ESTABLISHING AND STANDARDIZING SHORELINE ON SATELLITE IMAGES

Nguyen Hieu, Pham Xuan Canh, Doan Thu Phuong
Faculty of Geography, VNU University of Science, 334 Nguyen Trai - Thanh Xuan - Ha Noi
Email: nguyenhieu@hus.edu.vn

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ABSTRACT: Defining shoreline accurately is very important to land use planning and management of resource, environment, and natural hazard in coastal zone. Until now, many studies have been pubished containing the content of establishing the status quo of shoreline from satellite images for various purposes, especially for accessing coastal erosion - accretion hazard. However, their scientific basis as well as the method is still unclear. This may affect to the accuracy of research results, even may lead to the wrong conclusions. This report clarifies the characteristics of the shoreline, the factors that influence on determining and standardizing them on satellite images. Based on the identifiable signs, the project has been studied and established the methods of digital image classification on multi-date and multi-band images for determining and standardizing the shorelines on satellite images, which are typical types in Vietnam, including: swampy tidal coast with mangrove forest, bedrock coast, coast with dominated impact of waves, and coast with human constructions. These methods were applied in practice to establish automatically the shoreline of Sam Son beach (Thanh Hoa) and Hai Phong city's beach, using Landsat 8 and Spot 5 images to obtain high accuracy results.

1. DATABASES AND METHOD

1.1. Databases

All the data that were used to conduct this research include: 1) Landsat images captured at different times with high quality (Table 1) for establishing shoreline. 2) Topographic map with scale of 1:10,000 is used for coastal terrain studying and image registration.

Table 1. Characteristics of satellite data

<table>
<tr><th>No</th><th>Types of satellite</th><th>Date</th><th colspan="3">Spectral and spatial resolution</th></tr>
<tr><td>1</td><td>Landsat 8</td><td>27-Dec-13</td><td rowspan="2">Band No.
Band 1 - Coastal/Aerosol
Band 2 - Blue
Band 3 - Green
Band 4 - Red
Band 5 - NIR
Band 6 - SWIR
Band 7 - SWIR
Band 8 - PAN
Band 9 - Cirrus</td><td rowspan="2">Wavelength
0.433 - 0.453 µm
0.450 - 0.515 µm
0.525 - 0.600 µm
0.630 - 0.680 µm
0.845 - 0.885 µm
1.560 - 1.660 µm
2.100 - 2.300 µm
0.500 - 0.680 µm
1.360 - 1.390 µm</td><td rowspan="2">Ground resolution
30m
30m
30m
30m
30m
30m
30m
15m
30m</td></tr>
<tr><td>2</td><td>Landsat 8</td><td>26-Nov-13</td></tr>
<tr><td>3</td><td>Spot 5</td><td>6-Feb-11</td><td rowspan="2">Band No.
Band 1 - Green
Band 2 - Blue
Band 3 - NIR
Band 4 - SWIR
PAN</td><td rowspan="2">Wavelength
0,50 - 0,59 µm
0,61 - 0,68 µm
0,79 - 0,89 µm
1,58 - 1,75 µm
0,51 - 0,73 µm</td><td rowspan="2">Ground resolution
10m
10m
10m
20m
5m</td></tr>
<tr><td>4</td><td>Spot 5</td><td>8-Nov-11</td></tr>
</table>

1.2. Scientific basis and study method

1.2.1. Definition of shoreline

The term "shoreline" is mentioned as the edge of water line or the tangential line between land and water. However, it varies with the rise and fall of tides, and fluctuates at different parts of the day and night. In high tidal amplitude areas, for example in Western Australia where the tidal amplitude is over than 10m, the distance between the low-tide shoreline and high-tide shoreline is up to 8 km. Results of topomap analysis show that the shoreline in Vietnam are determined by the mid-tide shoreline, often identified by the seaward boundary of vegetation. On the bedrock coast, shoreline is defined as the foot of cliff at high tidal level.

1.2.2. Classification of coast for establishing shoreline

Shorelines have their specific characteristics depending on the characteristics of each type of coast. Therefore, determining the shoreline in each type needs special method. In Vietnam territory, base on the composition we classified the coast into different typical types:
a. Bedrock coasts: composed of resistant rocks, steep slope. The impact of wave destroys is mainly abrasion. Waves scour away at the base through processes of abrasion, hydraulic action and solution, untill over time a wave-cut notch forms. As the notch enlarges, the cliff face collapases under its own weight. Attrition and transportation then remove the cliff debris leaving behind a small bedrock ledge, which marks the old cliff line. This process is repeated over time as the cliff retreats forming a larger wave-cut platform, which is called bench.
b. Muddy coasts: mainly composed of clays and silts, usually develop in inter-tidal zone at river mouths, bays, or lagoons. Coasts are characterized by the wide flat terrain, small tilt, and often covered by mangrove forests. The sediment transport processes are affected by the domination of tide .
c. Sandy coasts: wave is the main factor that forms this type of coast by cross-shore sediment transport process. It affects to shape of coast in many means, which is eroded, which is deposited, which is under the impact of accretion and erosion at the same time.
d. Man-made coasts: created by human activities, including sea dikes, sea walls, marine-aquiculture zones, ports, salt fields, industrial zones, seaside tourist bases... They have line or block forms, run along and close to the sea. This type of coast has solid structure and little change over time.

1.2.3. Satellite image processing in establishing and standardizing shoreline

a. Determine shoreline in with alitle change of the land and water edge
Bedrock coast: In remote sensing, rocks in dry block forms have the spectral reflectance curve similar to dry soil but the absolute values are often greater.

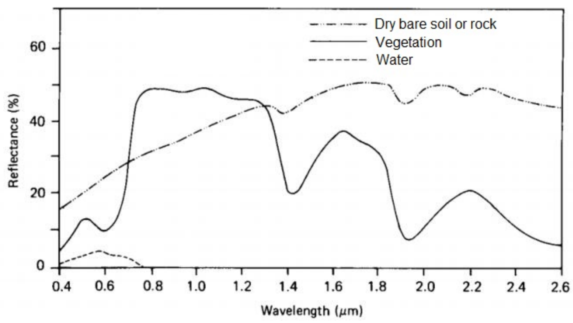

Figure 1. Reflectance spectrum curve of basic natural objects (Floyd F. Sabins)

There are varied methods for extractingland and waterboundary from optical imagery have been developed. Land and water boundary can even be extracted from only one band, since the reflectance of water is nearly equal to zero in reflective infrared band, and reflectance of absolute majority of landcovers is greater than water (A. A. Alesheikh. 2007). However, the difficulty of this method is to find the exact value, as any threshold value will be exact on some area, not all. Another method is to use the band ratio between band 6 and band 3 (Landsat 8). With this method, water can be separated directly. In cases where the shores are bedrock jutting into the sea, the shoreline is determined to coincide with land and water boundary.
Man-made coast: In this type of coast, there are many various groups of objects needed to differentiate from water, such as soils, rocks, plants... Depending on each specific area, there is proper formula suitable with each object, for concrete results:
- The ratio B5/B3 (Winarso G. 2001) results the boundary between land and water in developing plant coasts. However, in non-plant coasts, the values are shown as the values of sea. It is because plants reflex strongly near-infrared rays (band 5) and water reflex green light very well (band 3).
- On the contrary, B6/B3 index (Winarso G. 2001) represents the shoreline exactly in non-plant coasts. The reason is the reflected ability of plants decreases significantly; otherwise the absorbed ability increases, especially to mangrove forest with great biomass.
b. Determine shoreline in coasts with a big change of land and water edge
Muddy coast with mangrove forests developing: The major condition for growing and development of mangrove forests is semi-intertidal environment, particularly high intertidal zone. Therefore, the outermost edge of mangrove forests can be considered as the water line of mean tidal level for years, or the shoreline.

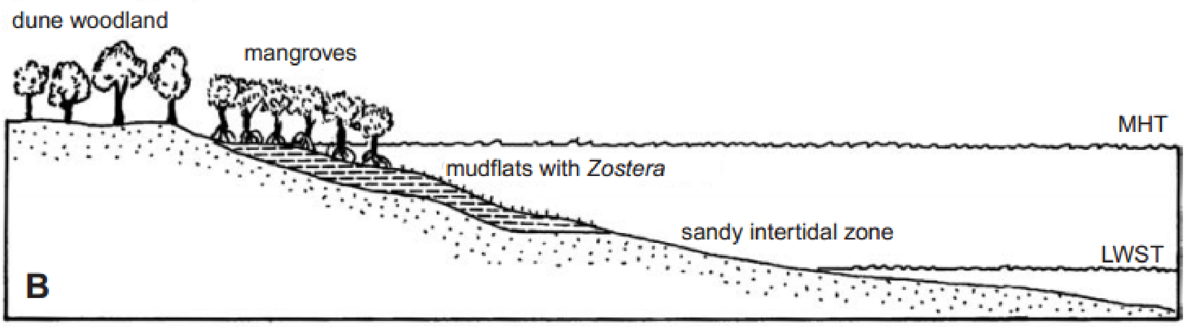

Figure 2. Cross section of muddy coast with mangrove forests developing (Eric Bird. 2008)

It is because mangrove forest has high vegetation density, NDVI index is used in processing images to distinguish accurately between plants and water. NDVI index is calculated by this formula below:

$$NDVI = \frac{NIR - Red}{NIR + Red} \quad \text{(Rouse et al, 1973)}$$

(The values range from -1 to 1)

Sandy coast affected mostly by waves

To slight tilt coasts, tides will go into lands hundreds of metres while they are rising. On the other hand, in the coasts affected strongly by waves, there are existences of surf zones, which have bright tones on imageries and easily confused with dry sandy coasts. Thus, it will be unexactly if the shorelines are determined by the edges of water on imagerys. We need to apply some methods to eliminate elements that falsify the shorelines and determine them indirectly:

- Reduce surf zone: on remote sensing image, surf creates heterogeneousness on seawater surface. Bright tones generated by sponges on beach will easily cause confusion in identifying the edge of water. The formula given for noise reduction is performed based on statistical values of ratio band 6/band7 (Landsat 8 satellite).
- Establish the edge of water at mean tidal level: shorelines in areas affected by wave are defined as the water line of mean tidal level for years. However, images taken do not always coincide with the time when the tides reach to average water level. In this case, the research team used multi-temporal satellite images to determine the average water level as below:

Consider: h_1, h_2 as the height of tides at time t_1, t_2
Δh as the variance between two tidal levels at time t_1 and t_2
Δa as the variance of two tidal level lines measured when overlaping two images at two different times
x as the average slope angle of coast

According to the formula applied for right-angled triangle, we have tan x= $\Delta h/\Delta a \rightarrow x = \arctan(\Delta h/\Delta a)$.

It is because the slope angle x is constant so it is used to calculate mean tidal level in study area as below:

Consider: $\Delta h'$ as the variance between two tidal level lines at mean tidal level and at time photo taken.
$\Delta a'$ as the distance between two tidal level lines at mean tidal level and at time photo taken

Angle x has already known, we have: $\Delta a' = \Delta h'/(\tan x)$. When the distance $\Delta a'$ is determined, we can find the water level line at mean tidal level.

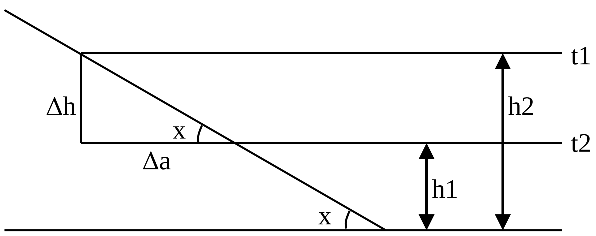

Figure 3. Simulating cross-section of the beach in study area

2. ESTABLISHING AND STANDARDIZING SHORELINE FOR SOME TYPICAL COASTS IN HAI PHONG CITY AND THANH HOA PROVINCE USING LANDSAT AND SPOT IMAGERIES

2.1. Establishing shoreline in bedrock coasts and man-made coasts

The area was chosen to establish these types of coasts are located in the south of Sam Son beach, Quang Xuong District, Thanh Hoa Province.

After using the ratio Band 6/Band 3 (Landsat images) and determining the threshold value between land and water is B6/B3<0.79, the shoreline in this area is identified quickly and accurately (Fig.4).

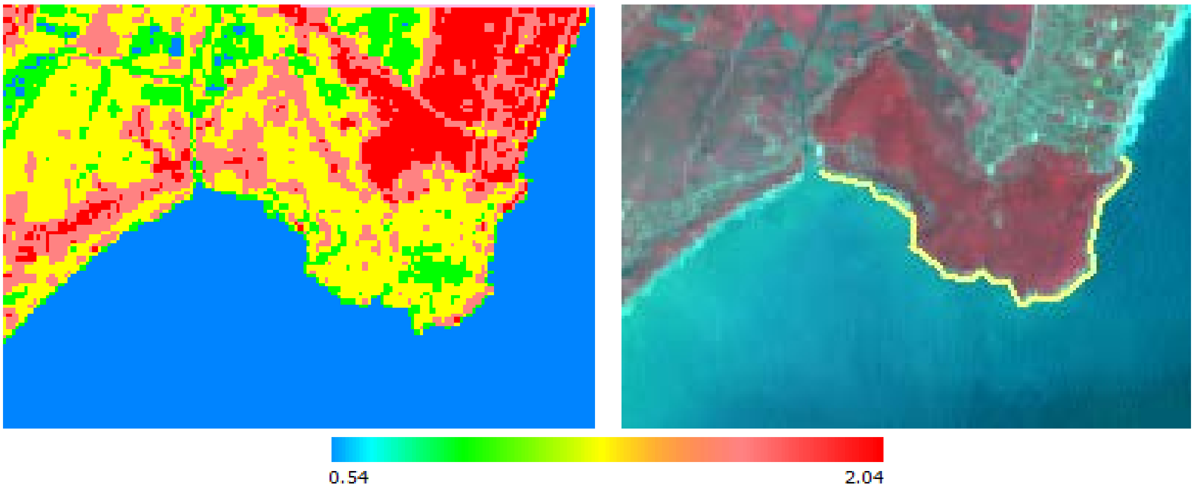

Figure 4. The result of B6/B3 threshold splitting for identifying shoreline on bedrock coast in Sam Son, Thanh Hoa

Due to enhancing spectrum quality by combining both band 6 and band 3, the water level line identified is suitable with the one that is displayed in Landsat 8 color combination image of bands 543 in Sam Son.
Using this method, the research team conducts to establish the shoreline in Dinh Vu peninsula (Hai An District, Hai Phong City) (Fig.5). In this area, there are industrial zones, ports, marine-aquaculture zones, litte or non-plant coasts. The threshold value in this case is B6/B3<0.693. In image processing, as can be seen that band 6 - short infrared band will display clearly the contrast between land and water. It is because water absorbs infrared energy (even turbid water does this). Therefore, band 6 is used to remove noise, limit error due to turbid water.

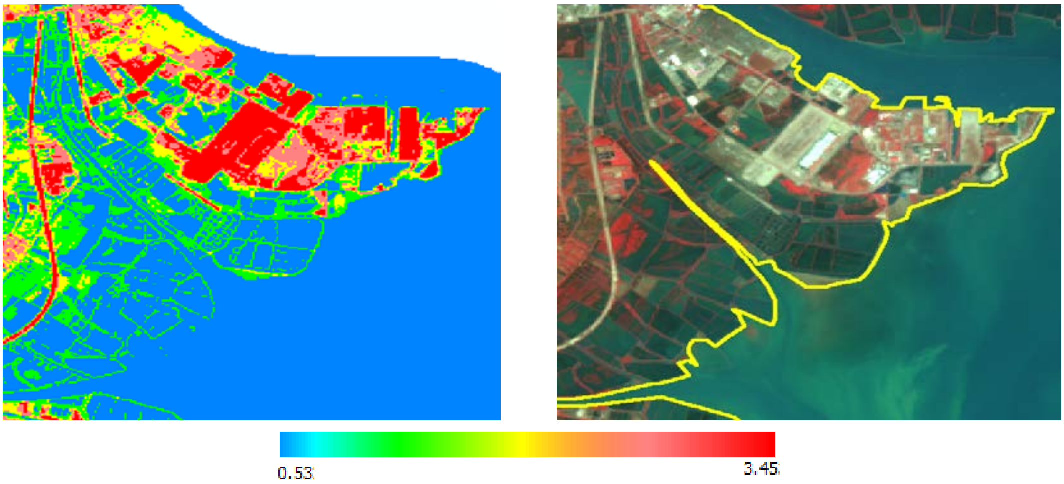

Figure 5. The result of B6/B3 threshold splitting for identifying shoreline on man-made coasts with ponds circled by dykes and concrete embankments in Dinh Vu, Hai Phong

2.2. Establishing shoreline on intertidal flats with mangrove forests developing

Mangrove forest chosen is located outside the Sea Dyke 2, belongs to Bang La commune, Do Son District, Hai Phong city (Fig.6)
From Landsat imagery as well as field photographs, it can be easily realized that the terrain of this coast is relatively flat. We can also see the spread of mangrove forest on the intertidal flat. Non-plant section in the photo is the lower intertidal flat. It only exposes when the tide falls. In addition, because it is submerged in the seawater most time, mangrove plants cannot survive in this section. The outermost edge of mangrove forests in this case, as mention in part 1.2.3, can be considered as the water line of mean tidal level for years, or the shoreline. The method was conducted is to distinguish between mangrove plants and water by NDVI index. The NDVI threshold value in this study is NDVI>0.1. The results are illustrated in Fig.7.

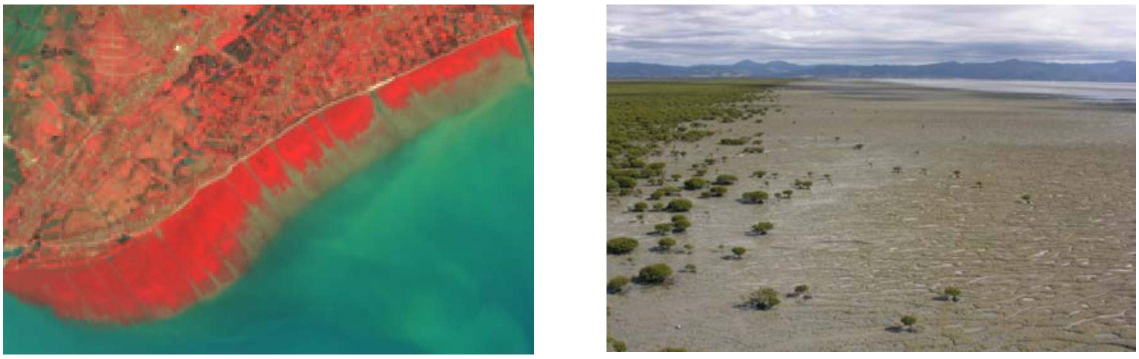

Fig 6. Intertidal flat with mangrove forest developing in Landsat color combination and in field

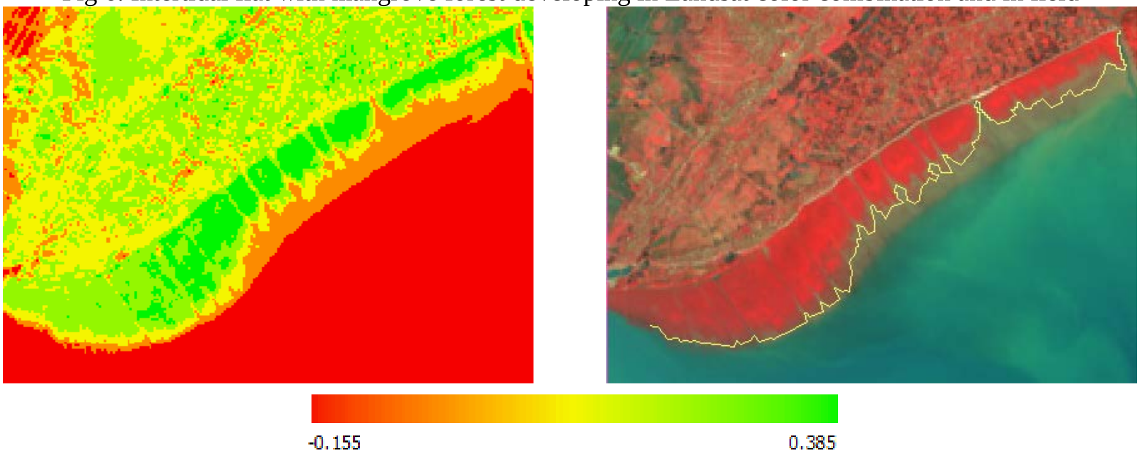

Figure 7. The result of NDVI threshold splitting for identifying shoreline on coast with mangrove forest in Do Son, Hai Phong

2.3. Establishing shoreline on sandy coasts affected by the domination of wave

The research team has chosen Sam Son Beach, Thanh Hoa Province to apply the method mentioned in part 1.2.3 above. Based on SPOT5 images taken at the same time (11a.m) on two day 6/2/2011 and 8/11/2011 on Sam Son beach (Fig.8a,b) and local tide table in 2011, the edge of water lines and tidal level in two cases are determined. According to the results, the average value Δa = 44.70m, Δh = 2.7m, the average slope angle of coast x - 3.48°. Using this value, the research team have established the edge of water line at mean tidal level - coinciding with the shoreline in study area (Fig.8c)

Fig 8. a) SPOT5 image taken on 06/02/2011 with the red line representing the edge of water line; b) SPOT5 image taken on 08/11/2011 with the blue line represent the edge of water; c) The shoreline determined at the mean tidal level by the pink line in Sam Son beach.

3. CONCLUSION

Defining and standardizing shoreline accurately is very important to land use planning and management of resource, environment, and natural hazard in coastal zone.

To research and determine exactly the shoreline, we need to have wide and complete knowledge about terrains and coastal processes, the characteristics of each coast and the factors that affect to their change.

Based on the methods of digital image classification on multi-date and multi-band images combining with knowledge about coastal geomorphorlogy, it can be establish and standard the shoreline on satellite images for typical coasts: swampy tidal coast with mangrove forest, bedrock coast, coast with dominated impact of waves, and man-made coast.

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