USING REMOTE SENSING TECHNIQUES FOR COASTAL ZONE MANAGEMENT IN HALONG BAY (VIETNAM)

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ABSTRACT

Coastal zone is the area where consist of many fragile ecosystem, mangrove ecosystems are very sensitive and high vulnerable. The pressures of increasing population and development such as the expansion of industrial, urban development and aquaculture have caused a significant proportion of the mangroves to be destroyed. The Halong bay area is a famous World Heritage site and also well-known of its biodiversity but in recent years, the mangrove ecosystem in this area is degraded. Monitoring the change of mangrove and coastline can support for coastal zone management and environmental protection of the bay. Reliable and timely information is therefore required in order to monitor and manage the remaining mangrove resources.

The analysis was applied integrated technique in digital image processing such as: The Normalized Difference Vegetation Index (NDVI) was computed for each date of imagery to define high and low vegetation biomass. The interactive stretching technique helps to detect the range of mangrove from the NDVI band of different dates of Landsat satellite imagery. The moisture detection from infrared band is also applied to support for detecting mangrove from general vegetation in the area. Integrated results with the change logic to interpret the change of mangrove forest and coastal zone area over time. The analysis using 3 dates of landsat TM in 1988, 1998 and 2002, and combined with the survey data during the field trip in 2004.

The result show that area of mangrove has been reduced about 21% for aquaculture and tidal wetland is replaced by reclamation, that also impacted to the coast line change and change the landscape of the bay. This result express the impact of development in recent years.

1. INTRODUCTION

Coastal zone management becomes an important task in coastal and marine management, which promote sustainable development in practices, and manage emerging sector conflicts. Coastal ecosystems, especially mangroves, have rich biodiversity resources but they are easily destroyed by both natural and human impacts. Especially in the Halong bay, mangrove ecosystem takes an important role for the bay protection. In recent year, the industrial activities and tourism development, the Halong city has changed rapidly. The expanding space for new planning area means reclamation to the sea for settlement, transport infrastructure, deep sea port construction and also develop intensive aquaculture.. these activities impact seriously to the ecosystem, reduce the area of mangrove, change the coastline and the wetland environment in the estuary and coastal zone area.

Mangrove represent a specific ecosystem found in the intertidal zone along coastline, and are often located near estuaries and deltas. Being highly productive ecosystems and harborage a large diversity of species adapted to these particular habitats, they considered of ecological importance.

Tools like Remote Sensing (RS) and Geographical Information System (GIS) could generate data required for planning of coastal management on a sustainable basis. GIS is a very useful tool in mapping, monitoring coastal resources and could help in assessing changes in coastal environmental conditions due to human interference. Satellite sensors are likely to be more cost-effective methodology. Remote sensing data, especially LANDSAT TM data have proved extremely useful for wetland mapping as well as for delineation high and low water lines; apply the NDVI (Normalised Difference Vegetation Index) formula for calculate the biomass of vegetation cover through the red and near-infrared spectral bands. Further, multi temporal satellite data could be used effectively to find out the changes in the area extent of mangroves. NDVI is one of techniques that could be applied for vegetation change monitoring in which many researchers study (Galvão et al., 2000; Sader and Winne 1992).

Typically for Halong Bay, there are some major characters of mangrove in the area which lead the difficulties in mangrove detection from the satellite image: Mangrove is distributed from sparse to dense mangrove forest along the coastline. Aquaculture ponds for shrimp farming with scattered mangrove and villages spreading surround the mangrove forests, that makes the value of mangrove on the satellite image is the same with valued with vegetation mixed with settlement; the tidal wetland area represent on the image is the same with the coal mining extraction area, that lead to difficult of classifying these objects, so the integrated technique could help to detect wetland habitats.

The results from this study could be providing draft information on mangrove changes, and support for wetland habitat monitoring, estimate and control impact of the development to promote coastal zone management of the Halong bay, the rate of mangrove change could be used as an indicator for sustainable development in the coastal area.

1.1. Objectives

This study aims to:

- Explore the formula of NDVI apply for mangrove in Halong area. Study the distribution of wetland ecosystem in the estuary; use the remote sensing technology for wetland mapping for Halong Bay area.
- A simple and logical technique to display and quantify mangrove forest change and also coastline change on different date interval.

1.2 Area of study

Study area is the whole coastal area of Halong city and Hoanhbo district (Quangninh province, in the North East of Vietnam). The area is a rectangular zone of which the angle points are defined by the following geographical co-ordinates: 20^{o} 54’ 45” N - 21^{o} 55’ 08”N and 106^{o} 49’ 53” E - 107^{o} 20’ 30” E.

The Halong city has great potential to develop the sea economy tourism and construction material industry. It has been defined by the State as part of the Hanoi – Haiphong - Quangninh economic triangle to be developed in northern Vietnam. Since 1994, after had been recognised as a World Heritage site, the area is under pressure of development both from master plan.

The area of study is included the Halong bay and Cua Luc bay, where the estuary is combined of 3 rivers. As research of the biologist, the biodiversity in this area is very rich. This area is selected as a typical mangrove forest area for the North East region of Vietnam (Phan Nguyen Hong, 1994). Mostly mangrove is extracted by local population for sea food and fuel wood, also exits clear cutting mangrove for shrimp pond in individually allocated mangrove, that caused the area of mangrove decreased incredibly.

2. MATERIALS AND METHODS

2.1 Material

Satellite image. Following the available data, it was decided to utilize the LANDSAT Thematic Mapper (TM). Landsat TM has the highest spectral discrimination, with six spectral bands and one thermal band. For vegetation mapping, bands 2, 3, 4, and 5 are particularly useful. Ground resolution of 30 m and high ability for detecting vegetation information this is the possible for the study area.

Three time series of satellite imagery were acquired, with the following date.

- LANDSAT 5 TM image taken on 4th November 1988;
- LANDSAT 5 TM image taken on 17th February 1998; these 2 satellites was acquired from Geo-Informatics and Space technology Development Agency (GISTDA).
- LANDSAT ETM7+ image taken on 31st August 2002; acquired from TRIFIC data centre University of Michigan.

Geographical data. Topographical map: scale: 1/50000; Projection: UTM - Zone 48; Ellipsoid: Everest 1830, Indian 1960. Published in 1997. The co-ordinate system of the baseline data map is applied for geometric correction for 3 satellite images. The digital image processing software was applied for analysis the change detection is PCI 6.2 and Arcview 3.2.

2.2 Methods

A multi-temporal remote-sensing approach was utilized as the spatial basis for mapping the mangrove and wetland area in the bay. Methodology is based on the combination of techniques to extract information from remotely sensed data.

The research involved these main steps:

- Geometric correction, and pre-processing for enhancing imagery data. Image preparation consisted of geometric rectification to the UTM (WGS 84 datum, zone 48) coordinate system to less than 10.5 m RMS error, utilizing 10 ground control points for each image.
- Second step, the NDVI formula was computed for 3 dates and investigate value of land cover features included mangrove in the histogram of each NDVI image.
- The Landsat band 3 (red), band 4 (Nir-Infrared) and 5 (Infrared) was used for water extraction by band subtraction and level slicing in the histogram to detect the wetland habitat, and the coastline.
- Logical overlay between NDVI image and water, wetland band, result of this overlay show only NDVI values of the wetland habitat.
- a NDVI- RGB false color composite of the mangrove and wetland habitat was developed to display and quantify mangrove forest change using three dates of Landsat satellite imagery. Unsupervise with ISODATA cluster, together with identifies range of the value of mangrove biomas in the histogram of NDVI images. Supervise classification of this color composite

was process to analysis the change of mangrove in the study area. Training site and sample for classification is based on the ground truth data and integrated with different combinations of NDVI values.

a) Water extraction: Water strongly absorbs infrared energy and weakly reflects red light. Thus, the infrared/red (IF/R) ratio also has the effect of depicting all surface water bodies. This technique could be use to separate aquatic and wetland and terrestrial vegetation. Band 4 Near-infrared is useful for determining for delineating water bodies, and for soil moisture discrimination.

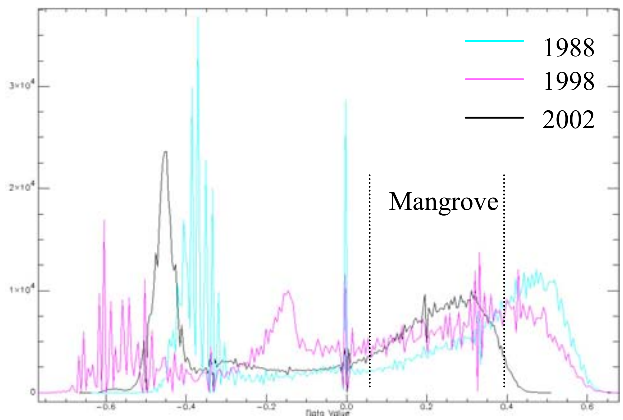
b) *The Normalized Difference Vegetation Index (NDVI)* is used to transform multi-spectral data into a single image band which representing vegetation distribution. The NDVI values indicate the amount of green vegetation present in the pixel. Higher NDVI values indicate more green vegetation. NDVI were computed according to the standard algorithm

For Landsat TM: NDVI = (TM band4 – TM band3) / (TM band4 + TM band3)

The NDVI equation produces values fall in the range of -1.0 to 1.0, where vegetated areas will typically have values greater than zero and negative values indicate non-vegetated surface features such as water, barren land (reclamation).

The investigation of the NDVI value in 3 dates combined with the field data, the table 1 and figure 1 shows the value of different type of features was investigated in the area. The NDVI which computed from each of the three date (1988-1998- 2002), were applied to ISODATA unsupervised classification. Change detection was taken an account on the changes which happen on 1988 to 2002.

Figure 1. Histogram of 3 bands NDVI (1988 – 1998 – 2002)



3. RESULT

The change of coastline. From the methodology, water extract with band Infrared of TM was computed, the level slicing was apply at the value of water reflection for each date. and change of coastline with 24 years was calculated, From 1988 to 2002, along this coastline. there are about 482.6 ha of deposition and reclamation, and 122.05 ha of eroded. On the map, the area focus of change is in the Baichay beach and in the Cua Luc bay. Most of the change in coastline over time is by human activities for development of infrastructure and aquaculture.

Mangrove and wetland habitat change detection: NDVI histograms (figure 1) showed 3 categories of data sets of 1988, 1998, and 2002. Green vegetation shown highest values on the histogram curve. Water bodies have shown low NDVI values as negative values. The range of vegetation in 2002 present as the lowest values compare to 1988 and 1998 values (value of mangrove from 0.05 and normal vegetation from 0.23) this show that the biomas of vegetation in 2002 is lower than before. Table 1 show the different range values of features.

Table 1: NDVI values of the feature investigate in different dates.

NDVI value / Year	Min	Max	Water body	Tidal wet land	Barren land	Mangrove	Vegetated area
1988	-0.63	0.66	< -0.34	-0.3 ÷ - 0.05	-0.1	0.2 ÷ 0.44	> 0.45
1998	-0.76	0.67	< -0.1	-0.05÷ 0.08	-0.21	0.1÷ 0.37	> 0.43
2002	-0.66	0.51	< -0.4	-0.19÷ 0.3	-0.27	0.05÷ 0.16	> 0.23

The histogram show that the features in 1988 has a highest value among 3 dates. The table 1 show general value of NDVI of each date, and the overall investigation of the feature in the area. Vegetation value present of 2002 is the lowest value compare the vegetation values of NDVI in 3 dates, the range of vegetated area in 2002 varied from 0.05 to 0.51 is narrower than other images, but the range of water and tidal wetland is largest, that show the value of biomass in 2002 is reduced as compare to the past (maximum NDVI is value in 1998 = 0.67). The range of tidal wetland in 1998 and 2002 greater than zero could explain the area of very sparse vegetation, this was confirmed by the field data in 2002, that is the transformation of mangrove become tidal wetland, and aquaculture, specially some tidal area with sparse mangrove is growing.
The logical overlay operation of NDVI and water area extraction was operated, that ensure only wetland features is presented on the histogram. Four features were extracted from the 3 NDVI histograms, these are tidal flat, mangrove, aquaculture, and barren land. The ground truth is needed in order to determine the exactly feature.
Tables below shows the statistical of mangrove and wetland habitat calculate in each date

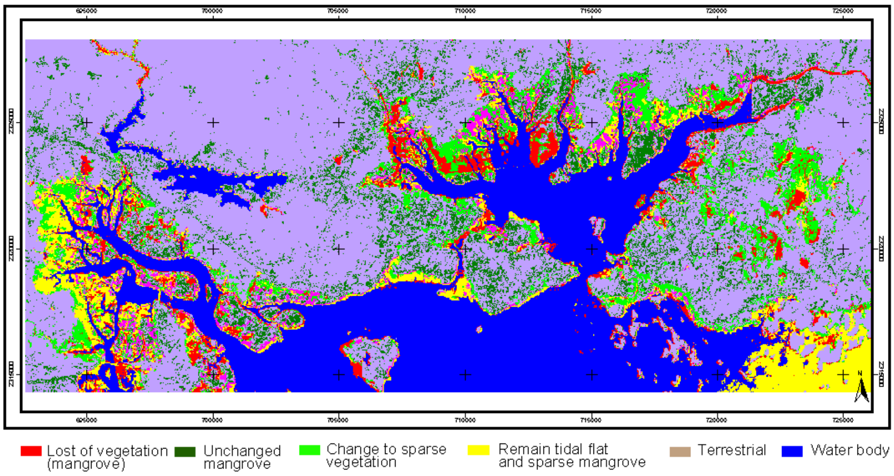
Table 2. Area of mangrove and wetland habitat

Wetland and coastal features	area in 1988	area in 1998	area in 2002
Tidal flat	1536.69	1210.87	1345.56
Mangrove area	3029.83	2582.41	2375.15
Aquaculture	0	752.61	852.34
Barren land (Reclamation)	0	141.02	296.24
Total	4566.52	4686.914	4869.29

In general, the table 2 show that the mangrove area is decrease about 654.68ha and tidal flat is decreases about 191.13ha in 22 years, this both loss area is conversion of mangrove to aquaculture (increase 852 ha) and some area is mangrove degradation become tidal. The tidal flat was filled up to be land for urban area.
So, the total area of wetland habitat has been change, reduce as compared to 1988.

The change of each categories among that is shown on the supervise - classification of NDVI - RGB false color composite, as figure 2.

Figure 2. Supervised- classification of NDVI- false color composite.



4. CONCLUSIONS

The Vegetation Index techniques of change detection were applied in this study show that: The Vegetation Index is represented to the vegetation distribution which transformed according the spectral reflectance characteristic. The mangrove change detection was done. a about 21% of mangrove in 1988 has been changed in to tidal and aquaculture, 12% of tidal wetland has been filled up for settlement and industrial zone. This impact present on the change of coastline, that lead to the change of the water level and effect on wetland habitat. The result of the study express the strong impact of development activities in the Halong bay, this development need to be corrected and monitor by the provincial authorities.

Applied the integrated remote sensing technique: band ratio, NDVI formula and clustering ISODATA for multi temporal analysis could bring a high accuracy classification and detect features in the coastal area, avoid the confusion between values (eg. coal mine and settlement area with tidal wetland). An advantage of this technique is to avoid the error in classification due to overlap between classes of the training areas (Brook and Kennel, 2002).

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