COASTAL ECOLOGY CHANGES AND AQUACULTURE MANAGEMENT IN PHU QUOC, VIETNAM (2006 TO 2011)

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ABSTRACT

Coastal regions are rich in diverse habitats that support many different groups of species, the interact with each other, and their environment. The changing of coastal ecosystem will mainly impact on marine habitat and water environment. LANDSAT TM and ALOS imageries using to monitor the changing status of coastal resources from 2006 to 2011. High-resolution THEOS and KOMPSAT-2 images determined fish cage and snail net pen culture sites in the Northern part of Phu Quoc Island in 2011. The coastal land use change from agricultural land and melaleuca forest into build up area is 349.89 hectares (51.13% of the total area changing). The benthic habitat with seagrass has increased from 10,985.84 hectares in 2008 to 12,869.83 hectares by the end of 2010. In fish cage culture, cholorophyll-a was determined by using interpolation methods that were generated from the spatial distribution for water environment. The chlorophyll-a concentration were determined for water quality from 0.26 to 1.046 μgL^{-1} for chlorophyll-a. Remote sensing and GIS techniques were very effective to monitor dynamics of coastal resources and marine environment in last decade. This information will contribute to decision-makers for sustainable development planning of Phu Quoc Island for increasing fish and snail culture and also rapid development related to tourism in near future.

1. INTRODUCTION

Coastal zone is an area of interaction between terrestrial and marine/tidal processes that is highly gaining pressure because of the increase in population, the activities related to trade and transport, natural resources, travel services, environmental habitats and deteriorating water quality (Nayak, 2002). Coastline changes can produce both a positive and negative impact. As a result, it is stated that changes in the shape of the coastline may fundamentally affect the environment of the coastal zone (Li et al., 1998; Wang et al., 2006). Besides, the coastal zone is essential to marine life and has the highest biological diversity of any part of the sea (Clark, 1992).

Phu Quoc is an island which has abundant natural resources and environment in coastal zone of Vietnam. Currently, this island faces the pressure of tourism planning leading to negative changes mostly in water environment. This paper examines the application of remotely sensed data and GIS to coastal management for detecting land use/land cover changes, marine habitat changes, aquaculture sites and chlorophyll-a marine environment in the northern part of Phu Quoc Island for coastal management, sustainable and planning.

2. RESEARCH AREA

This study focused on the northern part of this island stretching from 10°14'N in the south to 10°27'N in the north and between 103°50'E and 104°05'E longitude. This region includes 3 communes including Cua Can, Ganh Dau, Bai Thom and more than half area of Cua Duong commune. The study area is both seaward and landward sites at 5 Km from seashore.

2. METHOD

2.1 Remote Sensing Data

Remote sensing images, mainly used for classification were systematically corrected using UTM 48 North and WGS84 as the projection and reference ellipsoid, respectively. The images used in this study included LANDSAT images in 2006 and 2011; ALOS images in 2007 and 2010; THEOS and KOMSAT imagery in 2011.

2.2 Field survey and sampling

Field samples are essential as training sites for image classification not only improves the quality of the final output, but also increases the accuracy. There are 50 and 30 samplings for field surveys were conducted to collect samples of land use and seagrass with GPS coordinates.

Twenty water samples were collected on October 27th, 2011 during low tide around cage culture. Water samples were collected from the underneath of each cage which was stored in 1 litre bottle. On each sites, chlorophyll-a (ch-a) was filtered through filter paper in glass-fiber diameter 47 mm, filter size from 0.22 to 0.45 µm before analyzing in laboratory then keeping in 4-15 degree celsius ice and were transported to the laboratory within 12 hours of collection.

2.3 Image fusion

It is one of the techniques which applied to integrate the geometric the detail of two images, one high resolution of panchromatic (PAN) image and one low resolution of multispectral (MS) image, to produce the MS image with high resolution. In this study, the fusion technique is applied for THEOS image for producing the THEOS MS image with 2 meters resolution which was fused from one band of THEOS PAN (2 m) and two bands of THEOS MS (15 m). Also, applied this technique for KOMPSAT-2 image to produce the KOMPSAT MS image with 1 meters resolution which generated from one band of KOMPSAT Pan (1 meters resolution) and four bands of KOMPSAT MS (4 meters resolution)

2.4 Image processing

2.4.1 Principal Component Analysis (PCA)

In this study, PC (principal component) bands of images were generated benthic habitat using visible bands. Band 1 and band 2 of ALOS were transformed to PC and named as PC1 and PC2. Analysis PC image was based on eigenvalues. Higher eigenvalues contain the larger amounts of data variance. Otherwise, bands with lower eigenvalues contain less data information and more noise. The transformation equations used to compute of PCA (Khan et al., 1992; Loveland and Sohl, 2002).

2.4.2 Supervised Classification

Integrating with field data, supervised classification method using Maximum Likelihood Classifier (MLC) was carried out in this study. LANDSAT images in 2006 and 2011 were classified into several classes. The essential classes are forest, agriculture, peat land and build up area for land use/ land cover (LULC) detection.

2.4.3 Feature selection

In this study, the image was georeferenced, so the areas of objects are the true area in square meter. By building the rules based on object attributes including area, compactness, elongation, band ratio and T-entropy, some unwanted small objects, land objects and other water body objects are eliminated. THEOS images were used for detection analysis, the analysis of THEOS image in this study had been used object-oriented classification method for obtaining aquaculture distribution

2.5 Interpolation

Spatial distribution maps of total nitrogen, total phosphorus and chlorophyll-a parameters were prepared. The sampling sites comprising of 20 samples covering fish cage culture were inserted as a basic separate layer and a database table containing the results of the nutrient water values was created. For each parameter, spatial analysis was applied based on the interpolation and surface analysis methods making a contour map.

2.6 Change Detection

One of the most definite reasons is that a wide variety of digital change detection techniques and algorithm have been developed and manipulated over last few decades commensurate with the fast-pace advancement of remote sensing technology with spatial, spectral, thematic and temporal properties. They can be broadly divided into two groups: pre-classification spectral change detection or post-classification methods (Nelson, 1983; Pilon et al., 1988; Singh, 1989). In this study, post-classification method was applied for change detection of coastal land use/land cover and seagrass habitat changes in this study. Three images were used for change detection analysis, one pair is LANDSAT image in 2006 and 2010 for coastal land use/land cover change.

3. RESULTS

3.1 Land use/Land cover and change detection

Results from post classification change detection technique for the land use change maps are shown in figure 1. In this study, most of agriculture and melaleuca forest land changed into build up area from 2006 to 2011. The areas of change of agriculture and melaleuca forest are 211.19 hectares and 159.87 hectares with 30.86% and 23.36%, respectively. The area of build up has increased to 349.89 hectares (about 51.13%) in this period (Figure 2).

The agricultural lands mainly include paper, cashew, coconut in perennial plants and vegetables, cassava in annual plants**.** These crops and melaleuca forest bring to low-income, unstable prices and domestic consumption for farmers so this area changed to build up area for tourism purpose. Moreover, most of forest and peat land have changed very less because both of these land types are restored and protected natural ecosystems. Phu Quoc forests are concentrated in northern and northeast of island, this forest are zoning protect national forests according to the protection and development of forests and biodiversity laws. Besides, peat lands are special ecological zones with diverse animals and plants. According to Organization

Wetlands International, the peat areas have great importance in nature, it helps to forest development, climate regulation, carbon storage, water storage and salinity limits, preserve the most types of plants and animals which have to protect and restore in the action on climate change.

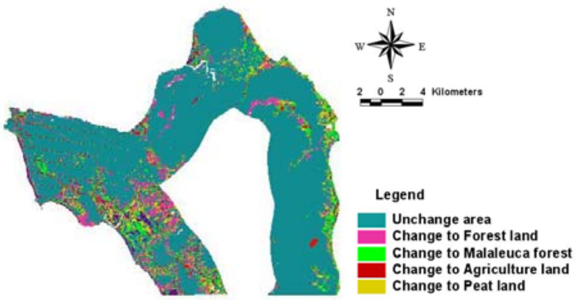

Figure 1. Land use changes from 2006 to 2011

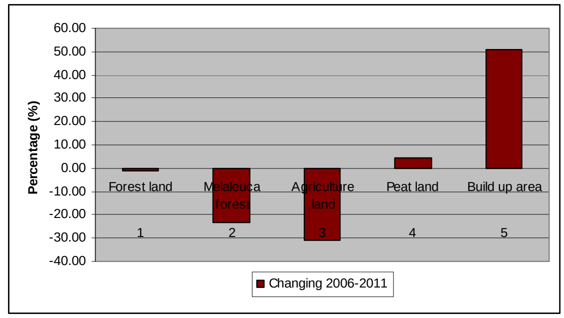

Figure 2. Percentage of land use changes

3.2 Seagrass Mapping and Change Detection

From the field survey, seagrass is located along coastal easthern side in northern coastal Phu quoc district due to the reflectance of sand which is quite higher than seagrass. The distribution of seagrass is shown in figure 3. The areas of seagrass have increased dramatically from 2007 to 2010. The seagrass habitat occupied in 8,618.31 hectare in 2001; 10,985.84 hectare in 2007 and 12,869.83 hectare in 2010. Seageass beds is a protection and conservation area in Phu Quoc Island to maintain biodiversity and marine habitat for fisheries species as feeding ground, nursery areas and growing (Nguyen, 2011) so seagrass beds in study site was increased dramatically in this period.

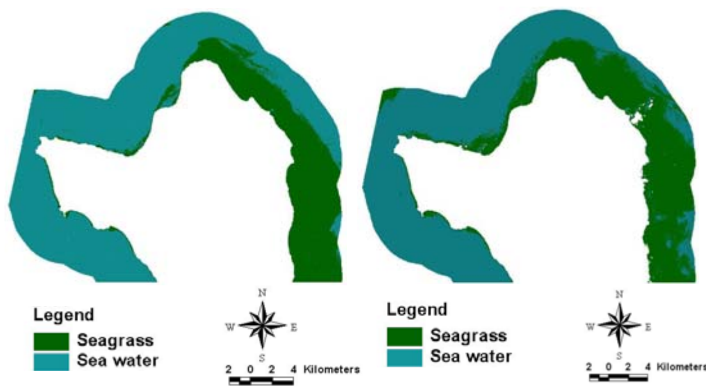

Figure 3. Seagrass distribution in 2007and 2010

3.3 Accuracy assessment

The accuracy assessment of land use maps classified of LANDSAT 2006 and 2011 was carried to assess accuracy based on 50 ground-truth sites. The overall classification accuracy of land use map in 2006 and 2011 equal 84.62% and 80.77%, respectively. The overall kappa coefficient of land use map in 2006 and 2011 equal 0.85 and 0.76, respectively.

The overall classification accuracy of ALOS image in 2007 and 2010 for seagrass habitat was 91.30% and 86.96%, respectively. The overall kappa statistics of classified image in 2007 and 2010 equal 0.89 and 0.84, respectively.

3.4 Aquaculture distribution

3.4.1 Snail net location

KOMPSAT-2 image fusion is showed in figure 3 that was helpful in providing classification accurately and improving the quality of information for snail culture area. On fusion image, snail culture sites were determinate based on coordination using GPS and net pens shape in field survey. The map of snail net pens culture was to develop showing on figure 4. Due to remote sensing, GPS and GIS technique, snail net pens culture are useful to manage and practical tool to map for snail culture resource in study site.

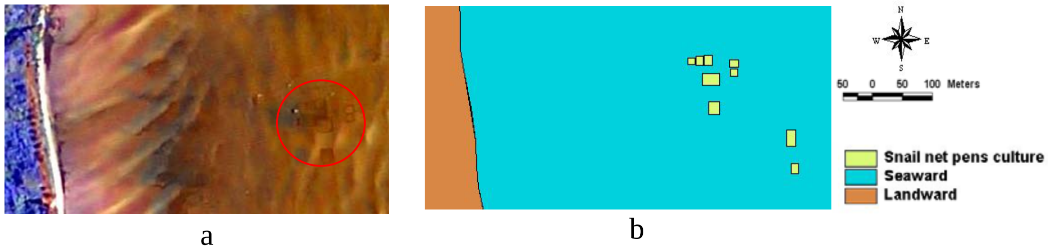

Figure 4. (a) Fused THEOS MS image with 2m resolution, (b) snail net pen distribution

3.4.1 Cobia cage location

The result of image fusion of THEOS data is shown in the figure 5a, this image product shows the fish cage culture sites clearly (inside red circle in figure 5a) because fish cage culture size is quite small having dimension as 4x4 meters. The object based image analysis (OBIA) method was used to detect sea cage culture. It has been proved to be suitable for processing for high resolution remote sensing images (Kumar, 2007). In this study, rule-based classification was used to extract aquaculture information. The rules based on object attributes including area, compactness, elongation, band ratio and T-entropy are eliminated some unwanted small objects, land object and other water body objects. The result was exported to shape file type and shown in figure 5.

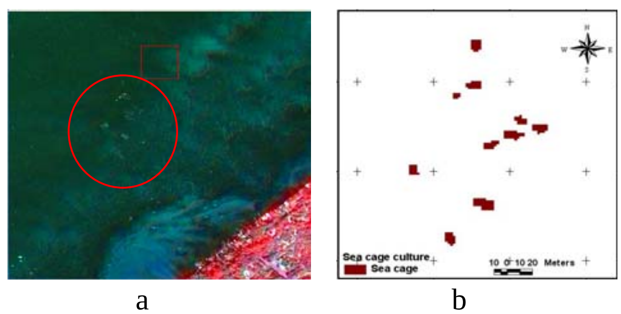

Figure 5. Fused THEOS MS image with 2m resolution and sea cage distribution

Along the coastal zone in Phu Quoc Island, there are high commercial marine species with cage or net culture including cobia and snail. Waste from these types of marine culture is one of the sources directly affecting water environments for marine ecology and water quality in coastal areas. The changing status of this area will directly affect the habitat in the coastal areas with both landward and seaward, it is creates high pressure on natural resource, environmental habitats and deteriorating water. Coastline changes can produce both positive and negative impact that is linked to a better understanding of environment, its conservation and carrying out actions leading to diminish possible impacts on sustainable development.

3.6 Marine environment

Chlorophyll-a is used as an estimate of phytoplankton biomass that may lead to nutrient over-enrichment and eutrophication in transitional, coastal and marine waters. Thus, chlorophyll-a parameter is one of the main indicators to monitor water quality. In this study, the interpolation method was used to make the map chlorophyll-a in the study site (Figure 6), the concentration of chlorophyll-a showed the lowest and the highest concentration in 0.26 µg/L and 1.046 µg/L, respectively to show chlorophyll-a distribution.

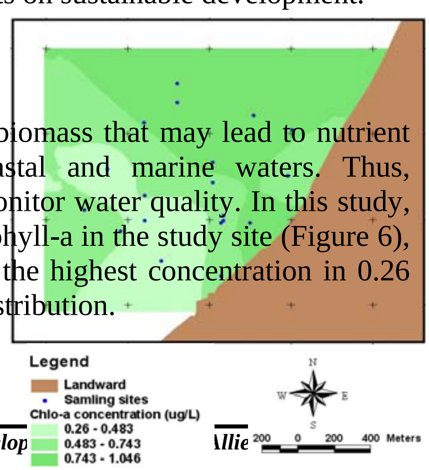

Figure 6. Chlorophyll-a distribution in fish cage culture

Assuming that the water quality has affected the fish cage with total 20 cages and household living in this area around 50 households, chlorophyll-a is still lower than the limit of water quality standard. This information can be supported to manage environment quality in study area.

Most of marine aquaculture in Phu Quoc is raised along the coastal zone with cage and net pen culture with different species so amount of waste released directly into water environment in aquaculture regions increases. Also, aquaculture related to coastal fisheries has economic value for local people and they can expand these farming types in near future

CONCLUSIONS

In this study, remote sensing and GIS technology has proved to be a great importance in acquiring data for effective resources management and hence could also be applied to coastal environment monitoring, management, analyzing the trends and estimating the changes that have occurred in different themes helps in management decision making process. Recent development of geospatial technologies can play an important role in coastal management. Moreover, GIS has been used for the integrating satellite based information for identifying aquaculture sites, coastal regulation and environmentally sensitive zones. In order to ensure sustainable development, it is necessary to develop accurate, up-to-date and comprehensive scientific databases on habitats, protected areas, water quality and environmental indicators.

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