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Application of Remote Sensing and GIS technology for monitoring coastal changes in estuary area of the Red river system, Vietnam

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Abstract

Coastline is the most dynamic part of seascape since its shape is affected by various factors. Coastal zone is an area with immense geological, geomorphological and ecological interest. Monitoring coastal change is very important for safe navigation, coastal resource management. This paper shows a result of monitoring coastal morphological changes using Remote Sensing and GIS. Study was carried out to obtain intensity of erosion, deposition and sand bar movement in the Red River Delta. Satellite images of ALOS/AVNIR-2 and Landsat were used for the monitoring of coastal morphological changes over the period of 1975 to 2009. Band rationing and threshold technique was used for the coastline extraction. Tidal levels at the time of image acquisition varied from -0.89m to 2.87m. Therefore, coastline from another image at a different tidal level in the same year was considered to get the corrected coastline by interpolation technique. A series of points were generated along the coastal line from 1975 image and were established as reference points to see the change in later periods. The changes were measured in Euclidean distances from these reference points. Positive values represented deposition to the sea and negative values are erosion. The result showed that the Red river delta area expanded to the sea 3500m in Red river mouth, and 2873m in Thai Binh river mouth from 1975 to 2009. The erosion process occurred continuously from 1975 up to now with the average magnitude 23.77m/year from 1975 to 1989 and 7.85m/year from 2001 to 2009 in Giao Thuy area. From 1975 to 2009, total 1095.2ha of settlement area was eroded by sea. On the other hand, land expanded to the sea in 4786.24ha of mangrove and 1673.98ha of aquaculture.

Keywords : Coastal morphological, coastal line extraction, coastal erosion, sand bar movement

1. Introduction

The coastal zone is currently a sensitive policy area for those involved with its management. Phenomena such as erosion and landslides affect the stability of both the natural and the built environment (Mills *et al*. 2005). The coastline is defined as the boundary between land and a water surface (Boak and Turner 2005; Guariglia *et al*. 2006). It is the most dynamic part of seascape since its shape is affected by different factors, such as hydrography, geology, climate, and vegetation (Guariglia *et al*. 2006). All these factors contribute to change the coastline morphology. In addition to natural factors, human activities, such as building dyke, expanded land and aquaculture also play a main role in modifying coastline. Therefore, a research of coastal morphological is needed to define the levels, forms and period of erosion and deposition and sand bar movement over years. After that, we can predict the trend,

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find out the causes and propose solutions to degrade the consequence of the erosion and deposition. On another hand, the statistic of what type of land use and how many land area was taken to the sea over time is indispensable. Based on the information we can know the driving factors, which can provide relevant information for coastal resource management, environmental protection and for planning sustainable development of coastal areas.

Traditional coastline mapping in small areas is carried out using conventional field surveying methods. Over last century, the popular method for delineating the shoreline is analytical stereo photogrammetry using tide-coordinated aerial photography controlled by kinematic GPS techniques (NOAA 1997). Nowadays, remote sensing technique, which can provide synoptic view, multispectral and high resolution data, plays an important role for monitoring and mapping coastal areas (Doydee 2005). Accuracy of coastline extraction from satellite image depends on water line, tidal level and several other conditions. Variations in coastline position can be: long-term, cyclical, random, due to specific events (Guariglia *et al*. 2006). This study used the band rationing method that is rationed between band 4 and 2 for Advanced Land Observing Satellite (ALOS) image and Landsat MSS, and between band 5 and 2 for Landsat TM, ETM.

Song Hong, the Red river, is the largest river in northern Vietnam provides and forms a great delta before entering the Gulf of Tonkin. Red river delta area is an intensely developed and densely populated area. Along the coastal line of Red river delta there are both phenomena occurring included erosion and deposition, that makes the coastline change is complex and fast. By using advantages of remote sensing and GIS technology, this paper aims to: i) detect the coastline position from satellite images, ii) analyze and assess the magnitude and direction of erosion, deposition as well as sand bars movement. Information derived from this paper will provide the overview of coastal morphological change in the past and trend of coastal line changes in the future in the Red river delta area in Vietnam. Moreover monitoring of land use change is also concerned as the consequence of the coastal morphological changes.

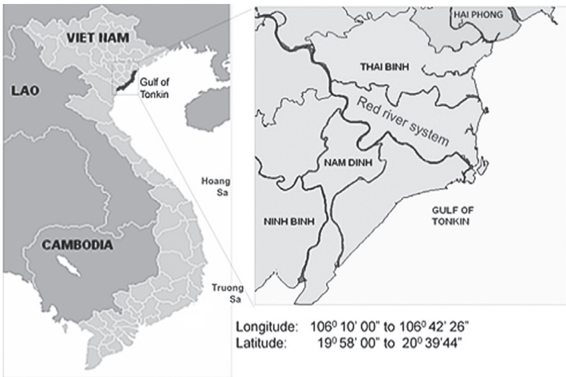


Fig. 1. Coastal area of Red river delta

2. Study area and materials

2.1 Study area

The Red River Delta in the North of Vietnam is characterized by a triangular shaped low-lying delta plain that developed during the major part of the Holocene (Hoekstra *et al*. 2007). It has length of 130 km coastline beside Gulf of Tonkin, it covers five districts as Tien Lang (Hai Phong province); Thai Thuy and Tien Hai (Thai Binh province); Giao Thuy, Nghia Hung and Hai Hau (Nam Dinh province). The study area (see Fig. 1) has seven large mouths of rivers along the coastline. This coastline follows Northeastern to Southwestern direction starting from Van Uc estuary and ending up to Day estuary.

2.2 Materials

Maps and satellite images are the main materials in this research. We were provided a topographic map at scale 1/50000 built in 2002 from Center of Surveying and Map Data (COSAMD). Tide level table from 1975 to 2009 for each hour from Hondau station and statistical data of direction and speed of sea flow along the coastline was provided by Institute of Marine Geology and Geophysis (IMGG).

Satellite images, which are used for extracting coastline, include: Landsat MSS, TM, ETM+ images free downloaded from Global Visualization Viewer (GLOVIS), the United States Geological Survey (USGS), and ALOS-Advanced Visible and Near Infrared Radiometer type 2 (ALOS AVIRNIR-2) images provided by Japan Aerospace Exploration Agency (JAXA). List of satellite image and tidal heights at acquisition times was shown in table 1.

Table 1. List of satellite images and tidal heights at acquisition times

Images	Sensor	ParthRow	Date	Local Time	Resolution	Tidal height (m)
Landsat 2	MSS	136046	12/29/1975	9h40'	80	1.14
Landsat 5	TM	126046	11/23/1989	9h39'	30	-0.20
Landsat 4	TM	126046	4/21/1989	9h51'	30	0.47
Lansat 7	ETM+	126046	11/16/2001	10h6'	30	-0.89
Lansat 7	ETM+	126046	9/29/2001	10h5'	30	0.53
Lansat 7	ETM+	126046	10/5/2009	10h7'	30	0.81
Lansat 7	ETM+	126046	11/6/2009	10h8'	30	2.87
ALOS	AVINIR-2	201603200 201603190 201603180	11/6/2009	10h38'	10	2.45

3. Methodology

To complete the purposes of this research, a series of remote sensing and spatial analysis methods are implemented from preprocessing images, images analysis, modeling, and analysis vector data in GIS. A general method for this research is shown in Fig. 2.

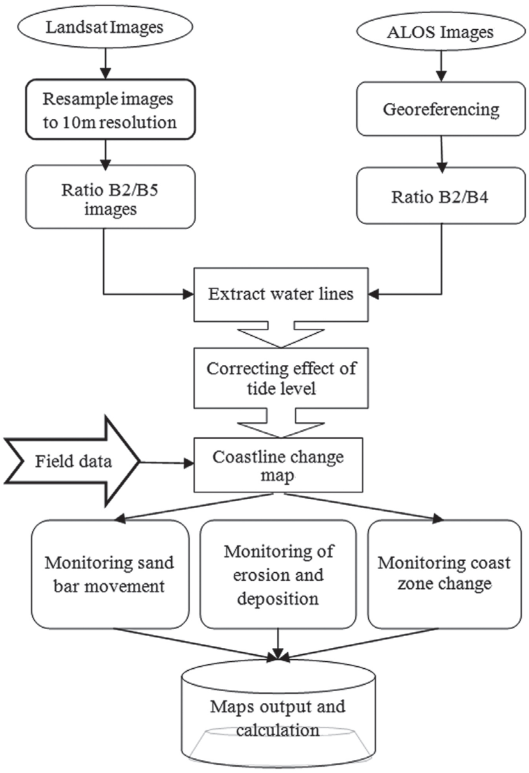


Fig. 2. Flow chart of the experimental method

In this reaearch, remote sensing technology is used to detect water lines and calculate land use change from satellite images over the years. Water lines are input data for spatial analysis in GIS sub-methods, which are contour interpolation method to correct effect of tidal lever, linear direction mean method to monitor sand bars movement, control points to monitor erosion, deposition, and intersect multi-temporal data to define the area of erosion or deposition. A field trip in 1 week has carried out along the coastal line to collect information about history of erosion, human activities effect to coastal line change, location of water lines at the highest and lowest tidal lever. In situ data plays very importance role in validate and assessment the change of coastal morphology as so as provided the evidences to define the driving factors of change.

3.1 Images pre-processing

After data covering the study sites in the respective period were obtained, a data preprocessing phase was performed to prepare the data for the experiments. The images were produced at different spatial resolutions. ALOS images, which have highest resolution (10m), were used as reference resolution for Landsat images. Therefore, before analysis, all images were resampled to the same spatial resolution (10m). To minimize the alteration of original spectral value of Landsat images, Nearest Neighbor method was used for resampling. Study area is covered by 3 scenes of ALOS AVIRNIR-2 images at the same path and date. These images are geo-corrected (RMS< 1pixel) using control points collected from panchromatic band (15m resolution) of Landsat 7 images acquired on 06, Nov 2009.

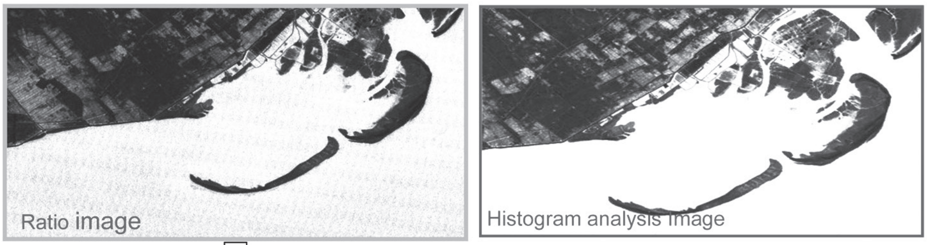
3.2 Coastline detection

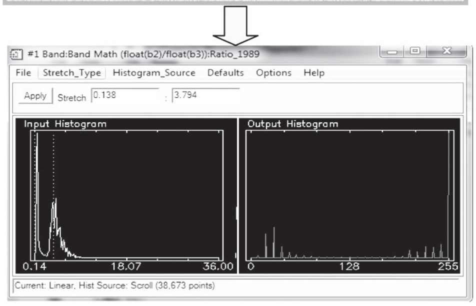
Since the coastline is the line of contact between sea and land (Boak and Turner 2005; Kumaravel *et al.*2013; Naji *et al*. 2011), as the sea level varies, this boundary also varies, and therefore it is difficult to exactly identify its position (Guariglia *et al*. 2006). Extraction coastline from satellite image depends on waterline, tidal level and several other conditions. Variations in coastline position can be: long-term, cyclical, random, due to specific events (Guariglia *et al*. 2006).

There are several methods for deriving coastline position from remote sensing data: the coastline can be digitized by eye, image can be classified into land and sea, often by identifying a threshold value for a single spectral band, or an edge detecting filter or segmentation algorithm can be applied to the image (White and Asmar 1999; Zhang *et al*. 2013). Band 5 of Landsat TM or ETM image can separate land and water features, but in the transition zone it is influenced by mixed pixels and moisture regimes between land and water. If the reflectance values are sliced to two discrete zones, they can be depicted water (low values) and land (higher values) (Alesheikh *et al*. 2007). However, this method is difficult to find the exact value, as any threshold value will be exact on some area, not all. To reduce influence of the threshold value choice and to improve extraction accuracy of the coast line, this study used the band rationing method that is rationing between band 2 and 4 for ALOS and Landsat MSS images, and between band 2 and 5 for Landsat TM, ETM. Water differs from other land surfaces because it tends to absorb strongly the near-infrared wavelengths (b4 for ALOS and Landsat MSS) and the Short Wave Infra Red wavelengths (b5 for Landsat TM, ETM) and reflects strongly in the green wavelengths (b2 for Landsat and ALOS). Band ratio (b2/b4; b2/b5) is a measure of the difference in reflectance between these wavelength ranges. Therefore, water and land can be distinguished clearly by using these ratios. Generally the ratio of b2/b5 is greater than one for water, and less than one for land in large areas of coastal zone (Chand and Acharya 2010; Alesheikh *et al*. 2007). The ratio images were calculated histogram and defined threshold by changing the value step by step with leap of 0.01 until distinguishing the most clearly between water and land. Rationing images were sliced and converted to shape file before editing, removing small objects and generating map for shoreline positions.

3.3 Correcting effects of tidal level

The definition of the coastline must be considered along-shore variation. A shoreline may also be considered over a slightly longer time scale, such as a tidal cycle, where the horizontal/vertical position of the shoreline could vary any-





Images	Land		Water	
	Min	Max	Min	Max
L12/29/1975	25.00	30.00	31.01	253.00
L4/05/1989	0.17	3.87	3.88	78.60
L11/23/1989	0.14	3.68	3.69	63.50
L9/29/2001	0.39	4.01	4.02	120.00
L11/16/2001	0.07	3.95	3.96	142.00
L10/05/2009	0.12	4.31	4.32	25.34
L11/06/2009	0.02	4.75	4.76	12.66
A11/06/2009	0.76	3.92	3.92	13.43

Fig.3. Using ratio images and defined thresholds to extract coastlines

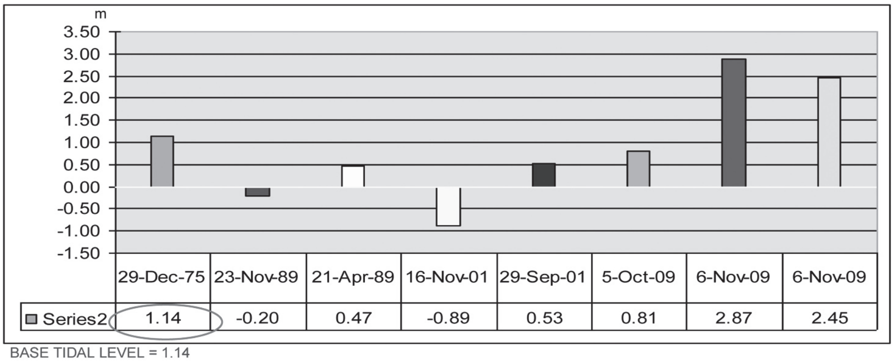


Fig. 4. Tidal level at the time of required images (horizontal axis is tidal lever at the time of image acquirement)

where between centimeters and tens of meters (or more), depending on the beach slope, tidal range, and prevailing wave/weather conditions (Boak and Turner 2005).

In the Red river delta, tidal level at the acquisition times of images are very different, its range is from -0.89m to 2.87m. Therefore, the influence of tidal level should be considered. In database of this study there are ten satellite images, including: two Landsat TM images in 1989; two Landsat ETM images in 2001; two Landsat ETM images in 2009, three ALOS images in 2009, and in 1975 there is only one Landsat MSS image. The problem is how to extract coastline at the same tidal level (we call base tide level). Assumption that coastline is considered as elevation contour, tidal level as elevation of contour, and beach slope is stable within 1 year. From 2 coastlines at 2 tidal levels, it is possible to interpolate another one at base tidal level. Because in 1975 we have only one coastline at tidal level of 1.14m, therefore we used 1.14m as the base tidal level. The coastline for each year was interpolated from 2 relevant coastlines. Totally, we have 4 coastlines for 4 years to analysis.

3.4 Monitoring coastline change

From the coastlines in 1975, 1989, 2001 and 2009, by visual evaluation it is clear to define that: coastline of the study area varies very complicated with different shapes, magnitudes and trends. Consequently, it was divided in three zones with different characteristic as A, B and C (Fig. 5). Zone A was from Van Uc estuary to Lan estuary, it was deposition area. Zone B has two parts in Red river mouth and Day river mouth, this area includes deposition and sandbar movement. Zone C includes Hai Hau and Giao Thuy district, and in this zone the erosion occurs very critically.

Fig. 5. Zoning study area

3.5 Monitoring erosion and deposition

The coastline of the Red River Delta is characterized by alternating patterns of rapid accretion and severe erosion (Maren 2007). To monitor the erosion and deposition (zone A, C), we used monitoring points. Along the coastline of 1975, we marked 42 points, each point is far from each other about 3km. These points are distributed to reflect the strategy of coastal line change. From each point, we draw a line, which is perpendicular with tangential line at the position of the point. Length of the perpendicular line to coastline 1989 is distance of coastline change in period from 1975 to 1989. The same process was performed for 1989 – 2001 and 2001 – 2009 periods. Monitoring coastline change starts in 1975, if the change distance is negative it means erosion and the positive values represent deposition. Erosion process only focuses at zone C. This zone has different geomorphic characters and it was divided into two parts: part C1 includes 18 sections (sections 1–18) from Northeastern to Southwestern. Part C2 includes 9 sections (sections19–27) from East to West. Both monitoring point method and line segment was used for monitoring erosion. Mean erosion distance was calculated by using the equation in Fig. 6

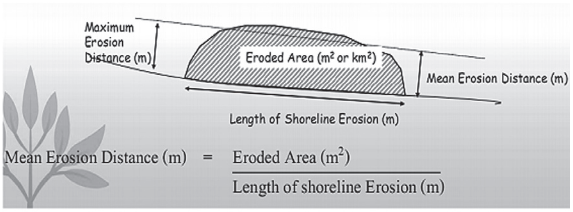


Fig. 6. Formula for analysis of mean erosion distance

3.6 Monitoring sand bar movement

The sand bar movement of the Red river delta is characterized by alternating location, rate of deposition and erosion. Its truth nature is sediment transport. Net of sediment transport patterns inferred from grain-size trends, based upon definition of transport vectors (Do *et al*. 2007). For convenience in the analysis, sand bars were converted into lines and extracted centerlines. The centerline is center of sandbar, which regards to direction along the sandbar. The mean direction interpolated from 2 center lines of 2 dates is the trend of sand bar movement. The trend of a set of line features is measured by calculating the average angle of the lines. The statistic used to calculate the trend is known as the directional mean.

4. Results and discussion

4.1 Precision accuracy

In this study, coastline was extracted from the band ratio image. The accuracy of coastline location must be considered to three aspects. The first is effective resolution of images (Gens 2010). Of course, coastline change can be detected with relatively coarse spatial resolution (White and Asmar 1999) such as Landsat TM image (30m nominal pixel size). However, the accuracy of resulted land cover classes depends on the relative size of spatial features and the spatial resolution of the remotely sensed image (Nguyen 2012). The second factor effecting accuracy is R.M.S. error of the registration. In the series of collected satellite images, all of the Landsat images were geometric correction already in the same coordinate projection (zone 48N, WGS84). Only the ALOS image needs to be geometric corrected to the same projection with Landsat image. Total RMS of georeferencing is 3.097m, below 0.3 pixel size. The third error resource refers to the ability of defining objects on satellite image, here is the eager between water and land. Coastline is extracted

The Linear Direction ean given as

$$LDM = \arctan \frac{\sum_{i=1}^{n} \sin \theta_i}{\sum_{i=1}^{n} \cos \theta_i}$$

where θ are the directions of the set of poly line features from singular origin

$$\sum_{i=1}^{n} \sin \theta_i > 0,\ \sum_{i=1}^{n} \cos \theta_i > 0 = LDM$$

$$\sum_{i=1}^{n} \sin \theta_i > 0,\ \sum_{i=1}^{n} \cos \theta_i < 0 = 180° - LDM$$

$$\sum_{i=1}^{n} \sin \theta_i < 0,\ \sum_{i=1}^{n} \cos \theta_i > 0 = 360° - LDM$$

$$\sum_{i=1}^{n} \sin \theta_i < 0,\ \sum_{i=1}^{n} \cos \theta_i < 0 = 180° - LDM$$

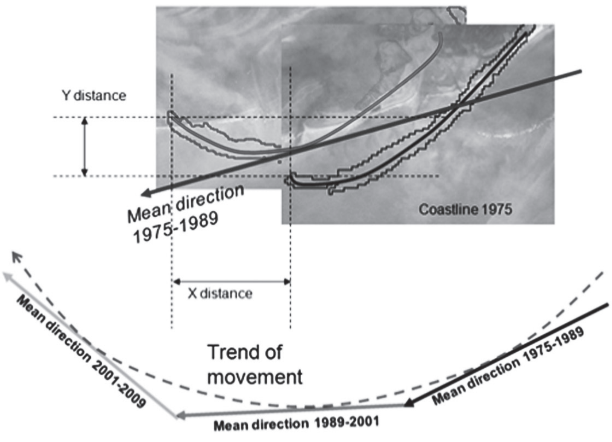


Fig.7. Measuring direction equation (Mitchell 2005)

from ratio images by changing the threshold value with leap of 0.01 until distinguishing the most clearly between water and land. Therefore the value change between leaps may also be considered as the accuracy of extracted coastline.

4.2 Coastline change detection

The study area has three geomorphic regions: eroded area; deposition area and sand bar area. The eroded and accreted area was surveyed by monitoring points. But sand bar area was surveyed by statistic of lost and accreted area. The results of coastline monitoring (See Fig. 8) indicated the change distance and change rate in the respective periods. Negative value indicates the distance and rate of erosion, positive value shows distance and rate of deposition.

4.2.1 Zone of erosion

The erosion area (zone C) was divided into 2 sections C1 (Hai Hau district) and C2 (Giao Thuy district) (See Fig. 8), these sections are separated by So river mouth. Table 2 shows area of erosion, length of coastline erosion, mean erosion distance and rate of erosion per year.

The highest rate of erosion is 23.77m/year on section C1 in the period of 1975-1989 with total 377.8 ha settlement was eroded by sea. In the period of 1989-2001 and 2001-2009, the erosion rate is smaller than that of period 1975-1989. In the map of erosion magnitude from 1975 to 2009, most of coastline in Giao Thuy is at very high erosion (more than 12m/year), however the magnitude of erosion reduces in Hai Hau coastline. To interpret the cause of the erosion, some studies showed that, the Ngo Dong river which was dammed in 1955, lost its importance as a major branch of the Red River towards the end of 19th century, when the erosion in the Hai Hau district started. It is not clear whether the decreased activity of this branch has been caused by natural developments or by man-made channeling works (Vinh *et al*. 1996). Moreover, the completion of a large dam (Hoa Binh dam) in 1987 upstream of the Red River system has led to a significant decrease in the amount of sediment supplied in front of the Red River mouth. Therefore it is likely that present coastal erosion in the Hai Hau area is partly due to a decrease in sediment supplied by the Red River mouth (Do *et al*. 2006). However, the main cause of very high erosion in the period of 1975-1989 was the storm in 1986, which broke completely a concrete dam in Hai Hau and Giao Thuy district.

4.2.2 Zone of deposition

From the Red river mouth (point 28) to the North (Thai Binh river), the expansion of land to the sea is at very high level. The highest deposition is at Red river mouth, the average rate is more than 80m/year. Every year sediment from Red river expands regularly land to the sea, this process is natural and no change from 1975 to 2009. At the Van Uc river mouth (point 41, 42), deposition is high magnitude (40-90m/year) from 1975 to 2009. Specially, in the period of 2001-2009, the deposition increase suddenly (1843m).

The combination of deposition analysis and fieldwork information shows that: very high magnitude of the accretion of land to the sea is due to complex impact of both aspects nature and human activities. Nature aspect is the contribution of sediment from Red river system. Annual average of alluvium of Red river system is 144 million tons (report from IMGG), which is transported to the river mouths and become alluvial ground. Human activities include planting mangrove on new tidal flat area and building dam to extend aquaculture area. Local government has been implementing projects to

Table 2. Table of the erosion components

Period	Section	Area (m^2)	Length of erosion (m)	Mean Erosion Distance (m)	Rate (m $year^{-1}$)
1975-1989	C1	3778591.77	10598.00	356.54	23.77
	C2	5979306.54	25478.00	234.69	15.65
1989-2001	C1	600073.22	10598.00	56.62	4.72
	C2	1495452.53	25478.00	58.70	4.89
2001-2009	C1	665376.85	10598.00	62.78	7.85
	C2	1456691.60	26774.00	54.41	6.80

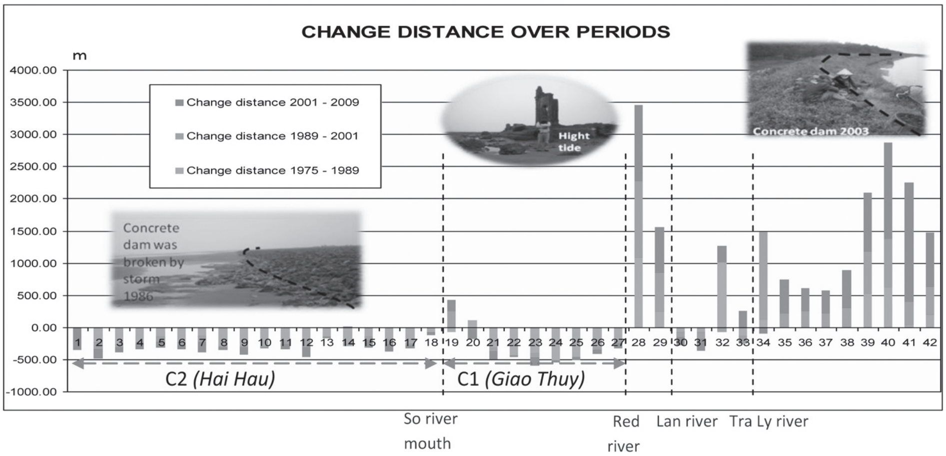


Fig.8. Chart of erosion and deposition distance of monitoring points

grow mangrove on these alluvial ground. When mangrove grows up and new warp appears, government will builds a concrete dam on the mangrove area to make shrimp ponds and continue to grow mangrove to the new warp. The process of deposition is going on by impacts relating to sediment transportation and man-made action. An example, in the period of 2001-2009 in Tra Ly estuary, the rate of deposition increase suddenly comparing with the other periods, main reason is impacts from building a concrete dam to expand aquaculture in 2003.

4.3 Sand bar movement

To monitor the movement of sandbars, the sandbars are named from the North to the South with A, B, K, D, E, G, F. Distance and rate of movement of sandbars are shown in table 3. Sandbars A, K, D appeared before 1975. The E, F, G started to appear from 1989 and sandbars B is from 2001 to 2009. The table 3 shows that, the highest rate is of sandbar K with 195.25 m/year, this sandbar is built by sediment from the Day river and Ninh Co river, which holds more than 30% of total of sediment from the Red river system. The Red river builds a couple of sandbars, which are K and D.

Every year, the sandbar D moves along the WestSouth direction with rate of 186.18m/year and the other one (K) moves to the North with rate of 149.21m/year. Using the method showed above, the trend of movement can be obtained by drawing a circle along the movement direction. Distance from sandbar D to coastline is 1318m in 2009. It moves with rate of 186.2m/ year, with this rate, it will take 7.8 year to reach to the coastline. And it will take 15 year for sandbar K to touch to the coastline.

Beside, this study is validated by field data with questionnaires. Interviewers said that there is a rule for sandbar D of the Red river mouth, it will exist in about 45 years and after that it will disappear. From 1975 to 2009 is 34 year and if the rate of movement does not change, the sandbar D will take 7 years to touch to the coastline. Totally, after existing about 41 years, approximately its life time (45 years), it will touch to the coastline. Moreover, the sandbar D on the image 2009 (red ellipse) was broken into three small parts and a new sandbar start to appear in blue ellipse (Fig. 9). Those dissociates show that sand bar movement derived from the satellite images is quite suitable for results of questionnaires

Table 3. Distance and rate of sandbars movement over periods of time

Direction	Distance 1975-1989 (m)	Distance 89-01 (m)	Distance 01-09 (m)	Rate (m/year)
A	1653.00	206.00	307.00	63.71
B			1089.00	136.13
K	3326.00	230.00	1517.00	149.21
D	3362.00	1814.00	1154.00	186.18
E		653.00	628.00	64.05
F		2162.00	1743.00	195.25
G		981.00	401.00	69.10

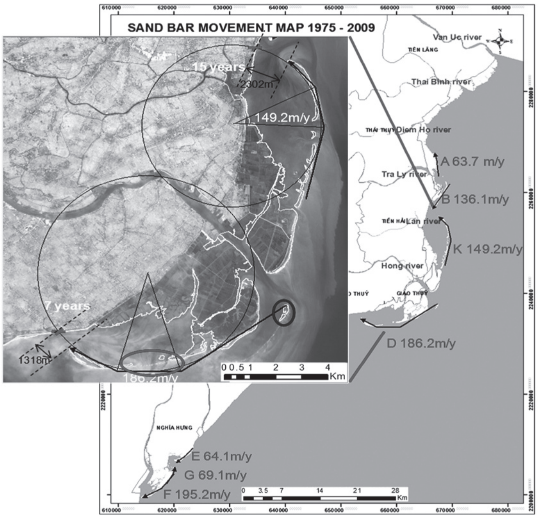


Fig. 9. Trend of sandbar movement

4.4 Land use change in zone of coastline change

The coastal zone is space in which terrestrial environments influence marine environment and vice versa. The coastal zone is of variable width, which is an extremely dynamic system. Therefore, changes of coastal land use are an important part of coastal dynamics (Doydee 2005). Unsupervised classification of land cover has been successfully used for many applications involving thematic mapping with an accuracy of about 80% for most land cover types (Guariglia *et al*. 2006). In this study, images were classified using ISODATA algorithm and coastal change as mask for classification. Table 4 shows the statistic of area of land use change from classification results.

Total eroded area of study area over period of 1975 to 2009 is 3808.72ha, including settlement, warp and mangrove. In fact, the area of erosion includes the change area cause by movement or unstableness of sand-dune near river mouth. The real area, in which reflects the serious damage of erosion is settlement to sea. From 1975 to 2009, 1095.2ha of houses, village were eroded, this area is along Hai Hau and Giao Thuy coastline. At that time, as a rule, more than 11174ha of land was expanded to the sea and became aquaculture and mangrove. Land use change maps show that, most of area around river mouths is changed from sea to mangrove, and the largest area is in Red river mouth and Day river mouth. The area of aquaculture only started to expand after 1986 (at this time, policy of assigning land for person manage and use was implemented) and more highly when some concrete dams were built.

Table 4. Area of land use change in zone of coastline change

Coastal change	Land use change	1975-1989 (ha)	1989-2001 (ha)	2001-2009 (ha)	Total
Erosion	Settlement to Sea	665.46	215.19	214.55	1095.2
	Warp to Sea	1004.31	696.24	701.03	2401.58
	Mangroves to Sea	103.59	153.54	54.81	311.94
Accretion	Sea to Warp	1707.57	1709.19	1297.09	4713.85
	Sea to Mangroves	1429.47	2372.49	984.28	4786.24
	Sea to Aquaculture	0	1308.51	365.47	1673.98

5. Conclusions

This paper aims to monitor coastal change in Vietnam using remote sensing and GIS. The study shows that: 1) approach of band rationing thresholds is very useful for defining waterline in tidal flat area, 2) coastline interpolation based on coastline from another image at a different tidal level in the same year is a good method for reducing errors caused by different acquisition time of images.

Combination of deposition analysis and fieldwork information showed that, the first cause of deposition is the transportation of sediment from river mouths, and second cause is the growing mangrove and the dam construction to expand the shrimp pond to the sea (From 1975 to 2009, expanded to the sea 3500m in Red river mouth, 2873m in Thai Binh river mouth). The erosion process occurred continuously from 1975 up to now with the average magnitude 23.77m/year from 1975 to 1989 and 7.85m/year from 2001 to 2009 in Giao Thuy area. From 1975 to 2009, total 1095.2ha of settlement area was eroded by sea. On the other hand, land expanded to the sea in 4786.24ha of mangrove and 1673.98ha of aquaculture.

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References

Alesheikh, A.A., Ghorbanali, A., Nouri, N., (2007), Coastline change detection using remote sensing, *Journal of Environment Science, Technology*, 4(1), pp. 61-66.

Boak, E.H., Turner, I.L., (2005), Shoreline Definition and Detection: A Review, *Journal of Coastal Research*, 21(4), pp. 688-703.

Chand, P., Acharya, P., (2010), Shoreline change and sea level rise along coast of Bhitarkanika wildlife sanctuary, Orissa; An analytical approach of remote sensing and statistical techniques, *International Journal of Geomatics and Geosciences*, 3(1), pp. 436-455

Do, M.D., Mai, T.N., Chu, V.N., Tran, N., Dao, M.T., Weering, T.C.E., Bergh, G.D., (2007), Sediment distribution and transport at the nearshore zone of the Red River delta, Northern Vietnam, *Journal of Asian Earth Sciences*, 29(4), pp. 558–565.

Doydee, D., (2005), Coastal Landuse Change Detection Using Remote Sensing Technique: Case Study in Banten Bay, West Java Island, Indonesia, *Kasetsart Journal : Natural Science*, 39(1), pp. 159-164.

JAXA., (2008), Earth Observation Research Center, Japan Aerospace Exploration Agency, *ALOS: User Handbook*.

Guariglia, A., Buonamassa, A., Losurdo, A., Saladino, R., Trivigno, M.R., Zaccagnino, A., Colangelo, A., (2006), A multisource approach for coastline mapping and identification of shoreline changes, *Annals of geophysics*, 49(1), pp. 295-304.

Gens, R., (2010), Remote sensing of coastlines: detection, extraction and monitoring, *International Journal of Remote Sensing*, 31(7), pp. 1819–1836.

Hoekstra, P., Weering, T.C.E, (2007), Morphodynamics of the Red River Delta, Vietnam, introduction to the special issue, *Journal of Asian Earth Sciences*, 29(4), pp. 505–507.

Kumar, A.C.N., Jayappaa, K.S., (2010), Shoreline changes and morphology of spits along southern Karnataka, west coast of India: A remote sensing and statistics-based approach, *Geomorphology*, 120, pp. 133–152.

Kumaravel, S., Ramkumar, T., Gurunanam, B., Suresh, M., Dharanirajan, K., (2013), An Application of Remote Sensing and GIS Based Shoreline Change Studies – A Case Study in the Cuddalore District, East Coast of Tamilnadu, South India, *International Journal of Innovative Technology and Exploring Engineering (IJITEE)*, 2(4), pp. 211-215

Maren, D.S., (2007), Water and sediment dynamics in the Red River mouth and adjacent coastal zone, *Journal of Asian Earth Sciences*, 29(4), pp. 508–522.

Mills, J.P., Buckley, S.J., Mitchell, H.L., Clarke, P.J., Edwards, S.J., (2005), A geomatics data integration technique for coastal change monitoring, *Earth Surface Processes and Landforms*, 30, pp. 651–664.

Mitchell, A., (2005), The ESRI Guide to GIS Analysis, *ESRI Press 2*.

Naji, T. A. H., Tawfeeq, R. J., (2011), Detection of Shoreline Change in AL-Thirthar Lake using Remotely Sensed Imagery and Topography Map, *Ibn Al-Haitham Journal For Pure And Applied Science*, 24 (1), pp. 79-85.

Nguyen, Q.M., (2012), Land Cover Super-resolution Mapping using Hopfield Neural Network from Simulated SPOT image, *Journal of the Korean Society of Surveying, Geodesy*, Photogrammetry and Cartography, 30, pp. 653-664.

NOAA, (1997), Shoreline mapping, Available at: http://shoreline.noaa.gov/intro/index.html.

Vinh, T.T., Kant, G., Huan, N., Pruszak, Z., (1996), Sea dike erosion and coastal retreat at Nam Ha province, Vietnam, *International Coastal Engineering Conference, American Society of Civil Engineers*, 25, pp. 2820-2828.

White, K., Asmar, H.M.E., (1999), Monitoring changing position of coastlines using Thematic Mapper imagery, an example from the Nile Delta, *Geomorphology*, 29(1-2), pp. 93-105.

Zhang, T., Yang, X., Hu, S., Su, F., (2013), Extraction of Coastline in Aquaculture Coast from Multispectral Remote Sensing Images: Object-Based Region Growing Integrating Edge Detection, *Remote Sensing*, 5, pp. 4470-4487.

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