Using remote sensing technology to detect the shoreline change caused by mining activities: case study of Thach Khe iron mine, Thanh Ha district, Ha Tinh province, Viet Nam

Hong Phuong TRINH, Thi Minh An NGO, Thi Thanh Thuy HOANG, Viet Nam

Key words: Remote sensing, coastal mining activities, shoreline change, Thach Khe iron mine, Viet Nam.

SUMMARY

Thach Khe iron mine is located in Thach Ha district, Ha Tinh province. It was the biggest iron mine in Viet Nam. Exploitation in Thach Khe mine has caused many environmental issues, especially changing shoreline. In the present study, the change of shoreline from Cua Sot to the Thach Ha District was assessed by using remote sensing technology and geological information system. The analysis of Landsat images from the year of 2005 to 2015 has shown that there was a significant decline in the shoreline of Thanh Ha district. The excavation of topsoil in Thach Khe mine has caused a significant impact of local morphology. Over the years, the variation of mine boundary and creation of several ponds have been detected. Besides that, the Thach Ha coast has lost an area of 0.75 km2 for a ten - year period. The result of this study shows that GIS and RS are effective tools to detect the change of the seashore line caused by coastal mining activities.

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1. INTRODUCTION

The shoreline that is one of the most important linear features on the earth's surface, which has a dynamic nature (Abbott, et al., 2002; Winarso, et al., 2001). The shorelines worldwide are changing rapidly as a result of natural physical processes such as sediment supplement, wave energy, especially sea level rise phenomenon. In addition, human activities are catalysts which could cause disequilibrium conditions that accelerate changes (Niya, et al., 2013). Detection and monitoring of shoreline changes in this area are important for coastal zone management planning, hazard zoning, erosion-accretion studies, analysis and modeling the coastal morphodynamics (Alesheikh, et al., 2007).

Today, with the ingenious integration of remote sensing and GIS technology, tracking and calculations of shoreline fluctuations are made quite quickly and efficiently. In addition to field trips using traditional instruments and equipment, we can now perform shoreline measurements by using GPS, digital cameras, or video camera systems. In addition, shorelines can be obtained on a large scale from aerial photographs and satellite imagery. From these data, the assessment and analysis of shoreline evolution are performed directly. Since 1972, the Landsat and other remote sensing satellites provide digital imagery in infrared spectral bands where the land-water interface is well defined (Alesheikh, *et al*., 2007). Therefore remote sensing imagery has been widely used to detect the coastline change. Geographical information system (GIS) has been also proven to be an extremely useful approach for the coastline changes studies due to useful sources in large areas and its cost-effectiveness in comparison to conventional techniques (Chand, *et al*., 2010). Regarding the application of remote sensing in the analysis and assessment of shoreline variability, a number of studies have been conducted in some areas, mainly in the Red River and Mekong River deltas, and in several estuaries such as Loc An, Cua Dai, Thuan An ...

Thach Khe iron mine is located on the sand dunes of Thach Ha district, Ha Tinh province. This area has eastern bordering of more than 16km shoreline, the nearest is 500m far from the coast. The iron ore below sea level, at a depth of -8m to -550m, the total reserve of ore is estimated at 544 million tons. It was the biggest iron mine in Viet Nam. Iron exploitation in Thach Khe mine could cause many environmental issues, especially changing Thach Ha district's shoreline. This paper presents the results of using satellite images for shorelines change detection. The significant purpose is using satellite imagery to investigate the shoreline change at different times of about 16 km of shoreline from Cua Sot, Loc Ha District to Thach Ha District over a period of 10 years.

2. MATERIALS AND METHODOLOGY

2.1. The study area

The study area is extending between latitude 596,847.34mE to 608,640.45mE and longitude 2,042,930.77mN; 2,028,754.63mN (UTM 48 North) with a 16km shoreline, from Cua Sot, Loc Ha District to Thach Ha District. (Fig. 1). The project to exploit the Thach Khe mine has started in 2009 by the Thach Khe Iron Joint Stock Company. However, two years later, the project was stopped due to capital shortage. The mining activities have significant impacts of the landscape since 12.7 million cubic meters of topsoil were excavated, many working units have been built in this coastal zone.

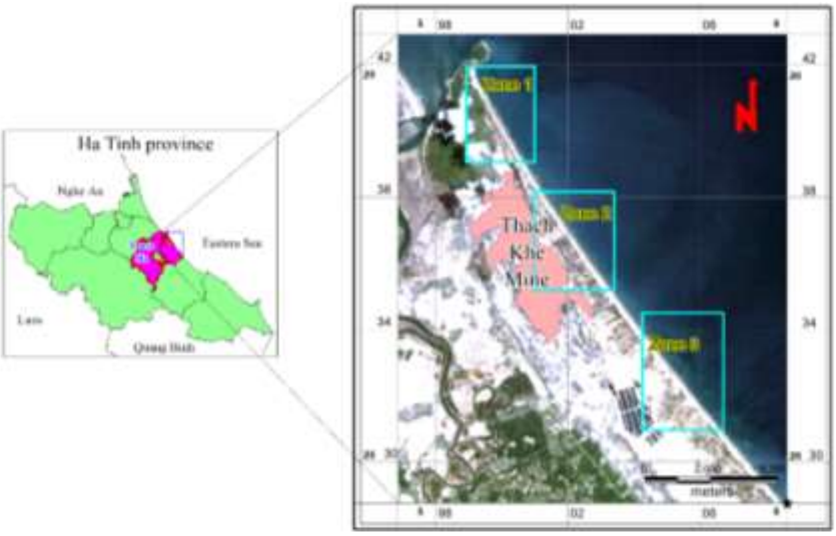


Fig. 1. Location of Study Area (with three-zone detail)

2.2. Data

In the present study, Landsat TM in 2005, 2010, 2011 and Landsat ETM+ in 2015 datasets was used in order to investigate the shoreline change (Table 1). Path/row of these images is 126/047. Those images present a weak cloud coverage on the coastal area and a pixel resolution of 30 meters. These images were downloaded freely from USGS EarthExplorer (EE) web page. The USGS Earth Explorer data set was provided in a standard GeoTIFF format with a UTM projection, using the WGS-84 datum.

Table 1. Satellite data used in the study

Acquisition time	Satellite	Sensor	Resolution (m)
July 14^{th}, 2005	Landsat 5	TM	30
July 12^{th}, 2010	Landsat 5	TM	30
June 13^{th}, 2011	Landsat 5	TM	30
August 11^{th}, 2015	Landsat 8	OLI/TIRS	30

Table 2 showed the spectral and spatial characteristics of Landsat 5 TM and Landsat 8 OLI/TIRS that help visualize the different satellite bands of Landsat and other sensors, along with selected spectra and convolving capabilities.

Table 2. The Spectral Characteristics Viewer of Landsat

Sensor	Band No.	Wavelength (micrometers)	Resolution (m)
Landsat 5 TM	1 - Blue	0.45-0.52	30
	2 - Green	0.52-0.60	30
	3 - Red	0.63-0.69	30
	4 - Near Infrared (NIR)	0.76-0.90	30
	5 - Shortwave Infrared (SWIR) 1	1.55-1.75	30
	6 - Thermal	10.40-12.50	120
	7 - Shortwave Infrared (SWIR) 2	2.08-2.35	30
Landsat 8 OLI/TIRS	1 - Ultra Blue (coastal/aerosol)	0.43 - 0.45	30
	2 - Blue	0.45 - 0.51	30
	3 - Green	0.53 - 0.59	30
	4 - Red	0.64 - 0.67	30
	5 - Near Infrared (NIR)	0.85 - 0.88	30
	6 - Shortwave Infrared (SWIR) 1	1.57 - 1.65	30
	7 - Shortwave Infrared (SWIR) 2	2.11 - 2.29	30
	8 - Panchromatic	0.50 - 0.68	15
	9 - Cirrus	1.36 - 1.38	30
	10 - Thermal Infrared (TIRS) 1	10.60 - 11.19	100 * (30)
	11 - Thermal Infrared (TIRS) 2	11.50 - 12.51	100 * (30)

* TIRS bands are acquired at 100-meter resolution but are resampled to 30 meters in delivered data product.

(Source: https://landsat.usgs.gov/)

2.3. Methodology

2.3.1. Remote Sensing

- Shoreline extraction

Shoreline can even be extracted from a single band image (Shortwave Infrared - SWIR) 1, band ratio is Near Infrared (NIR)/Green (NIR/ Green) and Shortwave Infrared (SWIR) 1/ Green ((SWIR) 1/Green) and with combining channel in the RGB composite 543 in TM and 653 in OLI/TIRS (Winarso, *et al.*, 2001; Alesheikh, *et al.*, 2007; Tran, *et al.*, 2009; Chand, *et al.*, 2010; Casse, *et al.*, 2012). Band Shortwave Infrared 1 (1.55-1.75μm) discriminates moisture content of soil and vegetation due to the high degree of absorption of mid-infrared energy by water (even turbid water) and strong reflectance of mid-infrared by vegetation and natural features in this range. The histogram of TM band 5 ordinarily displays a sharp double-peaked curve, due to tiny reflectance of water and high reflectance of vegetation, if the reflectance values are sliced to two discrete zones, they can be depicted water (low values) and land (higher values). But the difficulty of this method is how to find the exact value, as any threshold value will be exact in some area, not all (Alesheikh, *et al.*, 2007). Another method that water and land can be separated directly, is to use the band ratio between Landsat band 4 and 2 and band 5 and 2 in TM. The ratio NIR/Green offers an exact border in land covered by vegetation, and inland without vegetation will set to water (Winarso, *et al*., 2001), whereas the ratio SWIR1/Green will give higher accuracy in land covered with soil, but not for land with vegetative cover (Alesheikh, *et al*., 2007). To solve this problem, the two ratios are combined in this investigation. The result has to be corrected with visual interpretation with composite RGB 543 in TM and 654 in OLI/TIRS with visual editing to reduce errors in digital processing (Winarso, *et al*., 2001).

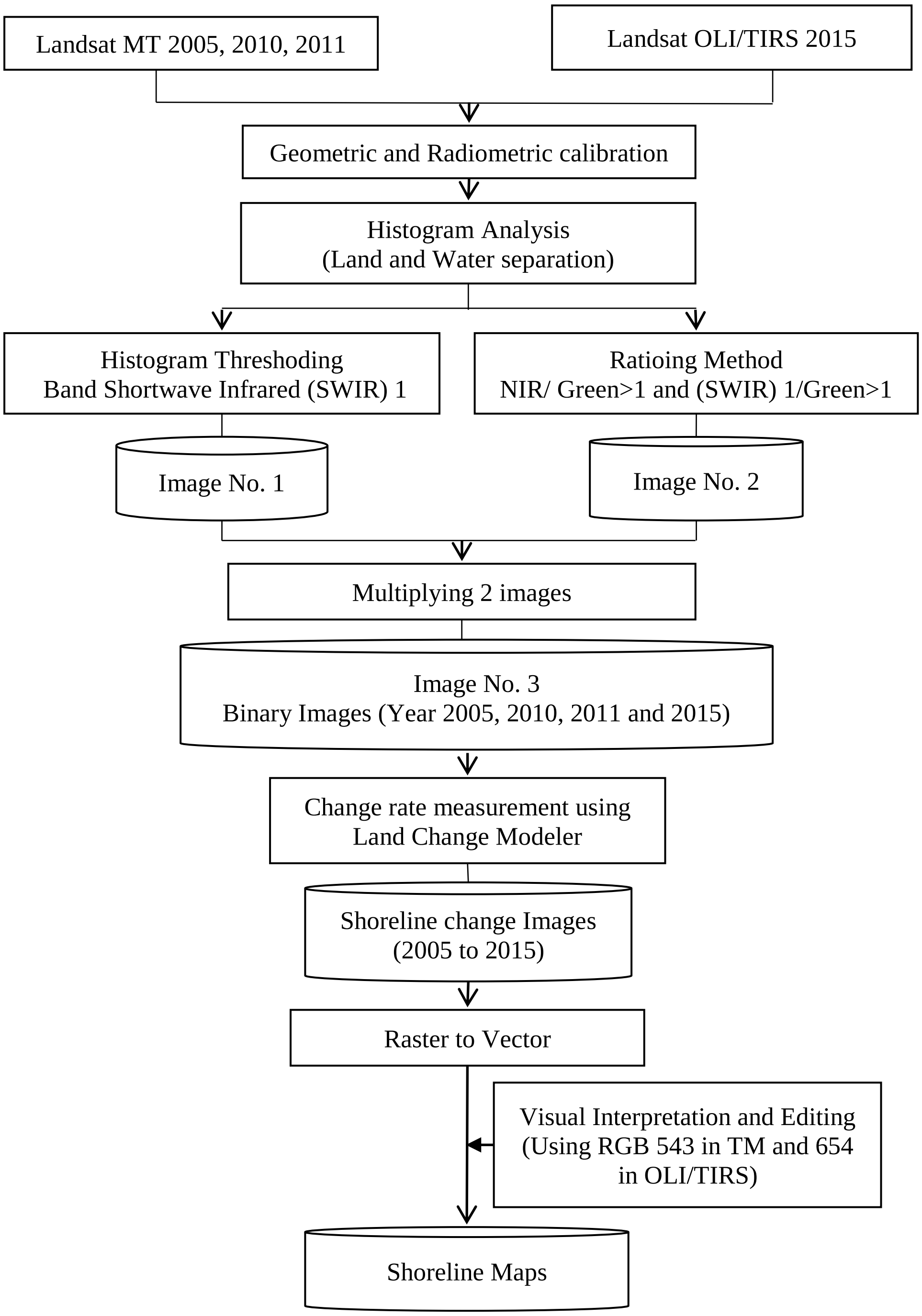


Fig. 2. The approach of the present study

- Shoreline change assessment

Land Change Modeler in IDRISI was used to analyze the land use/cover changes for various classes during the period 2005-2015. Land Change Modeler for ecological sustainability is integrated software developed by IDRISI Selva to analyze land cover changes. This is a module specifically used in the environment, based on the change of pixel values developed by Clark Lab with three major functions: (1) Analyze the change of the object over time, (2) Predict future changes and (3) Assess interventions to maintain ecosystem integrity.

The present study focused on the functional analysis of change of objects over time by using this two land cover maps were analyzed that have identical legends. The change analysis panel provides a rapid assessment of quantitative change by graphing gains and losses by land cover categories (Mishra, *et al.*, 2014). For this experiment, IDRIS 17.0 software is used for all the image processing

2.3.2. GIS

After completing the shoreline extraction and evaluation of the change, the results of the study were presented by the MapInfo 11.5 software.

3. MATERIALS AND METHODOLOGY

The excavation of topsoil in Thach Khe mine has caused a significant impact of local morphology. Over the years, the variation of mine boundary and the creation of several ponds have been detected (Fig. 3, 4). After the mine closure in 2011, eleven ponds have been created with different size and the largest was 0.2km^2 (Fig. 4).

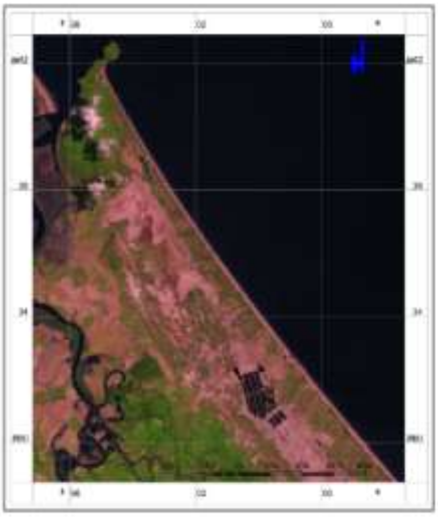


Fig. 3. The study area in 2005

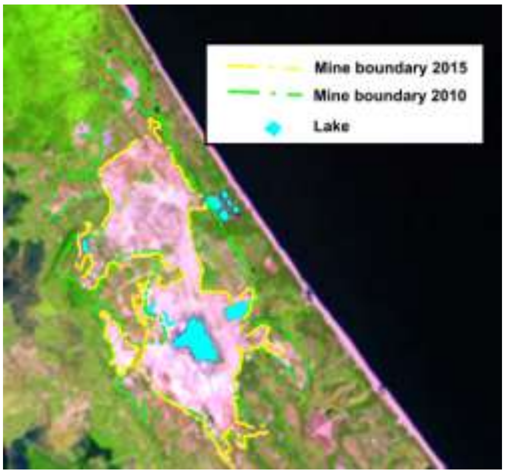


Fig. 4. The mine boundary changes in 2010 and 2015

Land Change Modeler was used to analyze the land use/cover changes for various classes during the period 2005-2015. This phase can be divided into two phases: operation (2005-

2010) covering an area of 7.57 km^2 and closure (2010 - 2015) covering an area of 5.12 km^2, respectively (Fig. 4). Along the entire shoreline of 16 km, through erosion the land of 0,68 km^2 during 2005-2010 to 0.30 km^2 during 2011–2015 have been lost, respectively. The study results have shown an elevated erosion rate in the study area in the working period of Thachkhe mine (2005-2010). When the mine was operating, the annual speed of coastal erosion has nearly two times higher as compared to after closure period (2011 – 2015).

In order to get a closer look of mining' effect on the shoreline, three zones are chosen for detailed study (Fig. 1 and Table 4).

Table 3. Coordinates of three areas 1,2 ,3 (UTM-48 North)

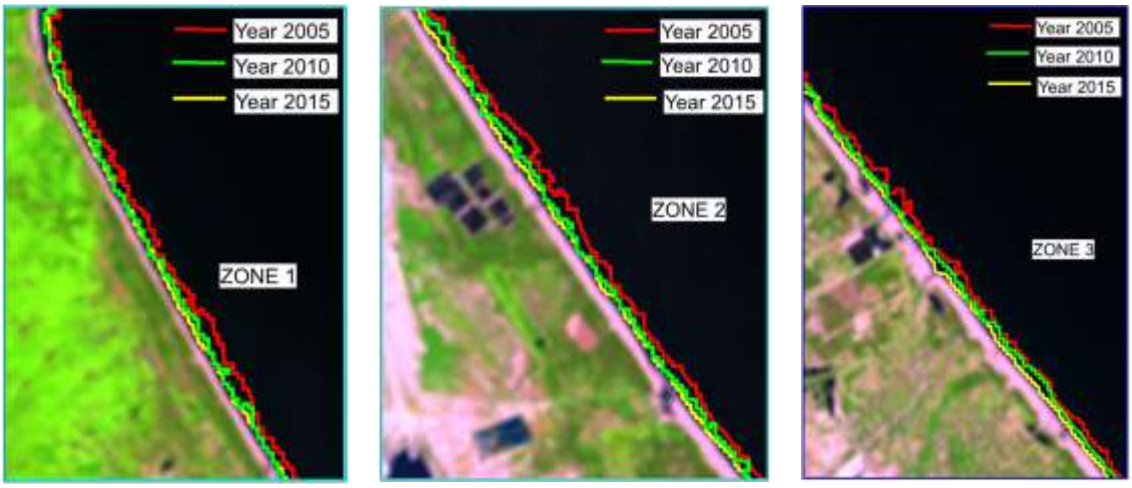
Zone	X (m)		Y (m)	
	Min	Max	Min	Max
1	2,039,062.16	2,041,945.36	598,931.01	600,994.22
2	2,035,185.00	2,038,166.13	600,967.77	603,405.00
3	2,030,954.99	2,034,486.08	604,274.18	606,705.00

Table 5 showed that the rate of losing land in three zones was similar to that of the whole area in two phases. In the operation period (2005-2010), the land lost nearly twice higher as compare the mine closure period (2010-2015) (0.26 and 0.49 km^2, respectively). In general, the second and third zone showed wide variation (0.28 km^2 and 0.27 km^2, respectively) as compared to the first zone (0.2 km^2).

Table 5. Losing land and max variable dynamic in three zones at two periods

Period	Losing land (km^2)			Total	Max variable dynamic (m)		
	1	2	3		1	2	3
2005-2010	0.15	0.19	0.15	0.49	-110	-140	-150
2010-2015	0.05	0.09	0.12	0.26	-52	-72	-85
2005-2015	0.20	0.28	0.27	0.75	-137	-158	-150

When comparing the rate of losing land in two phases of each area, the first and second zone showed a similar speed, decreasing tendency during the closure period (less than 2 to 3 times). However, in the third zone, the rate of land loss was almost unchanged between the two periods (0.15 km^2 and 0.12 km^2, respectively for the period 2005-2010 and 2010-2015). This may be due to the natural processes of this area and further study is needed.



(a) (b) (c)

Fig 6. The shoreline changing in different periods at three zones

Shoreline variation is significantly correlated with the rate of losing land. During 10 years, in the two zones with a large area of erosion (second and third zones), the shoreline has been more eroded, the largest erosion point is -158m (zone 2) and -150m (third zone), in comparision to the first zone (-110m). Coastal erosion showed wide variation between the two phases (mine operation and closure). In particular, in the third zone, although the lost land in two phases is nearly the same, the location of the largest shoreline changes in this area during the period 2010-2015 (-85m) is two times lower than period 2005-2010 (-150m). This is due to the fact that the losing land occurs throughout the shoreline (Figure 6c).

CONCLUSION

In the present study, Landsat-TM satellite data has been used to distinguish changes in morphology and coastline in Thach ha district over a 10-year time period. The results showed that, besides quantifying and analyzing the variation topsoil during mining excavation, the satellite images enabled the identification of new ponds and huge sand dune. Notably, the study results have shown that an intensification of coastal erosion has been noticed during the mine operation phase, with the maximum value of 0.49 km^2 during 2005- 2010. The higher rate of land has been lost in mine drainage outflow. After mine closure, the erosion rate has reduced with 0.26 km^2 during 2010 – 2015. The total land lost in 10 years is 0.75 km^2 with the max variable dynamic shortline changing is -158m. Thus, a further study that applied GIS and RS to assess and monitor the impact of mining activities in the coastal zone should be carried out.

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BIOGRAPHICAL NOTES

Assoc. Dr. Thuy Hoang is Chair of Department of Geology and Mineral Resources, Hochiminh City University of Natural Resources and Environment. She got her Diploma in Geology at Hanoi University of Mining and Geology in 1992 and Ph.D. in Applied Geology at the University of Erlangen-Nuremberg, Germany in 1999. The major courses she taught are Applied Geochemistry, Environmental Geology for undergraduate and graduate levels. Her research focuses on applied geochemistry of soil and aquatic system, ecotechnology for removal of inorganic and organic contaminants and sustainable mining extraction.

Hong Phuong Trinh is a lecturer on environmental geology at the University of Natural Resources and Environment in Ho Chi Minh City. She got her master's degree in environmental science at Ho Chi Minh City University of natural sciences. Her works focus on environmental issues in mining; environmental rehabilitation and restoration in mineral activities; apply GIS and remote sensing in geological hazard assessment.

CONTACTS

Trinh Hong Phuong
Institution: Hochiminh City University of Natural Resources and Environment
Address: 236B, Le Van Sy Street, Ward 1, Tan Binh District
City: Ho Chi Minh
COUNTRY: Viet Nam
Tel. (+84) 909 314 823
Email: thphuong@hcmunre.edu.vn
Web site: