Remote sensing application for coastline detection in Ca Mau, Mekong Delta

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ABSTRACT

Extraction of the coastline is an essential task of environment monitoring and change detection in coastal area. Ca Mau, the southernmost province of Vietnam, is affected by coastal environmental change and the coastline has been subjected to specific modifications over many years. The cause is determined by three factors including erosion, stability and sedimentation.

The pattern of coastline changes of Ca Mau was identified using LANDSAT images acquired from 2002 to 2009. In this study we proposed a semi-automatic technique to extract the coastline. The coastline indicator was defined as the vegetation border. Then, because of similarity in spectral response between land and tidal zone or turbid waters, the band ratio method with two normalized difference indices Normalized Difference Water Index (NDWI) and Normalized Difference Vegetation Index (NDVI) was combined to have the more correct and suitable results to detect the coastline change in Ca Mau province. The paper present the new method developed and discuss the first results obtained.

Key words: Coastline, NDWI, NDVI, LANDSAT, Band ratio, Ca Mau

1. INTRODUCTION

Coastline is defined as the line of contact between land and the water body (Alesheikh *et al.*, 2006), and is one of the most important linear features on the earth's surface, which has a dynamic nature (Winarso *et al.*, 2001). Detection and measurement of coastline changes are important tasks in environmental monitoring and coastal zone management (Zhao *et al.*, 2007), which include a lot of critical issues as shoreline protection and development, coastal and marine resources protection or hazards forecasting (Nayak, 2005). Despite a simple definition, the dynamic nature of the coastline makes it difficult to monitor. However these studies have showed that the use of satellite remote sensing data allows detecting the coastline accurately, with large ground coverage and a satisfactory acquisition repetition. Indeed, 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 (Kumaravel *et al.*, 2012).

This study was a preliminary step of a greater project for the assessment of climate change in the South Vietnam using remote sensing, GIS and math model. The aim was to find a way to extract the South Vietnam coastline, to later evaluate the changes in the last decade. Coastline extraction techniques from satellite imagery are adapted and based on band ratio in the infrared domain (Alesheikh *et al*, 2007; Van *et al*, 2009) to create a new method well adapted to the study area in South Vietnam. Indeed, turbidity of coast waters, needs of accurate results, and cost and time resources, required the development of a suitable methodology. The developed methodology is presented and discussed about the first results.

2. STUDY AREA AND DATA SET

2.1 Study area

The study area is located in Ca Mau province (Figure 1), the southernmost province of Vietnam. The climate is tropical, with two main seasons: the rainy or monsoon season, starting from May to November and the dry season from December to April. Average rainfall is 2.5 mm/year, and annual average temperature is around 26° to 27°C. Bac Lieu and Kien Giang provinces border respectively North East and North West of Ca Mau province. The coastal zone of this province is 307 km long. West and South coast correspond to the Gulf of Thailand, and the East coast to Eastern Sea..The coastal zone is stretch over latitude 9°27’4.73’’N to 8°34’57.12’’N and longitude 106°11’57.59’’E to 104°47’31.94’E (UTM zone 48 North). Ca Mau province’s coastal area is subject to two different tidal regimes, because of two adjacent currents; one North-South and the other West-South. Because of this particular tidal regime and the high density of the stream and canal network flowing into the Eastern Sea, the coastal waters are mixed with various materials (as suspended particles, sediments and phytoplankton) and present a high turbidity. On this part of Vietnam the main coastal vegetation is mangrove.

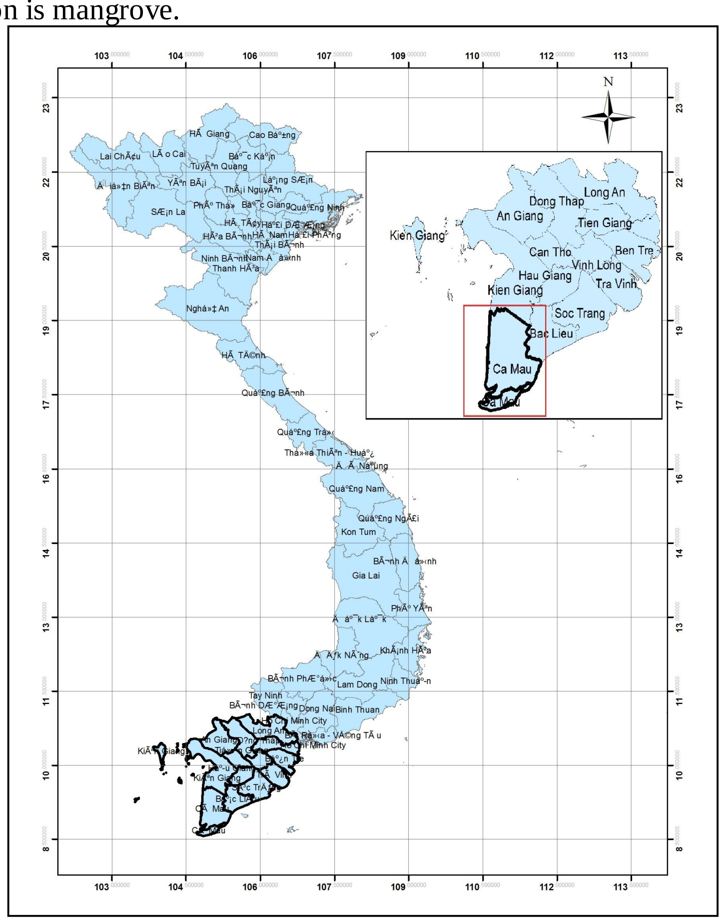

Figure 1. Localisation of the study area.

2.2 Data set

To extract and monitor the coastline, ten Landsat images (ETM+ 7, TM 5 and TM 4) were collected from 2002 to 2009, path/ row of these image is 125/054. Those images present a weak cloud coverage on the coastal area and a pixel resolution of 30 meters; other characteristics are shown in the Table 1. Five of those images, the Scan Line Corrector (SLC) was off, and a gap filling pre-processing step was done, using the NASA gap filling software, the spectral data across gaps in SLC off images was interpolated from a gap free image. Because the land cover corresponding to the gap has to be similar on the two images, the scenes to process have been carefully chosen. The maximum acquisition time difference between the scenes is one year and the acquisition season is similar.

Table 1. Satellite data used in the study.

Acquisition time	Satellite	Sensor/SLC*	Gap filling	Combination**
17-03-2002	Landsat 7	ETM+/ON	No	No
05-04-2003	Landsat 7	ETM+/ ON	No	No
07-04-2004	Landsat 7	ETM+/ OFF	Yes	No
10-04-2005	Landsat 7	ETM+/ OFF	Yes	Yes
20-11-2005	Landsat 7	ETM+/ OFF	Yes	Yes
08-06-2006	Landsat 4	TM/ ON	No	No
11-10-2008	Landsat 7	ETM+/ OFF	Yes	Yes
12-11-2008	Landsat 7	ETM+/OFF	Yes	Yes
08-02-2009	Landsat 5	TM/ ON	No	No
09-12-2009	Landsat 5	TM/ ON	No	No

* SLC: Scan Line Corrector, ** Combination: cf Methodology

3. METHODOLOGY

The aim of the methodology developed in this study was to adapt existing methods to extract the coastline, on the coastal area of South Vietnam.

3.1 Coastline definition

The coastline (or shoreline) is ideally defined as the physical interface between land and water (Boak and Turner, 2005). But the shape of this boundary is continually changing according to dynamic environmental conditions such as seaborne influences (waves and tides), climate (winds and storms) or geomorphological processes (erosion and accretion) (Selvavinayagam, 2008). Considering the data set used in this study, it was not expected to obtain images with similar conditions such as tide elevation and suspended particle concentration. In order to compare the coastlines extracted from multi-date images, with different seaborne and climate condition, a coastline indicator is chosen; which is a feature used to represent the coastline. Considering that in the study area all the coast is occupied by mangrove forest or other kind of vegetation, the contact line between vegetation and sand or water (depending on the tide elevation) had been considered as the coastline. This choice, using the vegetation limit as a coastline proxy, is all the more important because it also highlights the mangrove forest dynamic.

3.2 Coastline extraction

A semi-automatic technique (Figure 2), adapted to Ca Mau province, was developed to extract the coastline shape from satellite images. The first step of this technique is based on the spectral band ratio method between Landsat band 4 and 2 and between band 5 and 2 (Alesheikh *et al*, 2007; Van *et al*, 2009) and two indices that are the Normalized Difference Vegetation Index (NDVI; Rouse *et al*, 1973) and the Normalized Difference Water Index (NDWI; Gao, 1996). NDVI is calculated using equation (1) and NDWI with equation (2). NDVI and NDWI are applied to improve the land and water discrimination, to decrease the land pixels proportion mistakenly assigned to water. Indeed, NDVI allows detecting active vegetation (positive value), bare soil (null value) and water (negative value). As for NDWI, this index is usually used for the canopy water content, but in this case it just help to make discrimination between real vegetated land and tidal zone or turbid water, which will not have the same NDWI value.

$$NDVI = (band\ 4 - band\ 3)/\ (band\ 4 + band\ 3) \qquad (1)$$

$$NDWI = (band\ 4 - band\ 5)/\ (band\ 4 + band\ 5) \qquad (2)$$

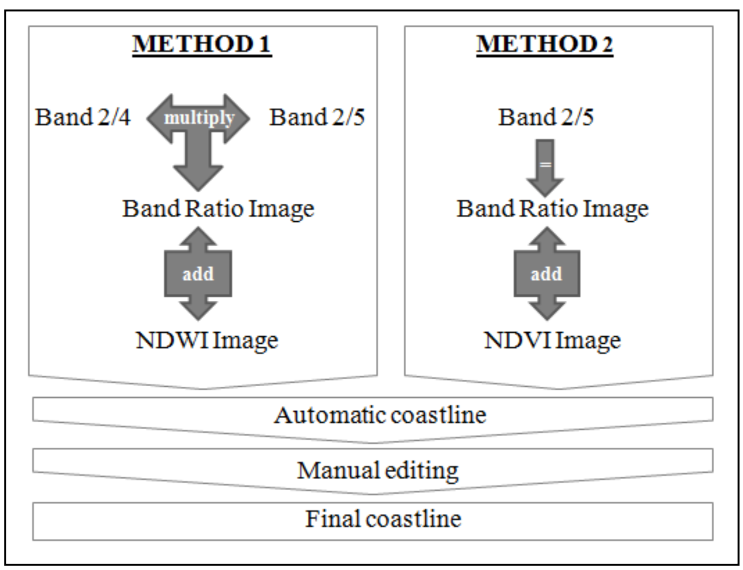

Figure 2. Flowchart of extracting the coastline from Landsat image.

Moreover, to extract a more realistic coastline shape, two similar techniques have been proceeded (Figure 2). The first one uses two band ratios (band 2/4 and band 2/5) and NDWI, and the second one is based on a single band ratio band 2/5 and NDVI. Using the most suitable method for each image, the quality of results is better than using a single method which does not match with all images (different seasons, tide elevations, sediment concentrations, and sensors). A combination between two dates of acquisition within one year is applied for cloudy or gap filled image to avoid discontinuity due to cloud or to unfilled gaps.

The last step of the extraction concerns the corrections of the automatically defined coastlines that rectifies the extracted coastlines in ArcGIS software (Winarso *et al.*, 2001). This is a time consuming task but it is necessary to obtain an accurate coastline shape, particularly Ca Mau province coasts have a dense system of rivers and canals flowing into the sea. This particularity creates a lot of discontinuities in the coastline automatically extracted, which have to be manually edited.

4. RESULTS AND DISCUSSION

This study was a preliminary step of a greater project concerning the assessment of climate change in the South Vietnam using remote sensing, GIS and math model. The aim was not to quantify coastline change in the last decade, but to adapt coastline detection technique to South Vietnam area to create a specific method, suitable to this environment and to the time and cost supplies for the upcoming project. The results of this study correspond to one coastline vector for each year (2002, 2003, 2004, 2005, 2006, 2008, and 2009) (Figure 3).

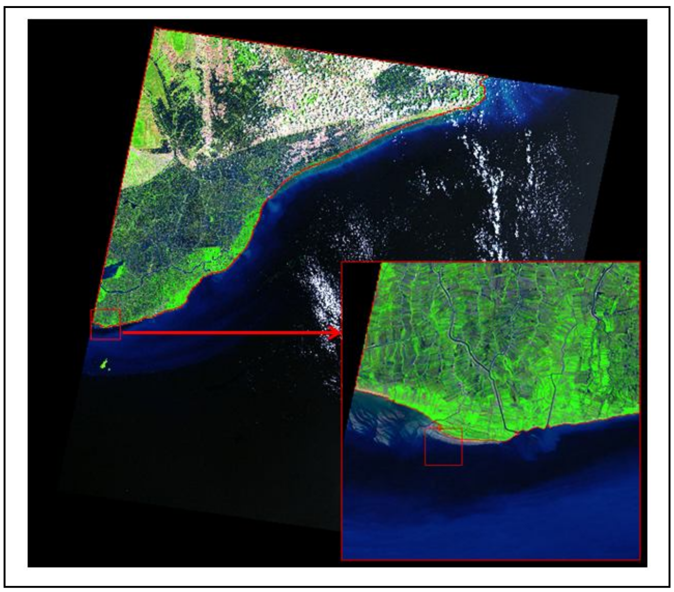

Figure 3. Landsat ETM+ 7 17 February 2002 with the final coastline extracted (red line) and a zoom in a specific tidal zone (RGB:543).

The first "automatic" coastline obtained (before manual edits), is realistic, but contain noteworthy anomalies. Parts of those errors are due to confusion between tidal zone or high turbid water pixels with land or vegetation pixels. Results show that the use of NDVI and NDWI limits wrong assignments. Then, like said previously the dense stream network flowing into the sea creates discontinuities all along the coastline. Other discontinuities appear on the "automatic" coastline because of clouds or gaps (Landsat ETM+7 SLC off images). Final coastline vectors (after manual edits) are visually satisfactory, and results of the combination technique for gap and cloudy image are also good. Indeed, the vegetated land boundary is visually clear, and it is easy to see flagrant errors or discontinuities and to edit its. Despite visually good results the precision of the coastline extracted should be discuss. Actually the precision of the method depend on several constituents: (i) parameters inherent to the satellite sensor (spatial and spectral resolution, precision of the geographic corrections (Zhu *et al.*, 2001)), (ii) parameters characteristic to the acquisition date seaborne and climate conditions (influencing the "automatic" coastline quality) or (iii) parameters depending on the user (subjectivity during manual editing). Concerning the precision depending on satellite sensor characteristics, all images have the same precision, and errors due to the spatial resolution have to be considered depending on the study aim and scale. Then, poor climate condition or water turbidity will drop the "automatic" coastline precision; but the manual editing is able to solve this problem. Lastly, the subjectivity of the coastline extraction is limited to the minimum in this method because user's modifications concern only strong anomalies and discontinuities. The aims of the automatic detection using band ratio and NDVI or NDWI is to limit subjective estimate and to reduce the processing time; moreover this part of the method is easily automated. So, the new semi-automatic method developed in this study is well adapted to the detection of the coastline in the South Vietnam, which presents turbid coast waters.

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