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Application of remote sensing for shoreline change detection in Cuu Long estuary

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Abstract. Coastal zone of Cuu Long estuary is a place through which Mekong River flows into the Eastern Sea with 8 estuaries. is the zone is formed under the influences in the interaction between river and sea. Geologically, coastal zone of Mekong delta is characterised by the predominat of clay and silt formations. These two factors makes the shoreline sensitive to exogenous processes such assedimentation and erosion.. This paper presents an application of satellite remote sensing technology to detect and analyze the spatial changes as well as quantify the shoreline change in Cuu Long estuary. Landsat and Aster satellite images were used with band ratio method for shoreline change detection.The results present shoreline changes maps in three periods: 1989, 2001 and 2004. The outcomes of the case study can be used as an orientation for the sustainable integrated management plan of coastal zones.

Keywords: accretion, band ratio, erosion, change detection, shoreline.

1. Introduction

Shoreline, the boundary between land and sea keeps changing its shape and position continuously due to dynamic conditions. The change in shoreline is mainly associated with waves, tides, winds, periodic storms, sea-level change, the geomorphological processes such as erosion and accretion and human activities [1]. Erosion and accretion affect human life, agricukture and aquculture practice and waterway transport 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; (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 [2]; (4) Multispectral remote sensing satellites provide digital imageries in infrared spectral bands where the land-water interface is well defined. Furthermore this

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method has advantages: not time consuming, inexpensive executed cost and large ground coverage monitoring [2,3].

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 [4]. This study applied satellite image interpretation 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. The climate has tropic and monsoon characters with two seasons: the rainy from May to November and the dry from December to April. The river system with high density is a place through which Mekong River flows into the Eastern Sea with 8 estuaries.

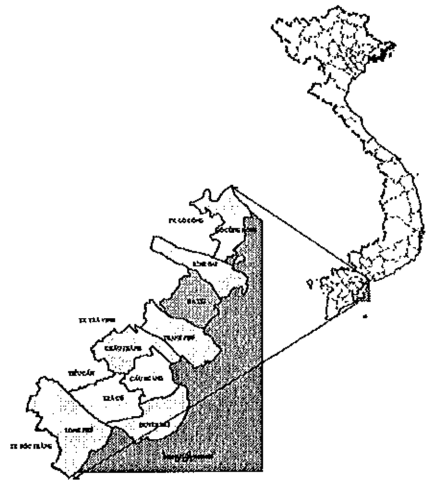

Fig. 1. The study area.

2.2. Data set

Satellite images were acquired in three dates: Landsat TM in 1989, Landsat ETM+ in 2001 and Aster in 2004 (Table 1). Landsat images have spatial resolution of spectral bands in 30m and ETM+ band 8 is panchromatic of 15m resolution. Aster image has 2 groups of spectral bands with different pixel resolutions: VNIR bands in 15m and SWIR bands in 30m. These image were taken in dry season. Therefore shoreline is easily identified due to the fact that the water level is not very high. Topographical map at scale 1:100.000, UTM coordinate and WGS-84 projection was use for geo-rectifying and determining erosion/ accretion locations.

Table 1. Satellite data used in the study

Acquisition Time	Satellite	Sensor	Resolution
16 /01/ 1989	Landsat5	TM	30m
11/12/2001	Landsat7	ETM+	15m, 30m
12/12/2004	Aster	Aster	15m, 30m

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 provides unique information not available in any single band that is useful for distinguishing earth surface 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 can 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 strong absorber of near infrared radiation (NIR), so Landsat band 4 (0.76-0.90μm) and Aster band 3 (0.76-0.86μm) are 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 necessary in ratioing settings. This study used band ratioing method in thes mentioned wavelength region to extract soil and water from Landsat and Aster images.

Image preprocessing: Aster image has the smallest spatial resolution of 15m of VNIR bands, so band 4 (pixel size in 30m) in SWIR spectrum will be downscaled to this one. This process is also appliedto Landsat bands with 30m 1 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 topographical map. Other Landsat images was rectified by Aster one. The RMSEs were less than 0.5 pixel.

Image analyzing: In the first step, histogram threshold method is used on NIR band for separating land from water. The threshold values are selected so that all water pixels are separated from the land pixels . 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". Image1 is multiplied to image2 to generate third image named "image3". Some isolated pixels are remove with sieveing and filtering technique for the final shoreline image. The resulted shoreline extraction is transformed into vector format and exported into MapInfo format for analyzing change of erosion/accretion areas. Change in pairs are examined such as 1989-2001 and 2001-2004. Fig. 2 illustrates the steps of the method.

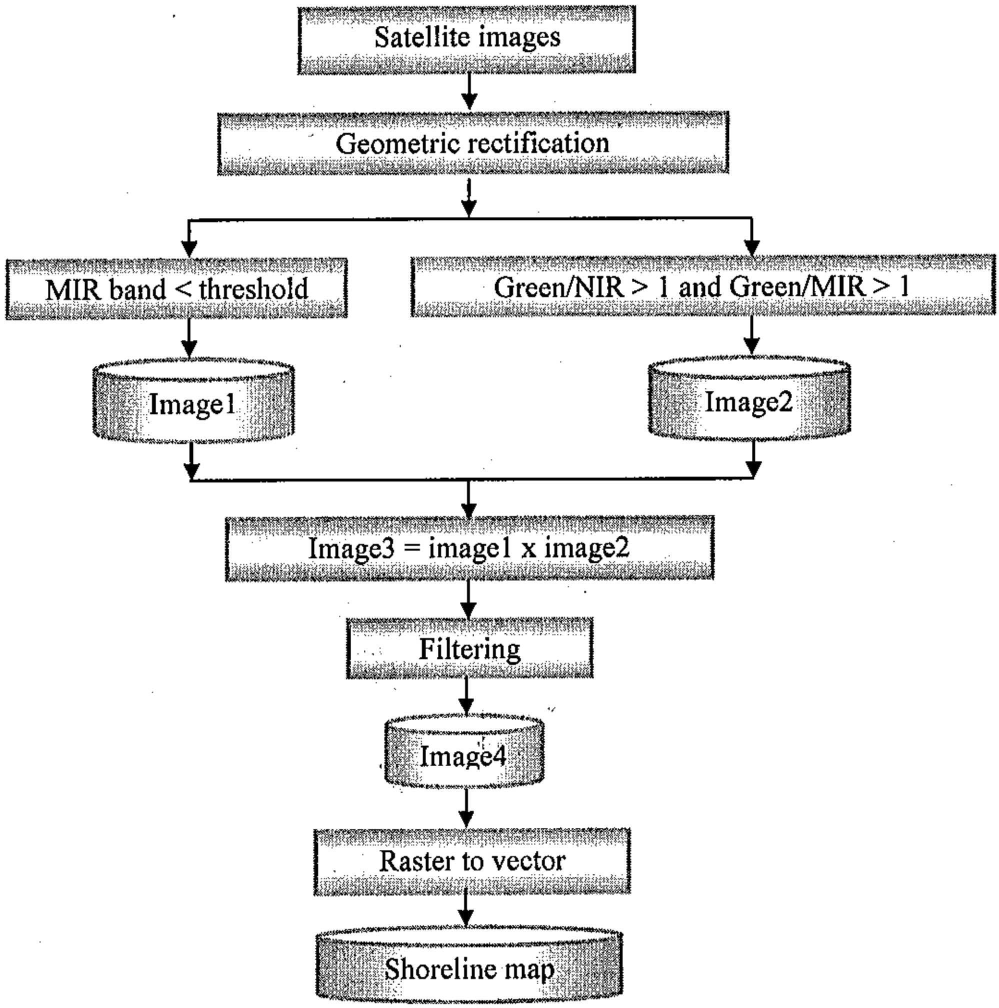

Fig. 2. Flowchart of extracting shoreline from satellite images.

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 the 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 sedimented in 1989-2001, but they were seriously eroded after 2001. It lengthened and joined with previous erosion sections. It is obviously observed in shoreline from Duyen Hai, Thanh Phong and Ba Tri districts.

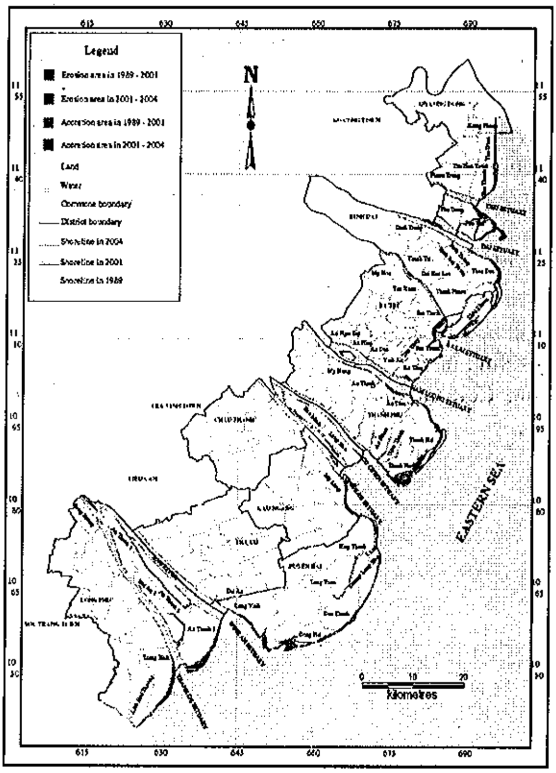

Fig. 3. Shoreline change in 1989-2004.

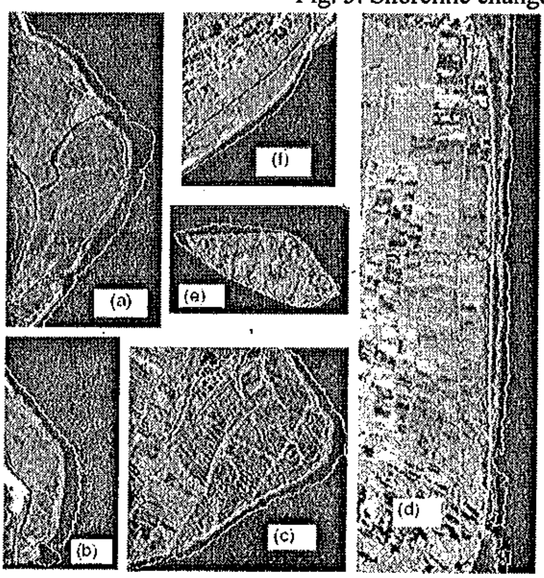

Fig. 4. Shore sections in coastal communes with the strongest erosion in 1989-2004 ordered decreasingly: Thanh Hai; (b) Thua Duc; (c) Phu Tan; (d) Tan Dien, Kieng Phuoc; (e) Cu Lao Dat dune, (f) Dan Thanh

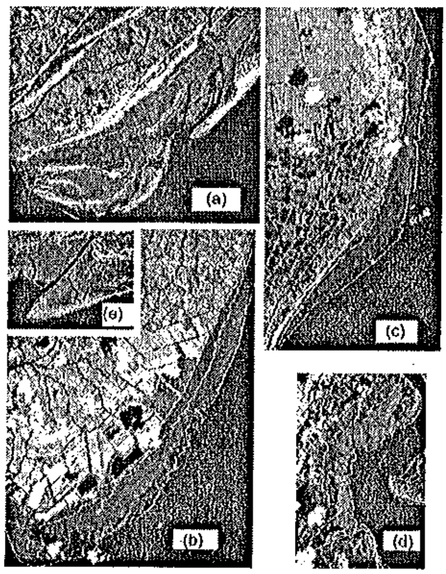

Fig. 5. Shore sections in coastal communes with the strongest accretion in 1989-2004 ordered decreasingly: (a) Thanh Phong, (b) An Thanh 3, (c) Trung Binh, (d) Bao Thuan- Bao Thach, (e) Dong Hai.

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

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