SHORELINE CHANGE DETECTION TO SERVE SUSTAINABLE MANAGEMENT OF COASTAL ZONE IN CUU LONG ESTUARY

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ABSTRACT

Coastal zone of Cuu Long estuary is a place that Mekong River flows into the Eastern Sea with 8 estuaries. It is influenced by driving force in river and sea. Furthermore main geological characteristics are clay and silt. Thus the shoreline in this area is very sensitive to external conditions, causing both deposition and erosion processes. This paper describes an application of satellite remote sensing technology and GIS to detect and analyze the spatial changes as well as quantify the result of shoreline change in Cuu Long estuary. Landsat and Aster satellite images were used with band ratio method to show the potential of technology in disaster monitoring. The results present shoreline change maps in three periods: 1989, 2001 and 2004. Outcomes of the case study can be used as an orientation for the sustainable integrated management plan of coastal zones.

1. INTRODUCTION

Shoreline, the boundary between land and sea keeps changing its shape and position continuously due to dynamic environmental conditions. The change in shoreline is mainly associated with waves, tides, winds, periodic storms, sea-level change, the geomorphic processes of erosion and accretion and human activities (Selvavinayagam, 2008). Erosion and accretion are very dangerous processes. They affect human life, cultivation and waterway transportation activities. Detection and measurement of shoreline changes are an important task in environmental monitoring and coastal zone management. Approaches to detecting shoreline changes can be roughly divided into four categories, all of which have both advantages and disadvantages: (1) conventional ground surveying can achieve high accuracy of measurement, but is labor intensive and time consuming; Approaches to detecting shoreline changes can be roughly divided into four categories, all of which have both advantages and disadvantages: (1) conventional ground surveying can achieve high accuracy of measurement, but is labor intensive and time consuming; (2) modern altimetry technology uses radar altimeters or laser altimeters. It has a great potential, but the detectors are currently less available; (3) airborne imagery measurement provides sufficient pictorial information, but the frequency of data acquisition is low, and the photogrammetric procedure including data acquisition and image mapping is costly as well as time consuming (Bin Zhao, *et al*., 2007); (4) Multispectral remote sensing satellites provide digital imageries in infrared spectral bands where the land-water interface is well defined. Furthermore this method has advantages: not time consuming, unexpensive executed cost and large ground coverage monitoring (Bin Zhao, *et al*., 2007; Winasor, *et al*., 2001).

Satellite optical images are simple to interpret and easily obtainable. Absorption of infrared wavelength region by water and its strong reflectance by vegetation and soil make such images an ideal combination for mapping the spatial distribution of land and water.

These characteristics of water, vegetation and soil make the use of the images that contain visible and infrared bands widely used for coastline mapping (DeWitt, *et al.,* 2002). This study applied satellite remote sensing technology and GIS to detect and analyze the spatial changes as well as quantify the result of shoreline change in Cuu Long estuary. The results present shoreline change maps in three periods: 1989, 2001 and 2004.

2. STUDY AREA AND DATA SETS

2.1. Study area:

Coastal zone of Cuu Long estuaries extends from Tranh De river mouth to Tieu river mouth. Study area is located between latitude 105° 58' 58"N to 106° 51' 8" N and longitude 9° 23' 55" E to 10° 25' 37E (Fig. 1). The mainland is limited by boundary of coastal districts, including 8 districts: Long Phu (Soc Trang Province), Cau Ngang, Duyen Hai, Tra Cu (Tra Vinh province) Binh Dai, Thanh Phu, Ba Tri (Ben Tre province) and part of Go Cong Dong (Tien Giang province). This area is relatively flat with a lot of sand dunes turning back to the sea. Climate shows tropic and monsoon characters with two seasons: rainy from May to November and dry from December to April. The river system with high density is a place that Mekong River flows into the Eastern Sea with 8 estuaries.

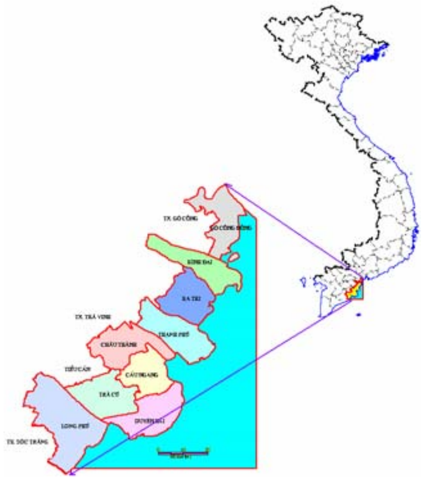

Fig. 1: The study area

2.2. Data set

Satellite images were acquired in three dates: Landsat TM in 1989, Landsat ETM$^+$ in 2001 và Aster in 2004 (Table 1). Landsat images have pixel resolution of band 1, 2, 3, 4, 5, 7 in 30m, ETM+ band 8 particularly in 15m. Aster image has 3 groups of bands with different pixel resolutions: VNIR bands in 15m, SWIR bands in 30m and TIR bands in 90m. These image were taken in dry season. Therefore shoreline is easily indentified because level water is not very high. Topographical map with scale 1:100.000, UTM coordinate and WGS-84 projection was use for geo-rectifying and determining erosion/accretion locations.

Table 1: characteristic of data image satellite

Acquisition Time	Satellite	Sensor	Coordinates	Datum/Ellipsoid	Zone
16 /1/ 1989	Landsat5	TM	UTM	WGS 84	+48N
11/12/2001	Landsat7	ETM$^+$	UTM	WGS 84	+48N
12/12/2004	Aster	Aster	UTM	WGS 84	+48N

3. METHODOLOGY

Spectral band ratio is one of the most common mathematical operations applied to multi-spectral image data. Ratio images are calculated as the division of DN values in one spectral band by the corresponding pixel value in another band. Band ratioing provide unique info not available in any single band that is useful for distinguishing earth features. Band ratio operation can reduce the environmentally induced variations in the DN values of a single band, such as brightness variations caused by topographic slope and aspect, shadows or seasonal changes in sunlight illumination angle and intensity. Therefore, band ratioing tends to emphasize and highlight subtle variations in the actual spectral responses of various surface covers.

Experiments have shown that green band in 0.52 – 0.6µm wavelengths (Landsat band 2 and Aster band 1) is sensitive to water turbidity differences plus sediment and pollution plumes. Because it covers the green reflectance peak from leaf surfaces. It can be useful for discriminating broad classes of vegetation. Water is a strong absorber of near infrared radiation (NIR), so Landsat band 4 (0.76-0.90µm) and Aster band 3 (0.76-0.86µm) useful for locating and delineating water bodies, distinguishing between dry and moist soil and providing information about coastal wetland, swamp and flooded areas. Landsat band 5 (1.60-1.70µm) and Aster band 4 (1.55-1.75µm) exhibits a strong contrast between land and water features due to the high degree of absorption of mid-infrared energy by water and strong reflectance of mid-infrared (MIR) by vegetation and natural features in this range. The wavelength information is very useful in ratioing settings. This study used band ratioing method in these wavelength region to extract soil, water and vegetation from Landsat and Aster images.

Image preprocessing: Aster image has smallest pixel resolution in 15m of VNIR bands, so band 4 (pixel size in 30m) in SWIR region will be downscale to this one. This process is also to carry out for Landsat bands with 30m pixel resolution. In change detection, geo-rectification of images with different spatial resolution is constrained for guaranteeing the smallest error in overlaying results. Aster 2004 was used to geo-rectify with the topographycal map. Other Landsat images was rectified by Aster one. The RMSEs were less than 0.5 pixel.

Image analyzing: In the first step, histogram thresholding method is used on NIR band for separating land from water. The threshold values have been selected so that all water pixels are classified as water, and most of land pixels have been classified as land. In this case, few land pixels have been mistakenly assigned to water pixels but not vice versa. Water pixels are then assigned to “1” and land pixels to “0”. A binary image has been achieved then. This image is named “image1”. In the second step, ratioing method is used with ratios green/NIR and green/MIR. Green/NIR ratio is useful for separating land from vegetation, green/MIR for separating non-vegetation land. Water pixels will be greater than 1. Two these ratio images are multiply for rejecting mistake and forming the new image named “image2”. Image 1 is multiplied to image 2 to generate third image named “image3”. Some idle pixels will be remove with sieveing and filtering technique for the final shoreline image. The result shoreline extraction is transformed into vector format and exported into MapInfo GIS system for analyzing change of erosion/accretion areas. Change in pairs will be examined such as 1989-2001 and 2001-2004. Fig. 2 illustrates the steps of the method.

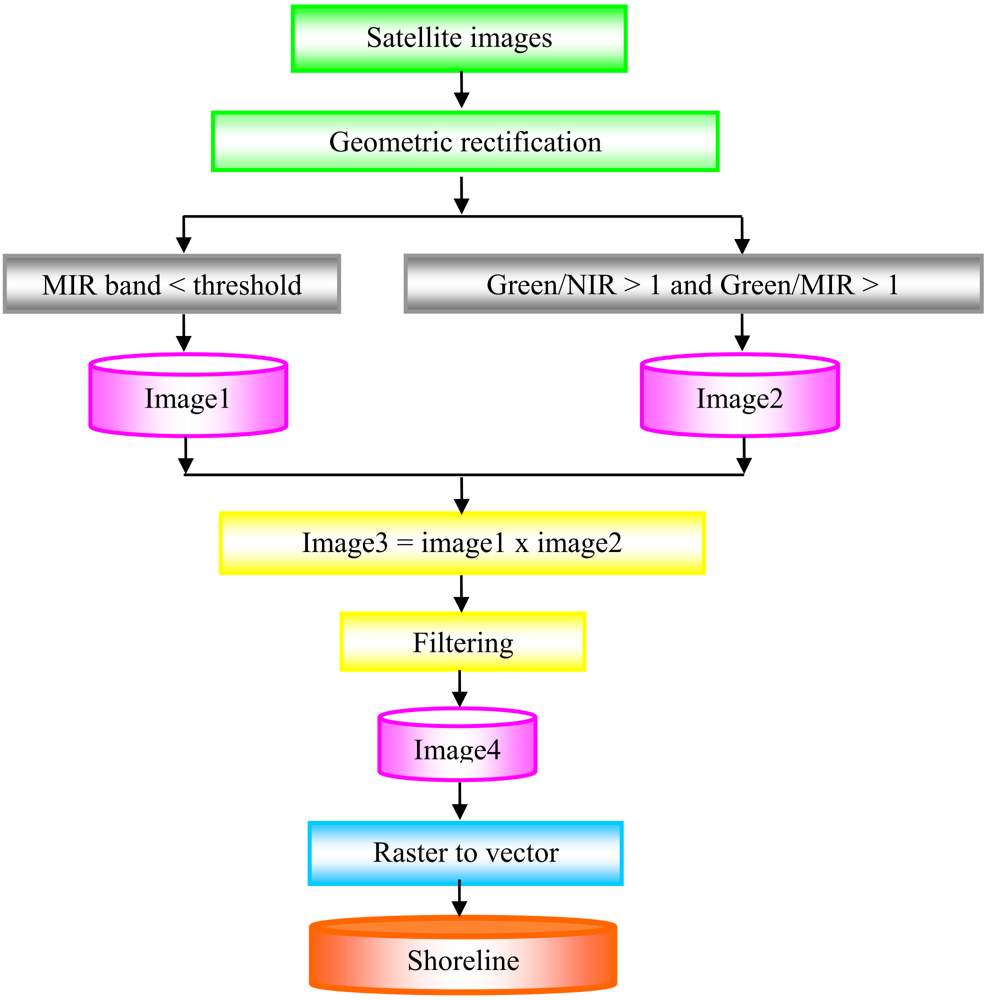

Fig. 2: Flowchart of extracting shorelines from satellite images

4. RESULTS AND DISCUSSION

Accretion and erosion are two inverse processes. Accretion increases the area of agricultural, forest and fishing land, but yields the sediment in the sea port, baring waterway transportation activities. While erosion causes the loss of land, destroys constructed buildings, houses, threatening human life. The analyzing results has shown the erosion/accretion areas through time in fig. 3.

Shore is often eroded robustly in well-aired zones and when it has direction perpendicular to northeast and southeast wind. Most of accretion/erosion sections in 1989-2001 are continued in next stage in 2001-2004 with the higher and more rapid measure. Section in confluence between middle Hau river and Quan Chanh Bo channel had eroded in 1989-2001, but had no change in 2001-2004. This region was examined with full vegetation cover in 3 satellite images. Lots of sections were deposited in 1989-2001, but they were seriously eroded after 2001. It lengthened and joined with previous erosion sections. It is obviously in shoreline from Duyen Hai, Thanh Phong and Ba Tri districts.

Fig. 4 shows shoreline was eroded from 1989 to 2004. The shore in Thanh Hai commune, Thanh Phu district was blowed up with the strongest speed in two stages. In 1989-

2001, the erosion extent was 19.5km in length with land loss area of 214ha, in 2001-2004 the erosion section was extended to 30km with the loss area of 146ha in only 3 years. Fig. 5 shows accretion shore sections with the largest accretion area in stages of 1989-2001. It belongs to Thanh Phong commune, Thanh Phu district with the length of 43.7km and area of 944ha in 1898-2001. In the stages of 2001-2004 the accretion measure was weaker with the length of 6.5km and area of 54.7ha.

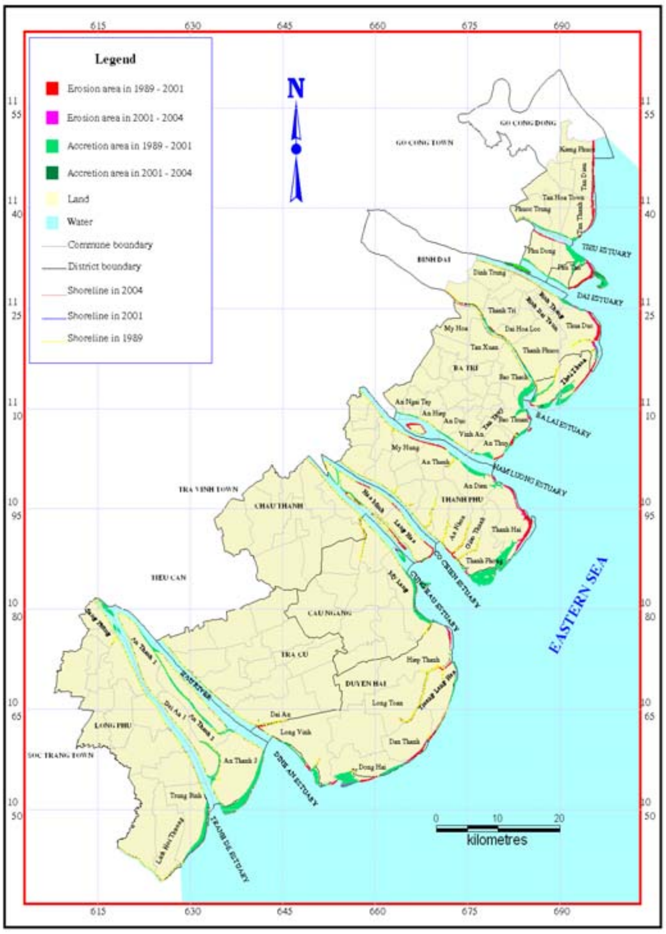

Fig. 3: Shoreline change in 1989-2004

A lot of studies have found that the reasons causing accretion/erosion disasters in the coastal area in Cuu Long estuaries are mainly natural. First of all is due to weak and loose geological structure with mainly mud flats and sand bars. The second is by northeast wind combined force forming wave striking directly the shore with great intensity. It pulls seashore trees and soils into the sea. Then under the effect of inshore flow in the time of ebbed tide with high velocity it moves mud and sand going another place causing shore erosion. In addition the human impacts has contributed not a little to the shoreline change in recent years, such as: (1) reclaiming and dyking unscientifically with sea encroaching purposes causing the loss of mud and sand balance; (2) digging ditch in protective forests along the shore for enticing aquatic being. When the tide is on the ebb, internal sea water runs on narrow swift-flowing surfaces causing land erosion; (3) digging pit to exploit rashly aquatic products along the shore; (4) transportation activities with high density making stronger waves beating the shore; (5) conversing cultivation from forest and crop land into shrimp hatching land in the coastal areas. The quality of natural forest is decreased due to uncontrolled exploitation, lack of care expense. Aluminous soil is risen making forest less developed and died down by stages. The more natural forest area is decreased the more erosion intesity is increased, and (6) sea water rising due to global warming causing ice melting in the poles inundating coastal areas and intensifying sea waves strongly beating the shoreline causing more erosion. Finally, discovering those erosion reasons plus the results of shoreline change detection will be useful for leadership in bring out solutions managing sustainable coastal zones.

5. CONCLUSIONS

The results from satellite image analysis has shown that accretion/erosion situation in Cuu Long estuaries has happened very strong and seriously, especially in the global climate change circumstances. The integration of remote sensing and GIS has shown the potential in feature identification, feature extraction and change detection in coastal zones particularly in large areas. Erosion disaster is very dangerous caused by natural and even human reasons. It is harmful for human life. Therefore it is necessary to have a long-term strategy for disaster management in national level.

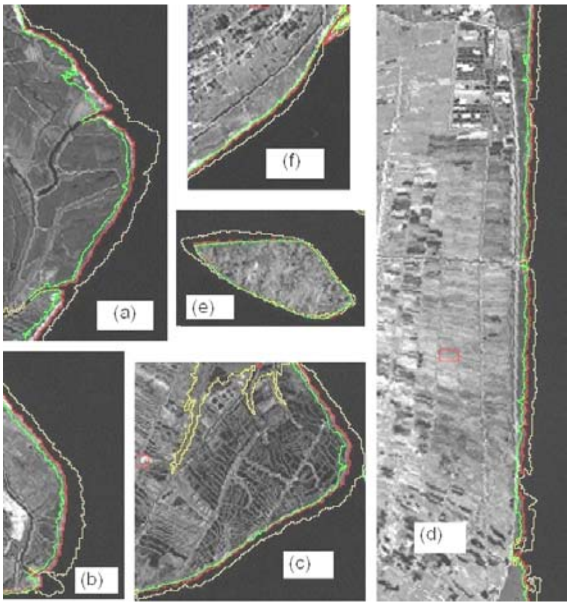

Fig. 4: Shore sections in coastal communes with the strongest erosion in 1989-2004 ordered decreasingly:
(a) Thanh Hai; (b) Thua Duc; (c) Phu Tan; (d) Tan Dien, Kieng Phuoc; (e) Cu Lao Dat dune, (f) Dan Thanh

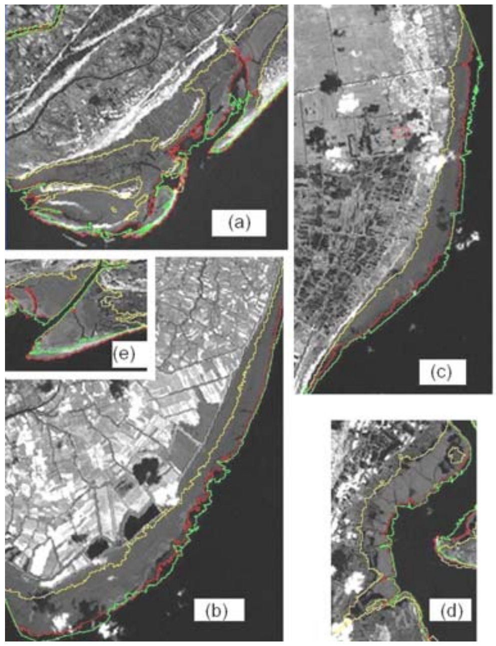

Fig. 5: Shore sections in coastal communes with the strongest accretion in 1989-2004 ordered decreasingly:
(a) Thanh Phong, (b) An Thanh 3, (c) Trung Binh, (d) Bao Thuan- Bao Thach, (e) Dong Hai

Shoreline 1989 in yellow, 2001 in red, 2004 in green

7. REFERENCES

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