Kasetsart J. (Nat. Sci.) 39 : 159 - 164 (2005)

Coastal Landuse Change Detection Using Remote Sensing Technique: Case Study in Banten Bay, West Java Island, Indonesia

Puvadol Doydee

ABSTRACT

Various forms of coastal landuse covering study site (46,785.69 hectares) were observed to underwent changes as evidently detected between satellite images sensed in 1994 and 2001 at the Banten Bay. It was important to identify what these changes were. Therefore, appropriate change detection must be selected. The image preprocessing step involved removing errors from raster data. This was done by performing basic processes, such as, radiometric correction, geometric correction and image calibration. The image processing step comprised of supervised classification and change detection techniques. Red green method gave the best result for detecting coastal landuse change because the numbers of changed area closely resembled the total number of changed area reference. Every coastal landuse category increased in utility area except for natural area. Observed reduction in the area size of natural area was due to growth rate of population and increased activities along this area.

Key words: coastal landuse change, remote sensing

INTRODUCTION

Remote sensing technique plays an important role for monitoring and mapping coastal areas. Coastal zone is the space in which terrestrial environment is influenced by marine environment, as reported by Carter (1988), which is an extremely dynamic system. Therefore, coastal landuse changes are important part of coastal dynamics. Theory suggests that global warming will result in a rise of global mean sea level hence coastal areas will be affected by potential changes not only with climate system, but also sea level. Potential impacts of coastal environmental change from humanity may be of greater natural action. Deterministic approach relies on data of flight parameters and terrain information, and are effective when types of distortion are well characterized (Richards, 1993). Statistical approach, by means of ground control point (GCP) data set, establishes mathematical relationship between image coordinates and their corresponding map coordinates using standard statistical procedures. Remote sensing can be used as management technology for mapping coastal landuse and monitoring coastal landuse change. According to regional development plan, northwest coast of Banten province has been allocated for industrial development area, such as, steel casting industry, petrochemical, dock, and power plant. On the other hand, northeastern coast is for coastal fish farming, conservation area, coastal green belt, and settlement area. Coastal and marine fisheries support some seventy thousand people who live around study site.

Coastal landuse change is an essential matter

Department of Fishery Management, Faculty of Fisheries, Kasetsart University, Bangkok 10900, Thailand.

Received date : 05/08/04 Accepted date : 20/12/04

that should be monitored for planning or avoiding any further changes that can damage or harm the environment in areas with dense population or built up areas with vital infrastructures. The technology used to accomplish in this study was remote sensing that offers a faster and better synoptic view of large areas compared with traditional way, such as, terrestrial mapping and aerial photo. It is easier and cheaper for sustainable coastal zone management.

The objectives of this study involved mapping coastal landuse and monitoring coastal landuse changed from Landsat image datas, which compared between the years of 1994 and 2001.

MATERIALS AND METHODS

Remote sensing data, Landsat 5 TM, whose acquisition date was on April 6, 1994 and the Landsat 7 ETM+ image with acquisition date was on August 7, 2001, both were the same path/row (123/064) and resolutions (30 ¥ 30 meters) used in this study. Topographic maps data was employed as map reference to the image in order to checking type of land cover, which included 6 sheets: 1109-643 Pontang, 1109-634 Serang, 1109-633 Cilegon, 1110-311 Bojonegara, 1110-312 Pasir Putih, and 1110-321 Lontar. All sheets had scale of 1: 25,000 and were published in 1999 by National Coordinating Agency for Surveys and Mapping. This study needed some supporting tools to accomplish in terms of software and hardware. ER Mapper 5.5 software was used for performing image processing. ArcView GIS 3.1 software brought geographic information, under visualize, explore, query and analyze data spatially and Microsoft Excel 97 software was used for basic database purpose. Hardware were including with personal computer (PC) Windows 98 Pentium(r) III, Global Positioning System (GPS) as eTrex handheld type; position format were Lat/Lon, UTM; accuracy was position: 15 meters (49 feet) RMS and Laser Printer.

The study area was located in the Banten Bay, West Java Island, Indonesia. The study area (Figure 1) is 46,785.69 hectares (ha); physical location is within 106:05 to 106:17 East longitude and 05:53 to 06:05 South latitude.

Radiometric and geometric error are the most common types of error encountered in remotely sensed imagery, which could reduce by preprocessing. Image calibration was needed to perform good quality results on change detection techniques. Image processing was prepared by cropping images of study area. Preferable areas were cloud free. Before performing supervised classification, there was a need to select training regions where annotation tools were used to define training regions in the image. Calculate statistics for pixels in each training region. Evaluate class signatures, views and statistics for training regions in tabular format or graphical format, using histogram or scattergram.

Supervised classification involved analysis of multispectral image data and application of statistically based decision rules for determining coastal landuse identity of each pixel on an image (Lillesand and Kiefer, 1994). These procedures fell into domain of spatial pattern recognition. The intent of classification process was to categorize all pixels in a digital image into one of several coastal landuse classes. Change detection techniques were composed of three methods, which included Red Green Method: RGM (input1 overlap with input2), Image Differencing Method: IDM (input1-input2) and Image Ratioing Method: IRM (input1/input2) Where: Input1 = Image_1994, Input2 = Image_2001 were shown by ER Mapper 5.5 (1997).

Image analysis in this study determined an area of coastal landuse change in Banten Bay of two dates. Defined coastal landuse changes by overlaying two images between Landsat 5 TM in 1994 and Landsat 7 ETM+ in 2001, using three methods of change detection technique. Determined method that suitable for this study and

Figure 1 The Study area (Banten Bay, West Java Island, Indonesia).

how many coastal landuse had changed, based on supervised classification.

RESULTS

Image classification: The results of coastal landuse in 1994 and 2001 were shown in 5 classes, which were paddy fields, fishponds, settlement, agriculture and natural area. Supervised classification had an advantage for mapping coastal landuse, and type of coastal landuse was defined by using band combination RGB_542. Banten Bay coastal landuse maps played as reference for coastal landuse category, were helpful to user to define category of coastal landuse and also aided to find out changed area between two dates.

Change detection: Red green method is widely used technique, particularly useful for interactive viewing of changed area. Image 1994 was displayed as red and image 2001 was displayed as green. Image differencing method, the DN value of image 2001 was subtracted from the

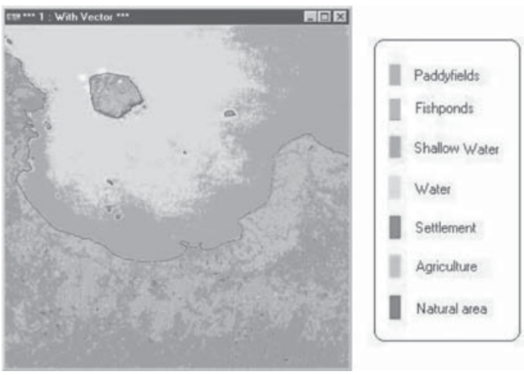

Figure 2 Coastal landuse in 1994.

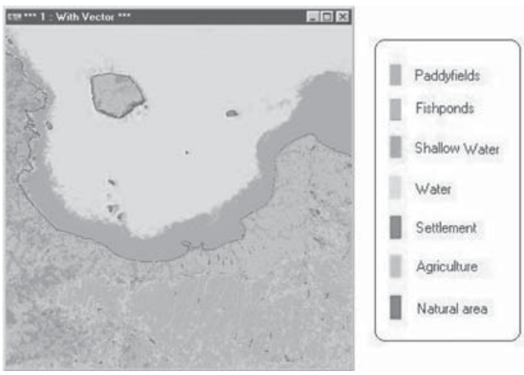

Figure 3 Coastal landuse in 2001.

spectral response DN value of image 1994. Image ratioing method was almost the same as image differencing method except formula changing from subtraction to division. DN value output of area was equal to 1 which meant those areas did not change.

Coastal change analysis: The entire study area was 46,785.69 hectares (ha), consisting of land (coastal landuse category, such as, paddy fields, fishponds, settlement, agriculture and natural area) 23,437.26 hectares, and sea (deep water and shallow water) 23,348.43 hectares.

Every coastal landuse category increased in utility area except for natural area. This was due to growth rate of population (In 1994 about 840 people per km.^{2} and in 2001 about 950 people per km.^{2}). Some parts of agriculture and paddy field were turned into fishponds where there were some stakeholders who took over areas and developed it into shrimp farm in year of 1995 and 1996. Total area of coastal landuse changed was 7,706.79 hectares (the first way was area increase and second was area decrease).

Results (Table 3) would conclude that red green method was better for detecting coastal landuse change according to total number of change area for red green method being more closely agreed with number of change area on total reference with assumption on same tidal information. The tide effect was not determined in this study.

DISCUSSION

This study assumed that both images had the same tidal information. Thus, tide effect was not determined because of the tidal information would be useful for coastline change detection. Tidal information for applying in image processing was Actual Apparent Coastline (AAC) which was the range between Lowest Astronomical Tide (LAT) and Highest Astronomical Tide (HAT), where it was not steadfast like the Mean Sea Level (MSL), in topographic map, the LAT, in navigation and the HAT, in island definition. Usually, the entire coastal landuse category especially made by human should be above the HAT in order to make it easy and convenient in terms of coastal area planning. Remotely sensed data used in this study consisted of 1994 image and 2001 image. This periodic was quite long time, so that the aspect of changed area would become more changed and easier to detect than the date of image with short time difference. For example, if change was between 1994 image and 1998 image, some areas would changed. However, if those areas changed not more than 30 meters, it would be unable to find out because of constrained resolution of landsat

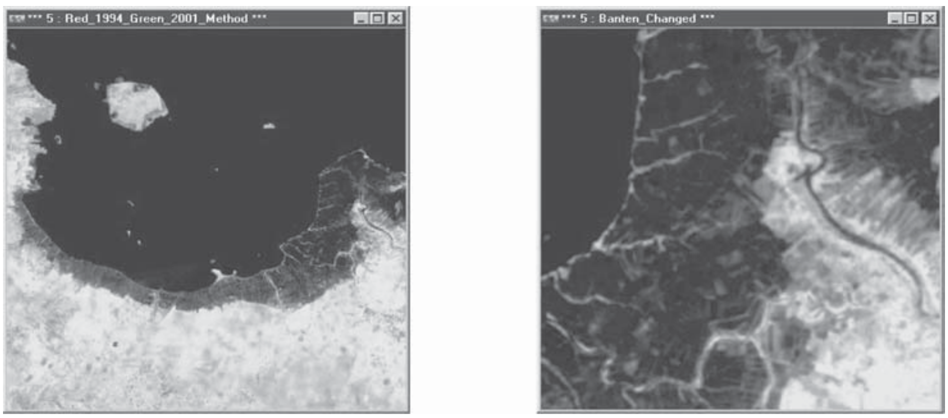

Figure 4 The red green method showed the entire area (left) and zoom in area (right).

Table 1 Areas of coastal landuse between two dates.

Categories	1994 (ha)	1994 (%)	2001 (ha)	2001 (%)
Paddy fields	3,814.20	16.27	5,827.77	24.87
Fishponds	3,454.02	14.74	5,755.14	24.56
Settlement	385.56	1.65	1,101.24	4.70
Agriculture	4,194.81	17.90	6,871.23	29.32
Natural area	11,588.67	49.45	3,881.88	16.56
Total	23,437.26	100.00	23,437.26	100.00

Table 2 Coastal landuse changes between 1994 and 2001.

1994 \ 2001	Paddy fields	Fishponds	Settlement	Agriculture	Natural area	Decrease
Paddy fields	0.00	812.46	70.16	712.66	0.00	1,595.28
Fishponds	0.00	0.00	8.15	0.00	0.00	8.15
Settlement	0.00	0.00	0.00	0.00	0.00	0.00
Agriculture	1,015.06	761.39	317.18	0.00	0.00	2,093.63
Natural area	998.51	727.27	320.19	1,963.76	0.00	4,009.73
Increase	2,013.57	2301.12	715.68	2,676.42	0.00	7,706.79

Table 3 Comparison of change detection techniques with total reference.

Change detection techniques	Area change (ha)	Area change difference (ha)
Red green method	7,094.97	611.82
Image differencing method	6,185.25	1,521.54
Image ratioing method	8,490.96	784.17
Total change reference	7,706.79	

imagery. Moreover, it was assumed that coastal landuse between years 1994 and 1998, the total area of fishpond changed was 20,000 hectare. Thus, it could be said that fishponds changed 5,000 ha per year (20,000 hectare/4 years = 5,000 ha per year). Yet, the result showed that 1994 and 2001 fishponds changed 40,000 ha, which in fact the total area of fishponds changed 5,714.28 ha per year by average. From the above example, it would give the idea that periodic of time had influence to the final result in coastal landuse change detection using remote sensing technique.

CONCLUSIONS

There were five classes of coastal landuse classification, which consisting of paddy fields, fishponds, settlement, agriculture and natural area. Change detection techniques used in this study were red green method, image ratioing method and image differencing method. The total of area changed was 7,706.79 hectares. The red green method gave the best result for detecting coastal landuse change. Every coastal landuse category increased in utility area except the natural area was reduced.

ACKNOWLEDGEMENTS

The author would like to express sincere thanks and faithful appreciation to the SEAMEO Regional Center for Graduate Study and Research in Agricultural (SEAMEO-SEARCA) for financial support of this research and also to thank Dr. Kungwan Juntarashote for his kind encouragement. A special thanks is extended to Dr. Ratana Chuenpagdee for reading and editing the manuscript.

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