hong Long *et al*., 2000).

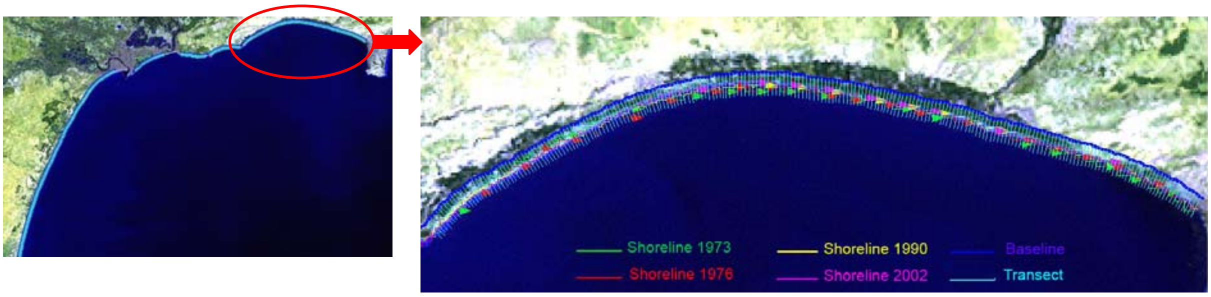
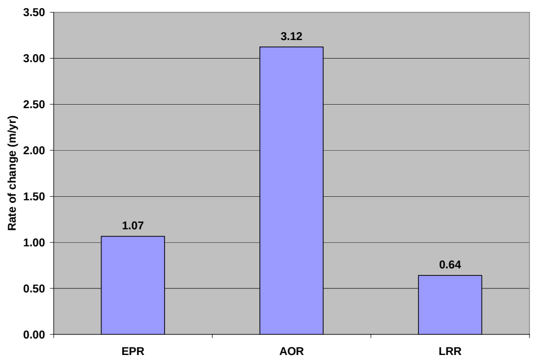


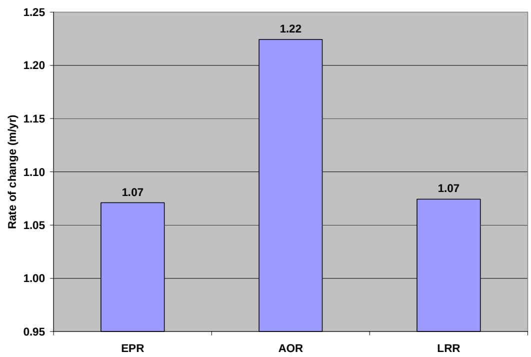
Figure 4. Transects in Mui Ne area.

Table 2. Computed rates of shoreline change using EPR, AOR, and LRR in one year for single of transects in Phan Thiet coastal area.

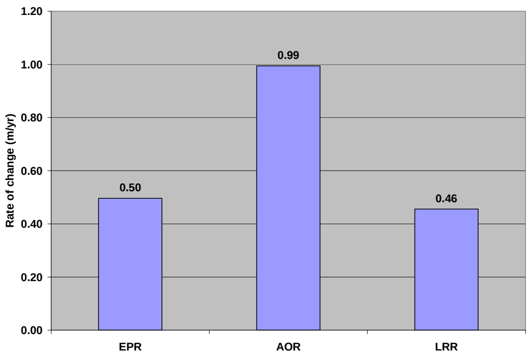
Methods	**Region 1** (*m/yr/ transect*)	**Region 2** (*m/yr/transect*)	**Region 3** (*m/yr/transect*)	
	~ 20km	~3km	A ~5km	B (Mui Ne) ~11km
EPR	1.07	1.07	0.50	-0.18
AOR	3.12	1.22	0.99	-0.29
LRR	0.64	1.07	0.46	-0.15



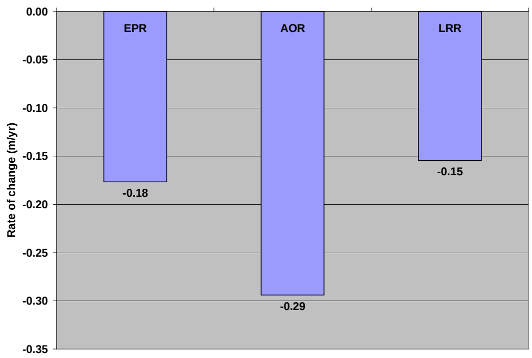
a) Region 1



b) Region 2



c) Region 3A



d) Region 3B – Mui Ne area

Figure 5. The computed rate of change in the study area.

6. CONCLUSION

The integration between remote sensing and GIS technology is a useful tool for coastal engineers and managers who need an overview of the long-term shoreline changes in the concerned area. The state of the art technique does not only reduce investment budgets, but also decrease time and facilitate human work-forces. The paper showed that Phan Thiet shoreline could be determined rapidly by the improved band ratio although tidal adjustments were neglected. The shoreline change rates could be calculated by several statistical methods which were built in the extension of GIS tool. Quantitatively, the shoreline of Phan Thiet bay on average advances 0.5-3.1m/yr over 30 years from 1973 to 2002. Specifically, the shoreline of Mui Ne area, in contrast, retreats 0.1-0.3m/yr for the same period.

7. REFERENCES

Alesheikh, A. A., Ghorbanali, A., and Nouri, N., 2007. *Coastline Change Detection Using Remote Sensing*. International Journal of Environmental Science and Technology, ***4** (1), p. 61-66.*

Bagli, S., and Soille, P., 2003. *Morphological Automatic Extraction of Pan-European Coastline from Landsat ETM+ Images*. CoastGIS 03, 5th Int. Symposium on GIS and Computer Cartography for Coastal Zone Management, Integrating Information in Coastal Zone Management, Genova.

Bui Hong Long *et al*., 2000. *Investigating natural conditions, environment, sources in Phan Thiet coast and building main sustainable development for local society and economy*. Institute of Oceanography, Nha Trang.

Doukakis, E., 2007. *Non-Linear Models for Coastal Evolution*. Recent Problems in Geodesy and Related Fields with International Importance 2007, Inter Expo Centre, Sofia, Bulgaria.

Jensen, J. R., 1996. *Introductory Digital Image Processing: A Remote Sensing Perspective*. Second Edition. Prentice Hall.

Jensen, J. R., 2000. *Remote Sensing of Environment – An Earth Resource Perspective*. Second Edition. Prentice Hall.

Thieler, E. R., *Martine*, D., and Ergui, A., 2003. *Tutorial for the Digital Shoreline Analysis System (DSAS) – Extension for ArcView*, USGS.

To, D.V., and Thao, P.T.P., 2008. *A Shoreline Analysis using DSAS in Nam Dinh Coastal Area*. International Journal of Geoinformatics, Vol. 4, No. 1, March, 2008, pp 37-42

US Army Corps of Engineers, 2003. *Engineering and Design: Remote Sensing*. Engineer Manual No. 1110-2-2907.