A Satellite based Monitoring of Changes in Mangroves in Krabi, Thailand

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Abstract

A RGB-NDVI was developed to display and quantify mangrove forest change using three dates of Landsat satellite imagery. The Normalized difference vegetation index (NDVI) was computed for each date of imagery to define high and low vegetation biomass. Color composites were generated by combining each date of NDVI in the red, green, and blue (RGB) image. Mangrove change logic was used to interpret forest change over the landscape on the three date NDVI color composite. Degraded and rehabilitation mangrove area coverage were quantified by applying an unsupervised classification generating a RGB-NDVI image with 5 classes which were grouped into 4 main categories. The utility of the RGB-NDVI techniques for updating mangrove forest information are presented and discussed.

Introduction

In research on mangrove remote sensing could provide useful information for mangrove management. Remote sensing data derived from different satellite such as LANDSAT MSS data can provide us information about the area extent, conditions and boundary of coastal wetlands. IRS LISS II LANDSAT TM data have also proved extremely useful for wetland mapping as well as for delineation high and low water lines Likewise; it is possible to distinguish mangroves from other plant communities (Nayak, 1993). Further, multi-date satellite data could be used effectively to find out the changes in the area extent of mangroves. For example, the 1986 TM and 1993 IRS LISS II data have helped to quantify the changes in the area cover of mangroves since both the sensors have similar resolution (Krishnamoorthy, 1997).

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).

This study aims to demonstrate a simple and logical technique to display and quantify mangrove forest change on different date interval. The results from this study could be providing draft information on mangrove changes.

Methodology

Study area

A study area of approximately 200 square kilometers was selected in Phang nga Bay, Southwest Thailand. The area is covered by mangrove forests of Krabi bay, Krabi province (figure 1) which ranges from 08º00´00´´–08º07´45´´N in latitude and from 98º51´45´´–99º00´00´´E in longitude. The topography is generally flat, with a few small mountains on the northern part of the area. The flat topography causes a very large tidal range with extended mudflats. The dominant land cover is agriculture such as para rubber plantation and oil palm plantation. Three main rivers are found in the area and reach the inner part of Phang-nga Bay at Krabi Bay. The mangroves are located around the three main rivers. Krabi town is located near the shoreline close to the mangrove forest. Krabi estuary is an important estuary which is located in front of Krabi town. It divides into Klong Ji Lad and Klong Krabi. Mangrove forests area generally found along the estuarine canal on the lower part of the area. Due to mangrove concession over the past 60 year, the Rhizophora was clear cut. The secondary mangrove forest is dominated by *Rhizophora* sp., *Bruguiera* sp., and *Xylocarpus* sp. could be found. Aquaculture ponds for shrimp farming and villages spreading surround the mangrove forests.

Materials and methods

Materials

1. Digital datasets of LANDSAT5 Thematic Mapper (TM) Satellite image on Krabi Bay, which are acquired on 1995, 2000 from Geo-Informatics and Space technology Development Agency (GISTDA).
2 Digital dataset of LANDSAT7 Enhanced Thematic Mapper Plus (ETM+) Satellite image on Krabi Bay, which is acquired on 2002 from GISTDA.

Methods

Three dates of satellite imagery were acquired. Landsat TM data were obtained 15 December 1995 and 12 February 2000. Landsat ETM+ data was acquired on 9 February 2002. The wavebands representing of near-infrared and visible-red region were extracted from each Landsat dataset. 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. In the ENVI system, NDVI were computed according to the standard algorithm:

$$NVDI = (NIR - Red) / (NIR + Red)$$

Valid results fall between -1 and +1.

The NDVI which computed from each of the three years (1995-2000-2002), were applied to ISODATA unsupervised classification. Change detection was taken an account on the changes which happen on 1995 to 2002. A statistic test (t-test single factors) was applied in order to compare 2 means on NDVI value among years. Change areas were significantly different at 95 % ($p<0.05$). The methods were used in this study presented in figure 2.

Results and discussions

Change detection and monitoring involve the use of multi-date images to evaluate differences in land cover due to environmental conditions and human actions between the acquisition dates of images. Successful use of satellite remote sensing for land use/cover change detection depends upon an adequate understanding of landscape features, imaging systems, and information extraction methodology employed in relation to the aims of analysis. In this study, The Vegetation Index techniques of change detection were applied.

The Vegetation Index is represented to the vegetation distribution which transformed according the spectral reflectance characteristic. The mangrove change detections was done by clustering algorithm on unsupervised classification (ISODATA) of the 3 vegetation index band of 1995, 2000, and 2002. 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).

Change detection using Normalized Difference Vegetation Index

The wavelength bands representing to the near-infrared and visible-red region of the electromagnetic spectrum were extracted from each LANDSAT TM and ETM+ datasets. The Normalized Difference Vegetation Index (NDVI) images had been generated. Green vegetation absorbs more red light and less-infrared than other surfaces. High NDVI values represents as leaf biomass or leaf area increased. On the grey scale NDVI image the vegetated area appeared in bright tones. NDVI histograms (figure 3) showed 3 categories of datasets of 1995, 2000, and 2002. Green vegetation shown high values on the histogram curve. Water bodies have shown low NDVI values as minus values. The histogram of NDVI acquired on 15 December 1995, presented the highest ranging in NDVI value between -0.677 to 0.733. Vegetated area appeared in the range of 0.388 to 0.733. Settlement area and built up land ranged 0.1174 to 0.388. Barren dry land and dry shrimp pond ranged -0.065 to 0.1174. Mud flat area appeared the low NDVI value ranged -0.065 to -0.189. Water bodies and mangrove canal were shown the lowest NDVI value ranged -0.189 to -0.677. The histogram of NDVI on 12 February 2000, provided the narrower NDVI value than the 1995, varied from -0.579 to 0.645. Vegetated area was ranged from 0.314 to 0.645. Barren lands and settlement areas ranged from -0.057 to 0.314. Mud flats varied from -0.057 to -0.196. Water bodies and mangrove canal were also shown the lowest NDVI value ranged from -

0.196 to -0.579. The histogram of NDVI on 9 February 2002, presented the narrowest NDVI value than the other images, ranged from 0.086 to 0.462. Although, vegetated area also appeared the highest NDVI value than other objects, varied from 0.086 to 0.462. But most of vegetated area contained the low NDVI value of 0.1988 to 0.3246. Barren lands and built-up areas ranged from -0.270 to 0.086. Water Bodies were also shown up the lowest NDVI value of -0.545 to -0.270.

Considerate on the NDVI histogram on each year, it presented the result similar as described according to Lillesand and Kiefer (2000). They stated that the vegetation areas present high value of the index because of proportion of high near infrared (band 4) reflectance and low visible reflectance (band 3). While water bodies had higher reflectance value on visible band than near infrared band, thus it shown negative on the index value. Consequences, rock and soil areas had the similar reflectance value on both wavelength and cause the index near zero.

Three features were extracted from the 3 NDVI histograms. It resulted that vegetation area occupied the higher value of the histogram. In contrast, water bodies also had the negative value and at near zero point which was the transition zone among water bodies and vegetation areas. It found that was urban area and barren land. Vegetation areas and water bodies were occupied most area of the image which could be accommodate to the real feature that terrestrial with cover by both mangrove forest and agriculture plants cover the upper portion of this area, while water bodies of sea features and canals were found cover the lower portion of the study area.

By visually comparison the 3 histogram, both NDVI values on 1995 and 2000 consist of 2 main curves of vegetation areas and water body area. Urban area and barren were found in small proportion. While, the new peak of near zero value was emerged in the 2002 histogram. Because it carried the value or urban and barren soil, it could be considerate that there had new development of this feature happened. However, ground truth is needed in order to determine the exactly feature.

Radiometric correction

Normally, the NDVI value of vegetation object ranges around 0.5-0.8, while the vegetation index value derived from the 2002 image presented the strange characteristic of low value. Although LANDSAT 5 and LANDSAT 7 have the similar orbits and repeated patterns, however detection calibration differences between the various sensors system might be affect pixel brightness value (Lillesand and Kiefer, 2000). Image normalization was performed in order to reduce pixel brightness value variation caused by non surface factors. Image normalization was achieved by applying regression equation to the 2002 imagery which predict what a given brightness value would be if it had been acquired under the same conditions as the 1995 reference scene.

A total of 21 radiometric control points was used to normalize the LANDSAT (ETM+) data on 2002 to the 1995 LANDSAT(TM) data. The band 3 of LANDSAT (ETM+) was normalized to the 1995 data using 3 common wet targets found within the sea area and 8 common dry points extracted from a bare soil area. Thus, linear regression was computed (figure 4). Same as band 3, the repeating procedure was done to the band 4 of the 2002 dataset on 9 wet targets and 6 dry target points. The linear equations computed were applied to the 2002 data using the ENVI system. Consequently, the new NDVI image on 2002 data was transformed (figure 5).

The new histogram of NDVI on 9 February 2002, presented the NDVI value ranged from -0.4031 to 0.7524. Although, vegetated area also appeared the highest NDVI value than other objects, varied from 0.3189 to 0.7524. Barren lands and built-up areas ranged from -0.0299 to 0.3189. Water Bodies had also shown up the lowest NDVI value of -0.0299 to -0.4036. Considering on histograms among 3 images of different time series found than urban area was expansion by give the higher curve ranged around 0.17 on the 2002 histogram than the previous years.

RGB-NDVI classification

Several methods apply for change detection monitoring by using NDVI classification (Fuller, 1998). Among those techniques, RGB-NDVI classification is the fastest and easiest method to perform (Sedar *et al.*, 2001; Sedar and Winne, 1992) The NDVI which computed from each of the three years (1995-2000-2002), were applied to ISODATA unsupervised classification. Change detection was taken an account on the changes which happen on 1995 to 2002. A statistic test (t-test single factors) was applied in order to compare 2 means on NDVI value among years. Change areas were significantly different at 95 % ($p<0.05$) (Table 1).

Table 1 mangrove change determined at significantly different at 95 % ($p<0.05$)

	1995-2000	2000-2002
1	-0.01159*	0.036624*
2	0.15200ns	0.166271*
3	0.32879*	0.351859ns
4	0.45834ns	0.49649ns
5	0.54715ns	0.598227ns

Considerate on only mangrove area, five categories were detected which could be grouped into 2 main categories of no change area, and change areas (Figure 6). The changes monitoring derived from NDVI technique presented the stable status within mangrove area covered an area approximately of 43.3 square meters. Changing occurred surrounding the territorial edge of the mangrove which major caused from shrimp aquaculture activity. Total of 9.3 square kilometer of mangrove area were destroyed during 1995 -2000, while non-detection on mangrove area decreased happen between 2000-2002. A total of 7.4 square kilometers of urban was remained in the study area. Since 1995 to 2002, moreover than 200% of Agricultural area was found destroyed for urban expansion and construction the built-up area which includes airport land. Most of changing was detected on territorial part of agriculture section. However, the changing seems to be caused from an alternative with in crop cycle of agricultural plants which occurred in this area such as para rubber, oil palm and paddy field.

Conclusions

Several techniques of change detection could be implementing according to the objective. In this study, NDVI -RGB classification were conducted in order to looking the fast and easy method which could be provide change information. The result from NDVI-RGB could be providing useful information as a draft of changing. It did not provide information in deep stage. However, this method could be detected the changes around the mangrove area.

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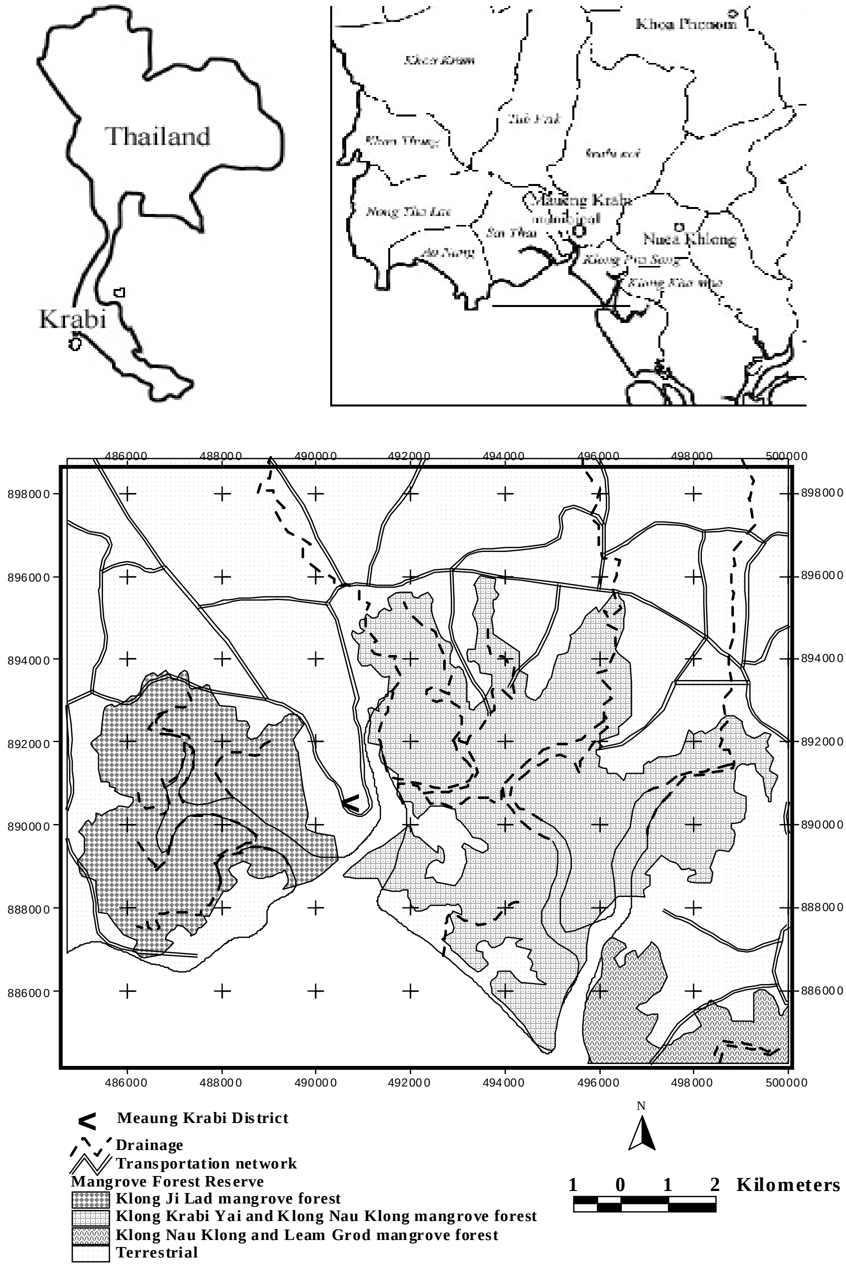

Figure 1 Study area

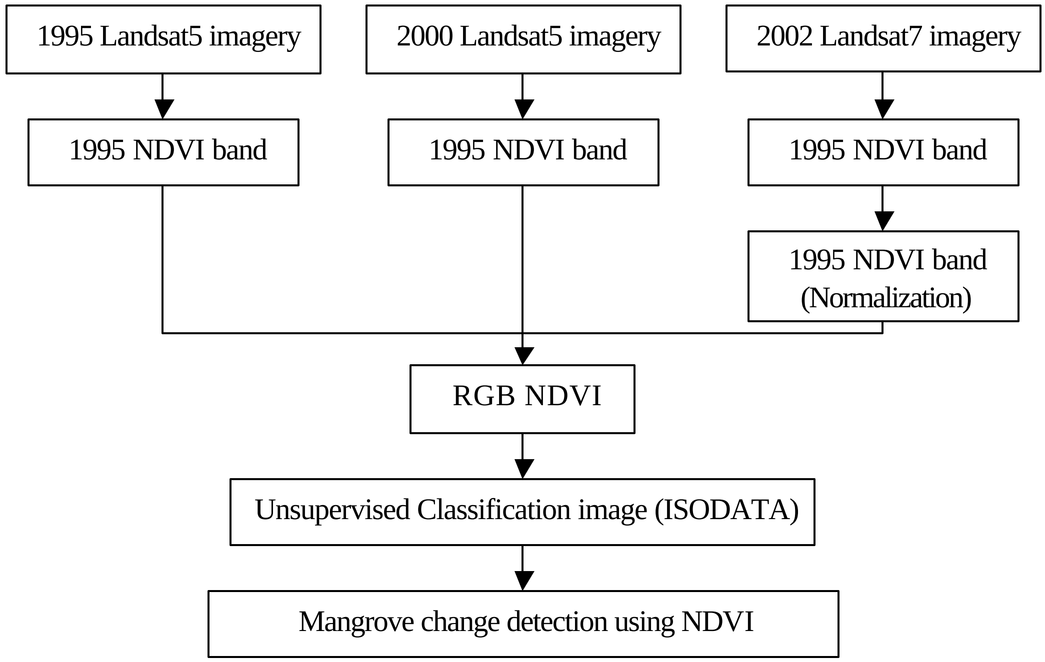

Figure 2 Methods

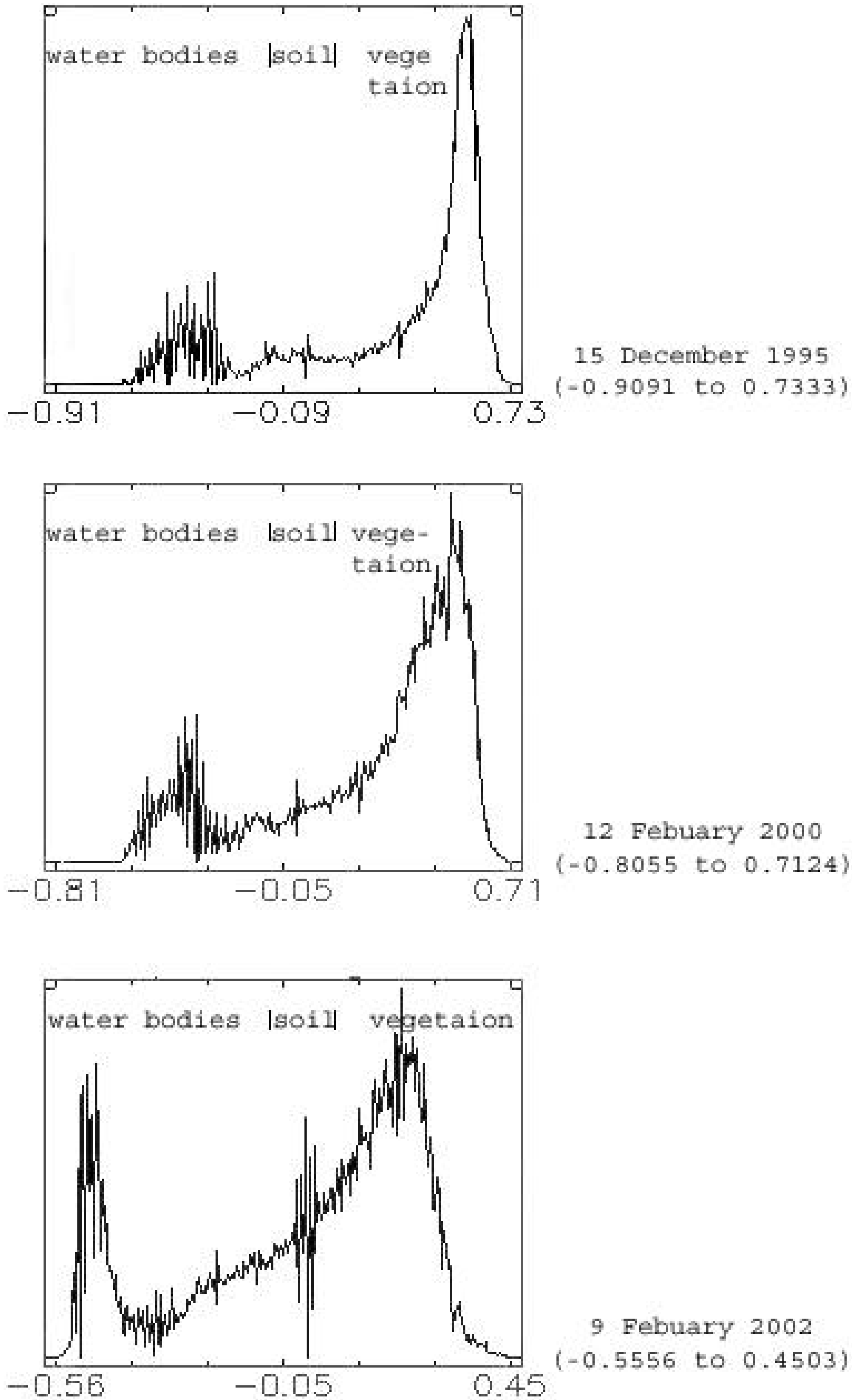

Figure 3 NDVI histogram calculated from 1995, 2000 and 2002 imagery

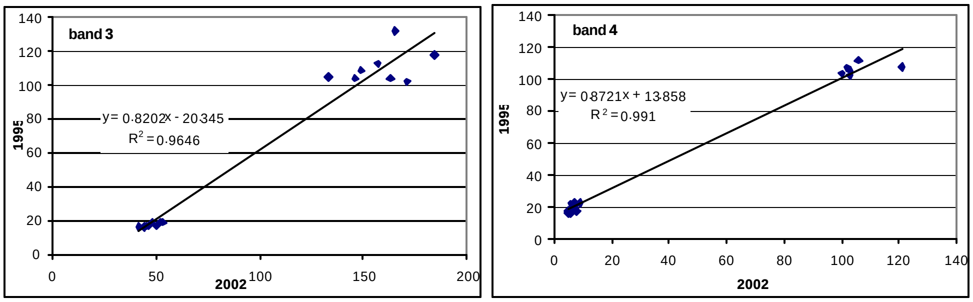

Figure 4 Radiometric correction of LANDSAT (ETM+) data set band 3 and band 4

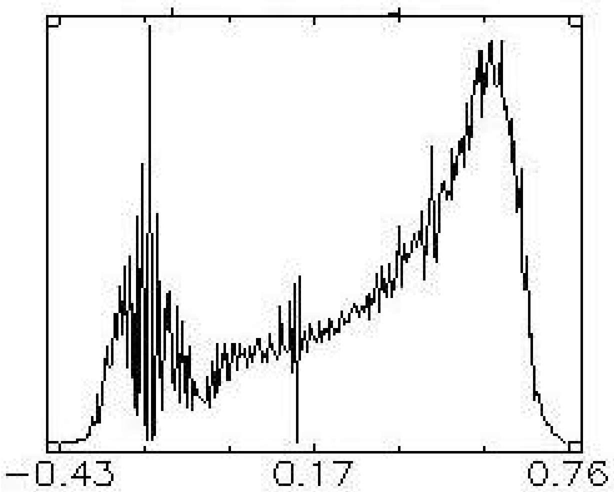

Figure 5 NDVI histogram on 2002 image after normalized to 1995 image

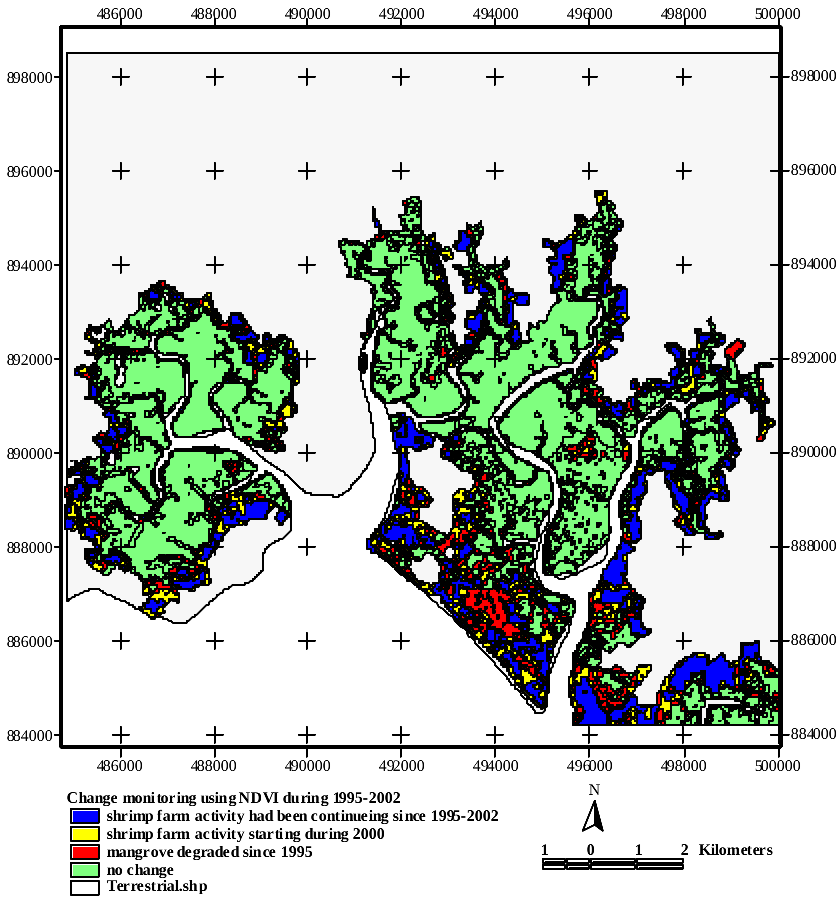

Figure 6 Changes monitoring during 1995-2002 using NDVI